

Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships

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International Journal of Offshore and Polar Engineering (IJOPE)

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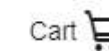


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Muhammad Zubair Muis Alie, Ph.D <zubair.m@eng.unhas.ac.id>

IJOPE Paper JC-708, Received Your MS

Claude Chung <isope4@gmail.com>

Sat, Dec 17, 2016 at 8:55 AM

To: zubair.m@eng.unhas.ac.id

Cc: ISOPE <isope@sbcglobal.net>, Janice Chung <isope-2@sbcglobal.net>

December 16, 2016

IJOPE Paper No. JC-708 "Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships"

Dear Dr. Muis Alie,

Thank you for your manuscript for possible publication in the International Journal of Offshore and Polar Engineering (IJOPE). Promptly return the copyright form in order to initiate peer-review.

As soon as the manuscript has been reviewed and evaluated, **Professor Jin S. Chung** (ISOPE, USA) will advise you as to the recommendation for its acceptability. Any changes in length, content, or style that seem desirable will be indicated. This evaluation requires at least two months, and frequently longer, but we will do our best not to delay the review process unnecessarily. Until then, please keep all the illustration files with you. In case you are not notified as to the review results in three months, please contact me.

We would like to thank you for sending your paper to our Journal. In future correspondence, please refer to this paper by its number above.

Sincerely yours,

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Paper No: -JC-708

Date of Review Request: _December 29, 2016_

Paper Title: **Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships**

Author(s): Muhammad Zubair Muis Alie

Please complete review by: **January 23, 2017**

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Please check in the boxes, which best describe the following features of the manuscript.

	YES	NO	REMARKS (e.g., Not Sure if you are not sure)
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Are you aware of prior publication or presentation of this work?	X ☐	☐	
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Category	Poor*	Marginal*	Acceptable	Good	Outstanding
1. Originality of the Work			X		
2. Significance of the Work or Results		X			
3. Completeness of the Reported Work			X		
4. Acknowledgment of the Work of Others by References			X		
5. Clarity in Writing, Tables, Graphs or Illustrations		X			

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A. Type of Paper	YES	NO	REMARKS
Is this paper an original contribution to the technical literature?	X ☐	☐	
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Does this paper have current interest value?	X ☐	☐	
Does this paper provide permanent value to the technical literature?	X ☐	☐	

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Paper No.: JC-708

Lead Author: Muis Alie

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☐ As Brief Transactions Journal paper (this shorter version must also have permanent value.)

D. Reviewer's Remarks. To assist the author in revising his manuscript, please separate your remarks into two clearly identified categories. Remarks that are not clearly identified will be assumed to fall into **category (1)** below. For additional comments, please attach a sheet.

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Category (1) Those suggestions which, in your opinion, would improve the quality of the manuscript but are not essential for publication.

Category (2) Changes which in your judgment should be made before publication.

- (1) Why the author selected only the sagging condition for ultimate hull girder strength estimation. Under the hogging condition, the damaged part is in tension side of the hull girder bending. This may cause the further extension of the damaged part and further reduction of the ultimate hull girder strength. The author is recommended to say something about this and describe the reason when only the sagging condition is selected in this paper.
- (2) P.2; left Column; L.35: The chapter title: "ESTIMATION OF THE ULTIMATE HULL GIRDER STRENGTH NEUTRAL AXIS EFFECT" is difficult to understand. It could be "EFFECT OF NEUTRAL AXIS ROTATION ON ESTIMATION OF THE ULTIMATE HULL GIRDER STRENGTH"
- (3) P.2; right column; 1st line: "relationship in given in" → "relationship is given in"
- (4) A cross-section of a ship's hull girder is in general symmetric with respect to the centreline of the cross-section. Therefore, $EI_{HV} = EI_{VH} = 0$ when a cross-section is not damaged. It is when the cross-section is damaged that EI_{HV} and EI_{VH} become not zero. From this aspect, it is recommended to describe that Eqs.(4) through (8) are for the asymmetrically damaged cross-section and Eqs.(9) and (10) are for intact cross-section.
- (5) Another important point is a floating condition. When a collision is large, there could be a water ingress which results in non-upright condition of the hull girder. In this case, both vertical and horizontal bending moments acts on the cross-section of a hull girder when only vertical bending moment acts on an inclined hull girder. Something has to be mentioned about this and what assumption is made for your calculation.
- (6) P.3; left column; 3rd line in "RESULT AND DISCUSSEION": "Case1" → Case 1"
- (7) P.3; left column; 3rd line in "RESULT AND DISCUSSEION": "is given as follows," → "is given as follows."
And what is "as follows." No description can be found.
- (8) P.3; right column; last line: it is described that "because the horizontal curvature is constrained." However, explanation is necessary how the constraint of the horizontal curvature makes higher ultimate hull girder strength of Case 2 compared to that of Case 1.

MAILING ADDRESS OF SUGGESTED DISCUSSERS

List names and postal and E-mail addresses of potential discussers. The reviewer may include his or her own name.

- (9) For the damaged condition, not only the vertical bending moment but the resultant bending moment has to be discussed.

PLEASE ANSWER THE FOLLOWING QUESTION

What, in your opinion, is the significant contribution of this paper to the permanent literature?

Actually working bending moment is the resultant bending moment of vertical and horizontal bending moments in the η - ζ coordinate system in Fig. 1.

(10) P.4; right column; 15th line: “curvature induce by” → “curvature induced by”

(11) P.4; right column; 28th line: “in ship structural.” → “in ship structures.”

(12) P.4; Fig. 11 (b): The overlapping of letters has to be revised.

(13) P.5; Fig. 12 (b): The overlapping of letters has to be reviced.

(14) P.5; CONCLUSIONS; 2nd line: “with asymmetrically damaged has” → “with asymmetrically damaged cross section has”

(15) P.5; CONCLUSIONS; 13rd – 14th lines: “because the horizontal curvature is constrained.” As was mentioned in (8), the real reason which is derived from the constrained horizontal curvature has to be described here.



Muhammad Zubair Muis Alie, Ph.D <zubair.m@eng.unhas.ac.id>

IJOPE paper JC-708: Review is completed

Claude Chung <isope4@gmail.com>

Sat, Jan 28, 2017 at 5:27 AM

To: Muhammad Zubair Muis Alie <zubair.m@eng.unhas.ac.id>

Cc: ISOPE <isope@sbcglobal.net>, Janice Chung <isope-2@sbcglobal.net>

Ref. IJOPE Paper JC-708, "Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships"

Dear Dr. Muis Alie,

Review has been completed on your paper. In the opinion of the reviewers, with which I also agree, your paper in its present form is not judged to be acceptable for publication in the International Journal of Offshore and Polar Engineers (IJOPE). Some of the reasons for this decision are contained in the reviewer comments, which are attached for your information.

If you wish, you may revise the paper thoroughly based on the reviewer comments and resubmit for further journal evaluation. If so, please promptly let us know approximately when you plan to submit the revised paper (within one month). Thank you.

Sincerely yours,

Prof. Jin S Chung, Technical Editor

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Attachments: Reviews (3), Author Information

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Paper No: -JC-708

Date of Review Request: _December 29, 2016_

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Author(s): Muhammad Zubair Muis Alie

Please complete review by: **January 23, 2017**

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Category	Poor*	Marginal*	Acceptable	Good	Outstanding
1. Originality of the Work			X		
2. Significance of the Work or Results		X			
3. Completeness of the Reported Work			X		
4. Acknowledgment of the Work of Others by References				X	
5. Clarity in Writing, Tables, Graphs or Illustrations				X	

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Review Form (Page 2/2)

Paper No.: JC-708

Lead Author: Muis Alie

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C. Publication Classification Recommendation.

If acceptable (with revisions if necessary), I recommend that the paper be published:

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3. You compared the effects of damage between B1, B4 and T2, based on the Fig.7 and Fig.8. Whereas the results of B4 is not shown in this paper. This comparison is also referred in conclusion. If you want to refer the results of B4, you should include the graphs of B4.
4. If you add captions in Fig.11 and Fig.12, they will be easier to recognize.
5. In the second paragraph of conclusions, you use 'symbols' such as case1, case2, B1, B4 and T2. If you use more general expression, your conclusions will be easier to recognize.

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1. All the symbols should be explained at the time of reference. Please add explanations to M and I in eq.(4), for example.
2. The equation numbers just above the eq.(13) are incorrect. Please correct them.
3. The figures (a) and (b) in Fig.2 are the same. Perhaps, (a) is incorrect. Please change it.
4. The figure (b) in Fig.11 is digit shifted. Please correct it.

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PLEASE ANSWER THE FOLLOWING QUESTION

What, in your opinion, is the significant contribution of this paper to the permanent literature?



Muhammad Zubair Muis Alie, Ph.D <zubair.m@eng.unhas.ac.id>

Re: IJOPE paper JC-708 Newly Revised

Claude Chung <isope4@gmail.com>

Thu, Mar 2, 2017 at 1:42 AM

To: Zubair <zubair.m@eng.unhas.ac.id>

Dear Dr. Muis Alie,

Thank you for the revised manuscript. Could you please also send a file that highlights the changes made in this version? It will be very helpful to complete the review process. Thank you.

Best regards,

Claude
For Prof. Jin S. Chung
IJOPE

On 2/28/17, 5:23 PM, "Zubair" <zubair.m@eng.unhas.ac.id> wrote:

>Dear Claude Chung

>

>I have revised my full paper according to reviewers comments.

>Thank you and looking forward for your information.

>

>Sincerely yours,

>Muhammad Zubair Muis Alie

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>On 2017-01-31 02:40, Claude Chung wrote:

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>> Best regards,

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>> Claude
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>> On 1/30/17, 5:56 AM, "Zubair" <zubair.m@eng.unhas.ac.id> wrote:
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>>> Dear Claude Chung
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>>> Thank you for your information regarding my article and i am sorry for
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>>> Please give me time to revise it.
>>> Again, thank you so much.
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>>>> Review has been completed on your paper. In the opinion of the
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>>>> Prof. Jin S Chung, Technical Editor
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Paper No: -JC-708

Date of Review Request: _December 29, 2016_

Paper Title: **Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships**

Author(s): Muhammad Zubair Muis Alie

Please complete review by: **January 23, 2017**

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Category	Poor*	Marginal*	Acceptable	Good	Outstanding
1. Originality of the Work		V			
2. Significance of the Work or Results	V				
3. Completeness of the Reported Work		V			
4. Acknowledgment of the Work of Others by References			V		
5. Clarity in Writing, Tables, Graphs or Illustrations			V		

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A. Type of Paper

	YES	NO	REMARKS
Is this paper an original contribution to the technical literature?	☒	☐	
Is this paper a review or progress report?	☐	☒	
Does this paper have current interest value?	☐	☒	
Does this paper provide permanent value to the technical literature?	☐	☒	

B. Quality (Degree of Excellence) [Guideline for Reviewers: Provide written comments on backside.] The quality of the paper is:

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The reviews only with written comments are sent to the authors.

C. Publication Classification Recommendation.

If acceptable (with revisions if necessary), I recommend that the paper be published:

- ☐ As Transactions Journal paper (the paper must have permanent value.)
☐ As Brief Transactions Journal paper (this shorter version must also have permanent value.)

D. Reviewer's Remarks. To assist the author in revising his manuscript, please separate your remarks into two clearly identified categories. Remarks that are not clearly identified will be assumed to fall into **category** (1) below. For additional comments, please attach a sheet.

Type or legible handwriting please! Comments: ☐ attached on separate sheet ☐ not attached.

Category (1) Those suggestions which, in your opinion, would improve the quality of the manuscript but are not essential for publication.

- No definition about D_i , A_i , y_i in Eq. (2) (3)

Category (2) Changes which in your judgment should be made before publication.

The paper proposed a method based on the assumptions that the ultimate sagging strength is attained when a stiffened panel element at the critical element reached the ultimate strength and the ultimate strength of the critical member is predicted from the average axial stress and average axial strain relationship calculated by HULLST. However, this method is quite simple and far from a progressive failure method since the change of neutral axis is not reflected in the method.

Most of all, the approach needs to be verified with CSR's incremental-iterative approach or nonlinear FE analysis even if only vertical bending moment is taken into account. Then, the effect of rotation and translation needs to be verified further.

In addition, the assumption that the hull girder cross section is elastic until the failure of the critical member is too rough to use in the actual design. It is recommended to reflect the progressive failure process.

MAILING ADDRESS OF SUGGESTED DISCUSSERS

List names and postal and E-mail addresses of potential discussers. The reviewer may include his or her own name.

PLEASE ANSWER THE FOLLOWING QUESTION

What, in your opinion, is the significant contribution of this paper to the permanent literature?

Paper No: -JC-708

Date of Review Request: _March 03, 2017_

Paper Title: **Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships (Revised)**

Author(s): Muhammad Zubair Muis Alie

Please complete review by:

Please return this manuscript **immediately** if you can not complete the review by the indicated date.

PAPER PROFILE

Please check in the boxes, which best describe the following features of the manuscript.

	YES	NO	REMARKS (e.g., Not Sure if you are not sure)
In your opinion, is this work technically correct?	☒	☐	
Are data presented to support the technical claims?	☒	☐	Some are ☐ I didn't check ☐
Is this manuscript based on theories or results of refereed papers?	☒	☐	
Are you aware of prior publication or presentation of this work?	☒	☐	
Is this manuscript free of commercialism (e.g., software sales)?	☒	☐	
Is this manuscript too lengthy for the materials covered?	☐	☒	

Category	Poor*	Marginal*	Acceptable	Good	Outstanding
1. Originality of the Work			☒		
2. Significance of the Work or Results			☒		
3. Completeness of the Reported Work		☒			
4. Acknowledgment of the Work of Others by References			☒		
5. Clarity in Writing, Tables, Graphs or Illustrations			☒		

* **"Poor" and "Marginal" is not of acceptable quality.** Justify and provide guidance for improvement in the **Reviewer's Remarks** on the back side.

A. Type of Paper	YES	NO	REMARKS
Is this paper an original contribution to the technical literature?	☒	☐	
Is this paper a review or progress report?	☐	☒	
Does this paper have current interest value?	☒	☐	
Does this paper provide permanent value to the technical literature?	☐	☐	A little questionable!

B. Quality (Degree of Excellence) [Guideline for Reviewers: Provide written comments on backside.] The quality of the paper is:

- ☐ **Acceptable:** Check "Good" or "Outstanding" on all 5 categories and provide **specific comments on back side** [The paper should include some new technical information of significance.]
- ☐ **Acceptable with editorial changes** [The paper requires only editorial changes and/or possible minor additions or deletions.]
- ☒ **Acceptable with revision:** List specific comments on back side. [The paper requires changes or revisions of a moderate nature that would **aid the authors** in presenting the information more clearly. The paper may not require re-review.]
- ☐ **Acceptable only if revised:** List specific comments on back side. **Require re-review.** [The paper requires changes in content that would clarify or incorporate **the information or data** that are essential for clear presentation.]
- ☐ **Not acceptable for reasons stated on back side.** [This includes those papers having an obvious sales approach (e.g., patent or software sales) to a technical problem, those that have been previously published, those that have been submitted elsewhere, or those based on fallacious or dubious engineering analysis or those that present an approach superficially descriptive of widely accepted engineering practice.]

Return review to:

Name: Prof. Jin S. Chung

Address: ISOPE

Country:

E-mail: jschung@isope.org (cc: isope4@gmail.com)

Reviewer Name _____ Date _____

Co./Univ: _____

Address: _____

City: _____ Zip/Postal Code _____ Country _____

E-mail: _____ Fax: _____

The reviews only with written comments are sent to the authors.

C. Publication Classification Recommendation.

If acceptable (with revisions if necessary), I recommend that the paper be published:

- X As Transactions Journal paper (the paper must have permanent value.)
☐ As Brief Transactions Journal paper (this shorter version must also have permanent value.)

D. Reviewer's Remarks. To assist the author in revising his manuscript, please separate your remarks into two clearly identified categories. Remarks that are not clearly identified will be assumed to fall into **category (1)** below. For additional comments, please attach a sheet.

Type or legible handwriting please! Comments: ☐ attached on separate sheet ☐ not attached.

Category (1) Those suggestions which, in your opinion, would improve the quality of the manuscript but are not essential for publication.

Category (2) Changes which in your judgment should be made before publication.

- (1) English has to be improved. It is recommended to ask native English speaker to examine your English.
- (2) 3rd line in ABSTRACT: "simply supported of boundary condition" → "simply supported boundary condition"
- (3) Page 1; left column; 4th – 5th line: "safety ship" → "safety of ship"
- (4) Page 1; right column; 3rd line: "base on" → "based on"
- (5) Page 1; right column; 12th line: "applying the progressive collapse method and finding an" → "applying the progressive collapse calculation method and found an"
- (6) Page 1; right column; 26th line: "compared with" → "compared the calculated results with"
- (7) Page 2; left column; 1st line: "influence factor" → "influential factor"
- (8) Page 2; left column; 12th line: "damaged due, for example, to" → "damaged, for example, due to"
- (9) Page 2; right column; below Eq.(3): "Where D_i , A_i , y_i and z_i are the tangential stiffness obtained as a slope of the average stress-strain relationship, cross section and the coordinate position of the individual elements, respectively." → "where D_i , A_i , and (y_i, z_i) are the tangential stiffness obtained as a slope of the average stress-average strain curve, cross sectional area and the coordinates of the centroid of individual elements, respectively."
- (10) Page 2; 1st line below Fig. 1: "asymmetric damage cross section, the equations are used from Eqs.(4) to (8)," → "asymmetrically damaged cross section, Eqs.(4) through (8) are used,"
- (11) Page 2; 1st line below Eq.(5): "Where I and M is the" → "where I and M are the"
- (12) Page 4; left column; 7th line: "damage side shell" → "damaged side shell"
- (13) Page 4; Fig. 4 (a): There is no element at point, L_1 , in case of single hull bulk carrier. What σ_c is used for this case and what is the physical meaning of choosing this point in this case? No influence shall appear at this point as for buckling and yielding.
- (14) Page 4; 10th line from the bottom: "is place at" → "is placed at"

MAILING ADDRESS OF SUGGESTED DISCUSSERS

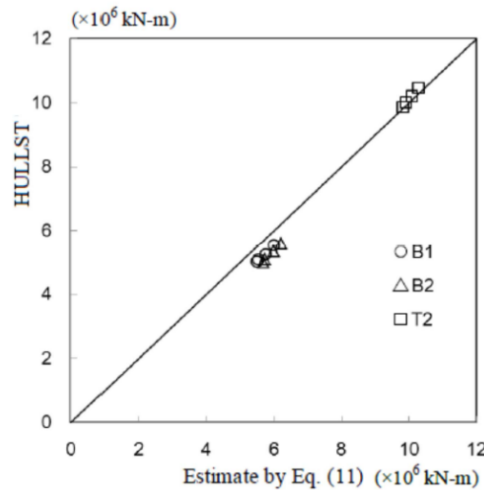
List names and postal and E-mail addresses of potential discussers. The reviewer may include his or her own name.

- (15) Page 4; 6th line from the bottom: "damaged takes place" → "damage has taken place"

PLEASE ANSWER THE FOLLOWING QUESTION

What, in your opinion, is the significant contribution of this paper to the permanent literature?

- (16) Page 4 – 5: Figures 5, 6, 7, 8, 9 and 10: It should be described what bending moment is indicated in the figures. Is it M_V or resultant bending moment of M_V and M_H ?
- (17) Page 5; right column; 7th line: What is “stiffened matrix”?
- (18) Page 5; right column; 7th – 8th lines: “horizontal and vertical and” → “horizontal and vertical **bending moments** and”
- (19) Page 5; right column; 15th line: “of damaged^d” → “of damages^s”
- (20) Page 5; Fig. 11: “HULLST” and “Estimate by Eq.(11)” have to be placed as below:



- (21) Page 6; 8th line: “the damage side” → “damaged^d side”
- (22) Page 6; 8th – 10th lines: “The location L1 cannot induced by M_V .” → This sentence may have no meaning since there exists no element at point L₁.
- (23) Page 6; CONCLUSIONS; 1st – 5th lines: “The ultimate ... member elements.” → Difficult to understand. It could be “Progressive collapse analysis was performed on two single hull bulk carriers and a double hull oil tanker with asymmetrically damaged cross section applying Smith’s method.”
- (24) Page 6; CONCLUSIONS; 12th – 13th lines: “than without constrained^d one.” → than **that** without constraint.”
- (25) Page 6; CONCLUSIONS; 13th – 14th lines: “even the horizontal curvature is constrained” → Meaning of this sentence is not understandable. Alternative expression is requested.
- (26) Page 6; CONCLUSIONS; 14th line: “because ^dof the” → “because the”
- (27) Page 6; CONCLUSIONS; 15th line: “the stiffness matrix interaction” → What is “stiffness matrix interaction”?
- (28) Page 6; CONCLUSIONS; 16th lines: “horizontal and vertical and” → “horizontal and vertical **bending moments** and”
- (29) Page 6; CONCLUSIONS; 16th – 17th lines: “strength ^dbecomes higher.” → “strength higher.”



Muhammad Zubair Muis Alie, Ph.D <zubair.m@eng.unhas.ac.id>

IJOPE paper JC-708: Re-review is completed (rev)

Claude Chung <isope4@gmail.com>

Fri, Mar 24, 2017 at 4:40 AM

To: Muhammad Zubair Muis Alie <zubair.m@eng.unhas.ac.id>

Cc: Jin S Chung <isope@sbcglobal.net>, Janice Chung <isope-2@sbcglobal.net>

Ref. IJOPE Paper JC-708, "Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships"

Dear Dr. Muis Alie,

Re-review has been completed on your paper.

In the opinion of the reviewers, with which I also agree, your paper in its present revised form is still not judged to be acceptable for publication in the Journal, but you may revise it one more time according to the comments in the attached file and below.

Reviewer 2:

I think it is OK except the following one point.

In the article just before equation4, equation 9 is referred. Please change from "Eqs. 9 and (10)" to "Eqs. (9) and (10)".

Also, Reviewer 3 found your response to his review comments unsatisfactory, so we recommend that you provide a more helpful response along with any related revisions.

Please confirm when you receive this message and whether you will be able to submit your further revised paper by **April 6**.

Sincerely yours,

Prof. Jin S Chung, Technical Editor

IJOPE

JSC/cc



JC-708 Muis Alie-Rereview-Reviewer1.pdf

233K



Muhammad Zubair Muis Alie, Ph.D <zubair.m@eng.unhas.ac.id>

Re: IJOPE Paper JC-708, Galley Proof due April 12

Claude Chung <isope4@gmail.com>

Fri, Apr 13, 2018 at 8:37 AM

To: Zubair <zubair.m@eng.unhas.ac.id>

Dear Dr. Muis Alie,

Yes, I did receive your email, including the Reprint Order form, which I forwarded to the ISOPE Office. They should have emailed you asking for your full mailing address and phone number for shipping purposes.

Best regards,

Claude Chung
Managing Editor
IJOPE

On 4/12/18, 5:23 PM, "Zubair" <zubair.m@eng.unhas.ac.id> wrote:

>Dear Claude Chung
>Managing Editor of IJOPE

>

>

>I just would like to confirm that did you receive this email ?
>Something problem with our email administrator system.

>

>

>Sincerely yours,
>Muhammad Zubair Muis Alie

>

>

>----- Original Message -----

>Subject: Re: IJOPE Paper JC-708, Galley Proof due April 12

>Date: 2018-04-12 16:06

> From: Zubair <zubair.m@eng.unhas.ac.id>

>To: Claude Chung <isope4@gmail.com>

>Cc: jschung@isope.org

>

>Dear Claude Chung

>Managing Editor of IJOPE
>cc : Professor Jin S Chung
>
>I have checked my full paper with the title "Simplified Approach on the
>Ultimate Hull Girder Strength of Asymmetrically Damaged Ships." with "No
>corrections".
>
>I also attach the Journal Reprint Order Form according to the previous
>attachment. Please check of this form whether if it is wright or wrong.
>
>Thank you and looking forward for your reply.

>
>
>Faithfully yours,
>Muhammad Zubair Muis Alie
>
>
>

>On 2018-04-10 23:59, Claude Chung wrote:

>> *
>> *
>> *
>>
>> Dear Dr. Muis Alie,
>>
>> See attached for your galley proof of Journal Paper JC-708 "Simplified
>> Approach on the Ultimate Hull Girder Strength of Asymmetrically
>> Damaged Ships."
>>
>> Please E-mail (with annotation for corrections on the PDF itself) back
>> to me at isope4@gmail.com with cc: to Prof. Chung at
>> "jschung@isope.org" with your corrections by APRIL 12 our time.
>>
>> Please take care to double-check ALL equations and figures to ensure
>> that they were transcribed correctly. Your close attention is
>> required. Per journal policy, replacing figures at this stage (except
>> in case of our error) will incur a \$100/figure charge.
>>
>> Your timely response is essential for our scheduling purposes and will
>> be appreciated. Even if there are no corrections, your reply with "No
>> corrections" is required.
>>
>> * Reprint form is attached.
>>
>> Sincerely,

>>
>> Claude Chung
>>
>> Managing Editor
>>
>> ISOPE
>>
>> isope4@gmail.com; www.isope.org [1]
>>
>>
>>
>> Links:
>> -----
>> [1] <http://www.isope.org>



Muhammad Zubair Muis Alie, Ph.D <zubair.m@eng.unhas.ac.id>

Re: IJOPE paper JC-708: Newly Revised

Claude Chung <isope4@gmail.com>
To: Zubair <zubair.m@eng.unhas.ac.id>
Cc: Jin S Chung <jschung@isope.org>

Fri, Apr 28, 2017 at 2:21 AM

Dear Dr. Muis Alie,

Reviewer 3 had the following assessment of your validation:

The attached validation file contains six curvature -Moment plots. They are detailed data to support Fig.11 results. That is, Fig. 11 compares only peak values for six cases but the plots of the attached validation file contains entire curves. These are not additional validation works and don't match with my comments.

If you would like to respond to this comment, please send me your response by May 5, and I will forward to the reviewer. Thank you.

Best regards,

Claude
For Prof. Jin S. Chung
IJOPE

On 4/6/17, 4:47 PM, "Zubair" <zubair.m@eng.unhas.ac.id> wrote:

>Dear Claude Chung
>
>
>Attachment, please find the revision of my full paper including response
>from the reviewer's comments. The sentence with color and underlined is
>newly revised. I also prepare a validation of the ultimate strength
>based on the 3rd reviewer comment as the previous email. The validation
>of the ultimate strength is taken for 20% damage of Single Hull Bulk
>Carrier (Ship B1 and Ship B2) and a Double Hull Oil Tanker (Ship T2).
>Thank you.

>
>Faithfully yours,
>Muhammad Zubair Muis Alie
>
>
>
>On 2017-03-24 03:40, Claude Chung wrote:
>> Ref. IJOPE Paper JC-708, "Simplified Approach on the Ultimate Hull
>> Girder Strength of Asymmetrically Damaged Ships"
>>
>> Dear Dr. Muis Alie,
>>
>> Re-review has been completed on your paper.
>>
>> In the opinion of the reviewers, with which I also agree, your paper
>> in its present revised form is still not judged to be acceptable for
>> publication in the Journal, but you may revise it one more time
>> according to the comments in the attached file and below.
>>
>> Reviewer 2:
>>
>> I think it is OK except the following one point.
>>
>> In the article just before equation4, equation 9 is referred. Please
>> change from "Eqs. 9 and (10)" to "Eqs. (9) and (10)".
>>
>> Also, Reviewer 3 found your response to his review comments
>> unsatisfactory, so we recommend that you provide a more helpful
>> response along with any related revisions.
>>
>> Please confirm when you receive this message and whether you will be
>> able to submit your further revised paper by APRIL 6.
>>
>> Sincerely yours,
>>
>> Prof. Jin S Chung, Technical Editor
>>
>> IJOPE
>>
>> JSC/cc



Muhammad Zubair Muis Alie, Ph.D <zubair.m@eng.unhas.ac.id>

IJOPE Paper JC-708 -- Accepted

Claude Chung <isope4@gmail.com>

Tue, Aug 29, 2017 at 7:09 AM

To: Muhammad Zubair Muis Alie <zubair.m@eng.unhas.ac.id>

Cc: Jin S Chung <jschung@isope.org>, Janice Chung <isope-2@sbcglobal.net>

August 28, 2017

IJOPE Paper No. JC-708 "Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships"

Dear Dr. Muis Alie,

Congratulations! It is a pleasure to inform you that your revised paper has been accepted for publication in the *International Journal of Offshore and Polar Engineering (IJOPE)*. We have also decided to publish a brief formal Discussion of your paper with comments from Reviewer 3 and your reply.

You will hear directly from the Managing Editor as to the scheduling of your paper's publication and/or further comments on format and figure quality plus details on the Discussion. On behalf of the International Society of Offshore and Polar Engineers (ISOPE), I want to express our appreciation for your contribution to our Journal.

Sincerely yours,

Prof. Jin S. Chung, Technical Editor

IJOPE

JSC/cc

cc: ISOPE Office



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337K



Muhammad Zubair Muis Alie, Ph.D <zubair.m@eng.unhas.ac.id>

IJOPE Paper JC-708 -- Accepted

Claude Chung <isope4@gmail.com>
To: Zubair <zubair.m@eng.unhas.ac.id>

Tue, Nov 21, 2017 at 7:49 AM

Dear Dr. Muis Alie,

Please send me a Word file of your final paper so that we may begin preparing it for publication. Make sure that figures are high-resolution and not compressed within the file.

Thank you.

Best regards,

Claude Chung
Managing Editor
IJOPE

On 9/6/17, 4:32 PM, "Zubair" <zubair.m@eng.unhas.ac.id> wrote:

>Dear Claude Chung
>Managing Editor of IJOPE
>
>Thank you so much for your information.
>
>
>Sincerely yours,
>Muhammad Zubair Muis Alie

>
>
>
>On 2017-09-06 07:26, Claude Chung wrote:

>> Dear Dr. Muis Alie,
>>
>> After consulting with Reviewer 3, we have decided that a Discussion of
>> your paper is unnecessary, so your paper will be published without an
>> accompanying Discussion. Feel free to check with me in three months
>> for an update on publication status.

>>
>> Best regards,
>>
>> Claude Chung
>> Managing Editor
>> IJOPE
>>
>> From: Claude Chung <isope4@gmail.com>
>> Date: Monday, August 28, 2017 at 4:09 PM
>> To: Muhammad Zubair Muis Alie <zubair.m@eng.unhas.ac.id>
>> Cc: Jin S Chung <jschung@isope.org>, Janice Chung
>> <isope-2@sbcglobal.net>
>> Subject: IJOPE Paper JC-708 -- Accepted
>>
>> August 28, 2017
>>
>> IJOPE Paper No. JC-708 "Simplified Approach on the Ultimate Hull
>> Girder Strength of Asymmetrically Damaged Ships"
>>
>> Dear Dr. Muis Alie,
>>
>> Congratulations! It is a pleasure to inform you that your revised
>> paper has been accepted for publication in the _International Journal
>> of Offshore and Polar Engineering (IJOPE). _We have also decided to

[Quoted text hidden]



Muhammad Zubair Muis Alie, Ph.D <zubair.m@eng.unhas.ac.id>

IJOPE Paper JC-708 -- Accepted

Claude Chung <isope4@gmail.com>

Wed, Sep 6, 2017 at 8:26 AM

To: Muhammad Zubair Muis Alie <zubair.m@eng.unhas.ac.id>

Cc: Jin S Chung <jschung@isope.org>

Dear Dr. Muis Alie,

After consulting with Reviewer 3, we have decided that a Discussion of your paper is unnecessary, so your paper will be published without an accompanying Discussion. Feel free to check with me in three months for an update on publication status.

Best regards,

Claude Chung
Managing Editor
IJOPE

[Quoted text hidden]



Muhammad Zubair Muis Alie, Ph.D <zubair.m@eng.unhas.ac.id>

IJOPE Paper JC-708 -- Accepted

Claude Chung <isope4@gmail.com>
To: Zubair <zubair.m@eng.unhas.ac.id>

Tue, Mar 27, 2018 at 8:37 AM

Dear Dr. Muis Alie,

Attached is a file of your paper containing several notes that explain edits we made or request clarification/correction. Please make any necessary text changes in this file and highlight them for easy identification. We request a higher-resolution file of Fig. 4 that includes the requested edit.

Please confirm when you receive this message and send me the updated paper and figure file at your earliest convenience. Thank you.

Best regards,

Claude Chung
Managing Editor
IJOPE

On 11/26/17, 1:32 PM, "Zubair" <zubair.m@eng.unhas.ac.id> wrote:

>Dear Claude Chung
>Managing Editor of IJOPE

>

>I am sorry for may late reply. Here is the word file of my paper.

>

>

>Faithfully yours,

[Quoted text hidden]



JC-708 Muis Alie-sm-cc-queries.docx
889K



Muhammad Zubair Muis Alie, Ph.D <zubair.m@eng.unhas.ac.id>

IJOPE Paper JC-708 -- Accepted

Claude Chung <isope4@gmail.com>

Sat, Mar 31, 2018 at 12:59 AM

To: Muhammad Zubair Muis Alie <zubair.m@eng.unhas.ac.id>

Dear Dr. Muis Alie,

Please confirm that you received the message below and that you will be sending the updated paper and figure file soon. Thank you.

Best regards,

Claude Chung
Managing Editor
IJOPE

[Quoted text hidden]



JC-708 Muis Alie-sm-cc-queries.docx
889K



Muhammad Zubair Muis Alie, Ph.D <zubair.m@eng.unhas.ac.id>

RE: IJOPE Paper JC-708, Reprints

isope-2@sbcglobal.net <isope-2@sbcglobal.net>

To: Muhammad Zubair Muis Alie <zubair.m@eng.unhas.ac.id>

Cc: zubair.m@eng.unhas.ac.id

Fri, Aug 31, 2018 at 5:56 AM

Dear Dr. Muis Alie,

First I apologize for the delay in sending you your Journal paper reprints. During the April madness of conference paper final PDFs, it fell through the cracks, and only now we are shipping 100 reprints of your paper (printed in June issue), by DHL courier service.

Sorry again.

Janice

ISOPE, [495 North Whisman Road, Suite 300](#)

[Mountain View, California 94043, USA](#)

T 1-650-254-1871; F 1-650-254-2038; isope-2@sbcglobal.net; isope-2@isope.org

[www. isope.org](http://www.isope.org)

From: isope-2@sbcglobal.net <isope-2@sbcglobal.net>

Sent: Thursday, April 12, 2018 9:57 AM

To: 'Muhammad Zubair Muis Alie' <zubair.m@eng.unhas.ac.id>

Subject: RE: IJOPE Paper JC-708, Galley Proof due April 12

Dear Dr. Muis Alie,

We received your Reprint order. We ship reprints by DHL courier service, and we need your contact phone number as well as your full mailing address.

Regards,

Janice

ISOPE

495 North Whisman Road, Suite 300, Mountain View, CA 94043, USA

Fax 1-650-254-2038; Tel 1-650-254-1871

[Isope-2@sbcglobal.net](mailto:isope-2@sbcglobal.net); isope-2@isope.org; www.isope.org

From: Claude Chung [<mailto:isope4@gmail.com>]
Sent: Tuesday, April 10, 2018 10:00 AM
To: Muhammad Zubair Muis Alie
Cc: Jin S Chung; Janice Chung
Subject: IJOPE Paper JC-708, Galley Proof due April 12

Dear Dr. Muis Alie,

See attached for your galley proof of Journal Paper JC-708 "Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships."

Please E-mail (with annotation for corrections on the PDF itself) back to me at isope4@gmail.com with cc: to Prof. Chung at "jschung@isope.org" with your corrections by **April 12** our time.

Please take care to double-check ALL equations and figures to ensure that they were transcribed correctly. Your close attention is required. Per journal policy, replacing figures at this stage (except in case of our error) will incur a \$100/figure charge.

Your timely response is essential for our scheduling purposes and will be appreciated. Even if there are no corrections, your reply with "No corrections" is required.

* Reprint form is attached.

Sincerely,

Claude Chung

Managing Editor

ISOPE

isope4@gmail.com; www.isope.org

Category (1)	No Comments
Category (2) Recommendation No. 1 English has to be improved. It is recommended to ask native English speaker to examine your English. Correction No. 2 3rd line in ABSTRACT: “simply supported of boundary condition” → “simply supported boundary condition” Correction No. 3 Page 1; left column; 4th – 5th line: “safety ship” → “safety of ship” Correction No. 4 Page 1; right column; 3rd line: “base on” → “based on” Correction No.5 Page 1; right column; 12th line: “applying the progressive collapse method and finding an” → “applying the progressive collapse calculation method and found an” Correction No.6 Page 1; right column; 26th line: “compared with” → “compared the calculated results with” Correction No.7 Page 2; left column; 1st line: “influence factor” → “influential factor” Correction No.8 Page 2; left column; 12th line: “damaged due, for example, to” → “damaged, for example, due to”	Response No.1 Has been done. Response No.2 Has been corrected, see the article on ABSTRACT. Response No.3 Has been corrected, see the article on page 1. Response No.4 Has been corrected, see the article on page 1. Response No. 5 Has been corrected, see the article on page 1. Response No. 6 Has been corrected, see the article on page 1. Response No. 7 Has been corrected, see the article on page 2. Response No.8 Has been corrected, see the article on page 2.

Correction No.9

Page 2; right column; below Eq.(3): “Where D_i , A_i , y_i and z_i are the tangential stiffness obtained as a slope of the average stress-strain relationship, cross section and the coordinate position of the individual elements, respectively.” → “where D_i , A_i , and (y_i, z_i) are the tangential stiffness obtained as a slope of the average stress-strain curve, cross sectional area and the coordinates of the centroid of individual elements, respectively.”

Correction No.10

Page 2; 1st line below Fig. 1: “asymmetric damage cross section, the equations are used from Eqs.(4) to (8), ” → “asymmetrically damaged cross section, Eqs.(4) through (8) are used,”

Correction No.11

Page 2; 1st line below Eq.(5): “Where I and M is the” à “where I and M are the”

Correction No.12

Page 4; left column; 7th line: “damage side shell” à “damaged side shell”

Correction No.13

Page 4; Fig. 4 (a): There is no element at point, L1, in case of single hull bulk carrier. What σ_c^u is used for this case and what is the physical meaning of choosing this point in this case? No influence shall appear at this point as for buckling and yielding.

Correction No.14

Page 4; 10th line from the bottom: “is place at” → “is placed at”

Response No.9

Has been corrected, see the article on page 2.

Response No.10

Has been corrected, see the article on page 2.

Response No.11

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Response No.12

Has been corrected, see the article on page 4.

Response No.13

To be consistent, σ_c^u need to be placed even there is no element at the deck of the single hull bulk carrier. Similarly on the double hull oil tanker.

Response No.14

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Correction No.15

Page 4; 6th line from the bottom: “damaged^d takes place” → “damage has taken place”

Question No.16

Page 4 – 5: Figures 5, 6, 7, 8, 9 and 10: It should be described what bending moment is indicated in the figures. Is it *MV* or resultant bending moment of *MV* and *MH*?

Question No.17

Page 5; right column; 7th line: What is “stiffened matrix”?

Correction No.18

Page 5; right column; 7th – 8th lines: “horizontal and vertical and” → “horizontal and vertical bending moments and”

Correction No.19

Page 5; right column; 15th line: “of damaged^d” → “of damages^s”

Correction No.20

Page 5; Fig. 11: “HULLST” and “Estimate by Eq.(11)” have to be placed as below:

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Page 6; 8th line: “the damage side” → “damaged^d side”

Correction No.22

Page 6; 8th – 10th lines: “The location L1 cannot induced by *MV*.” → This sentence may have no meaning since there exists no element at point L1.

Response No.15

Has been corrected, see the article on page 4.

Answer No.16

Has been explained, see the article on page 4.

Answer No.17

It should be the incremental equation for bending moment.

Response No.18

Has been corrected, see the article on page 5.

Response No.19

Has been corrected, see the article on page 5.

Response No.20

Fig. 11 has been modified, see the article on page 5.

Response No.21

Has been corrected, see the article on page 6.

Response No.22

Has been deleted, the sentence has been modified, see the article on page 6.

Correction No.23

Page 6; CONCLUSIONS; 1st – 5th lines: “The ultimate ... member elements.” → Difficult to understand. It could be “Progressive collapse analysis was performed on two single hull bulk carriers and a double hull oil tanker with asymmetrically damaged cross section applying Smith’s method.”

Correction No.24

Page 6; CONCLUSIONS; 12th – 13th lines: “than without constrained **ed one**.” → than **that** without constraint**t**.”

Correction No.25

Page 6; CONCLUSIONS; 13th – 14th lines: “even the horizontal curvature is constrained” → **Meaning of this sentence is not understandable. Alternative expression is requested.**

Correction No.26

Page 6; CONCLUSIONS; 14th line: “because **of** the” → “because the”

Question No.27

Page 6; CONCLUSIONS; 15th line: “the stiffness matrix interaction” → **What is “stiffness matrix interaction”?**

Correction No.28

Page 6; CONCLUSIONS; 16th lines: “horizontal and vertical and” → “horizontal and vertical **bending moments** and”

Response No.23

Has been modified, see the article on page 6.

Response No.24

Has been corrected, see the article on page 6.

Response No.25

The sentence is modified, see the article on page 6 (CONCLUSIONS).

Response No.26

Has been corrected, see the article on page 6.

Answer No.27

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Response No.28

Has been corrected, see the article on page 6.

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Page 6; CONCLUSIONS; 16th – 17th lines:
“strength becomes higher.” → “strength
higher.”

Response No.29

Has been corrected, see the article on page 6.

<u>Category (1)</u>	No Comments
<u>Category (2)</u> Recommendation No. 1 English has to be improved. It is recommended to ask native English speaker to examine your English. Correction No. 2 3rd line in ABSTRACT: “simply supported of boundary condition” → “simply supported boundary condition” Correction No. 3 Page 1; left column; 4th – 5th line: “safety ship” → “safety of ship” Correction No. 4 Page 1; right column; 3rd line: “base on” → “based on” Correction No.5 Page 1; right column; 12th line: “applying the progressive collapse method and finding an” → “applying the progressive collapse calculation method and found an” Correction No.6 Page 1; right column; 26th line: “compared with” → “compared the calculated results with” Correction No.7 Page 2; left column; 1st line: “influence factor” → “influential factor” Correction No.8 Page 2; left column; 12th line: “damaged due, for example, to” → “damaged, for example, due to”	Response No.1 Has been done. Response No.2 Has been corrected, see the article on ABSTRACT. Response No.3 Has been corrected, see the article on page 1. Response No.4 Has been corrected, see the article on page 1. Response No. 5 Has been corrected, see the article on page 1. Response No. 6 Has been corrected, see the article on page 1. Response No. 7 Has been corrected, see the article on page 2. Response No.8 Has been corrected, see the article on page 2.

Correction No.9

Page 2; right column; below Eq.(3): “Where D_i , A_i , y_i and z_i are the tangential stiffness obtained as a slope of the average stress-strain relationship, cross section and the coordinate position of the individual elements, respectively.” → “where D_i , A_i , and (y_i, z_i) are the tangential stiffness obtained as a slope of the average stress-strain curve, cross sectional area and the coordinates of the centroid of individual elements, respectively.”

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Bulk Carrier (B1) Idchk = 1			
10% damage			
frame space =	4.175	9.80E-06	1000
Moment	Rotation Curvature		
8.28E+08	8118.32	1.00E-06	0.00023952
1.66E+09	16228.8	2.00E-06	0.00047904
2.48E+09	24343.2	3.00E-06	0.00071856
3.31E+09	32457.6	4.00E-06	0.00095808
4.14E+09	40562.2	5.00E-06	0.0011976
4.97E+09	48676.6	6.00E-06	0.00143713
5.80E+09	56791	7.00E-06	0.00167665
6.62E+09	64905.4	8.00E-06	0.00191617
7.45E+09	73019.8	9.00E-06	0.00215569
8.28E+09	81124.4	1.00E-05	0.00239521
1.66E+10	162288	2.00E-05	0.00479042
2.48E+10	243334	3.00E-05	0.00718563
3.31E+10	324478	4.00E-05	0.00958084
4.14E+10	405622	5.00E-05	0.01197605
4.97E+10	486766	6.00E-05	0.01437126
5.79E+10	567812	7.00E-05	0.01676647
6.62E+10	648956	8.00E-05	0.01916168
7.45E+10	730100	9.00E-05	0.02155689
8.28E+10	811244	1.00E-04	0.0239521
9.11E+10	892388	1.10E-04	0.02634731
9.93E+10	973434	1.20E-04	0.02874251
1.08E+11	1054480	1.30E-04	0.03113772
1.16E+11	1135820	1.40E-04	0.03353293
1.24E+11	1217160	1.50E-04	0.03592814
1.32E+11	1297520	1.60E-04	0.03832335
1.41E+11	1378860	1.70E-04	0.04071856
1.49E+11	1460200	1.80E-04	0.04311377
1.57E+11	1541540	1.90E-04	0.04550898
1.66E+11	1622880	2.00E-04	0.04790419
1.74E+11	1703240	2.10E-04	0.0502994
1.82E+11	1784580	2.20E-04	0.05269461
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1.99E+11	1947260	2.40E-04	0.05748503
2.07E+11	2027620	2.50E-04	0.05988024
2.15E+11	2108960	2.60E-04	0.06227545
2.24E+11	2190300	2.70E-04	0.06467066
2.32E+11	2271640	2.80E-04	0.06706587
2.40E+11	2352000	2.90E-04	0.06946108
2.48E+11	2433340	3.00E-04	0.07185629
2.57E+11	2514680	3.10E-04	0.0742515

Bulk Carrier (B1)	
10% damage	
frame space =	4.175
Moment	
8.23E+08	8067.36
1.65E+09	16130.8
2.47E+09	24186.4
3.29E+09	32251.8
4.11E+09	40317.2
4.94E+09	48372.8
5.76E+09	56438.2
6.58E+09	64503.6
7.40E+09	72559.2
8.23E+09	80624.6
1.65E+10	161210
2.47E+10	241864
3.29E+10	322518
4.11E+10	403074
4.94E+10	483728
5.76E+10	564284
6.58E+10	644938
7.40E+10	725592
8.23E+10	806148
9.05E+10	886802
9.87E+10	967358
1.07E+11	1047620
1.15E+11	1128960
1.23E+11	1209320
1.32E+11	1289680
1.40E+11	1370040
1.48E+11	1451380
1.56E+11	1531740
1.65E+11	1612100
1.73E+11	1692460
1.81E+11	1773800
1.89E+11	1854160
1.97E+11	1934520
2.06E+11	2014880
2.14E+11	2096220
2.22E+11	2176580
2.30E+11	2256940
2.39E+11	2337300
2.47E+11	2417660
2.55E+11	2498020

2.65E+11	2596020	3.20E-04	0.07664671	2.63E+11	2579360
2.73E+11	2676380	3.30E-04	0.07904192	2.71E+11	2659720
2.81E+11	2757720	3.40E-04	0.08143713	2.80E+11	2740080
2.90E+11	2839060	3.50E-04	0.08383234	2.88E+11	2820440
2.98E+11	2920400	3.60E-04	0.08622754	2.96E+11	2900800
3.06E+11	3000760	3.70E-04	0.08862275	3.04E+11	2982140
3.15E+11	3082100	3.80E-04	0.09101796	3.13E+11	3062500
3.23E+11	3163440	3.90E-04	0.09341317	3.21E+11	3142860
3.31E+11	3243800	4.00E-04	0.09580838	3.29E+11	3223220
3.39E+11	3325140	4.10E-04	0.09820359	3.37E+11	3303580
3.48E+11	3406480	4.20E-04	0.1005988	3.45E+11	3383940
3.56E+11	3486840	4.30E-04	0.10299401	3.54E+11	3465280
3.64E+11	3568180	4.40E-04	0.10538922	3.62E+11	3545640
3.72E+11	3649520	4.50E-04	0.10778443	3.70E+11	3626000
3.81E+11	3729880	4.60E-04	0.11017964	3.78E+11	3706360
3.89E+11	3811220	4.70E-04	0.11257485	3.86E+11	3786720
3.97E+11	3892560	4.80E-04	0.11497006	3.95E+11	3867080
4.05E+11	3972920	4.90E-04	0.11736527	4.03E+11	3948420
4.14E+11	4054260	5.00E-04	0.11976048	4.11E+11	4028780
4.22E+11	4135600	5.10E-04	0.12215569	4.19E+11	4109140
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4.39E+11	4297300	5.30E-04	0.12694611	4.36E+11	4269860
4.47E+11	4378640	5.40E-04	0.12934132	4.44E+11	4350220
4.55E+11	4459000	5.50E-04	0.13173653	4.52E+11	4430580
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4.88E+11	4782400	5.90E-04	0.14131737	4.85E+11	4752020
4.96E+11	4862760	6.00E-04	0.14371257	4.93E+11	4831400
5.05E+11	4944100	6.10E-04	0.14610778	5.01E+11	4911760
5.13E+11	5024460	6.20E-04	0.14850299	5.09E+11	4991140
5.21E+11	5103840	6.30E-04	0.1508982	5.17E+11	5070520
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5.37E+11	5264560	6.50E-04	0.15568862	5.34E+11	5228300
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5.53E+11	5422340	6.70E-04	0.16047904	5.50E+11	5385100
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5.69E+11	5579140	6.90E-04	0.16526946	5.65E+11	5539940
5.77E+11	5656560	7.00E-04	0.16766467	5.73E+11	5617360
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5.93E+11	5810420	7.20E-04	0.17245509	5.81E+11	5693800
6.01E+11	5886860	7.30E-04	0.1748503	5.87E+11	5755540
6.08E+11	5962320	7.40E-04	0.17724551	5.90E+11	5778080
6.09E+11	5970160	7.41E-04	0.17750898	5.96E+11	5838840
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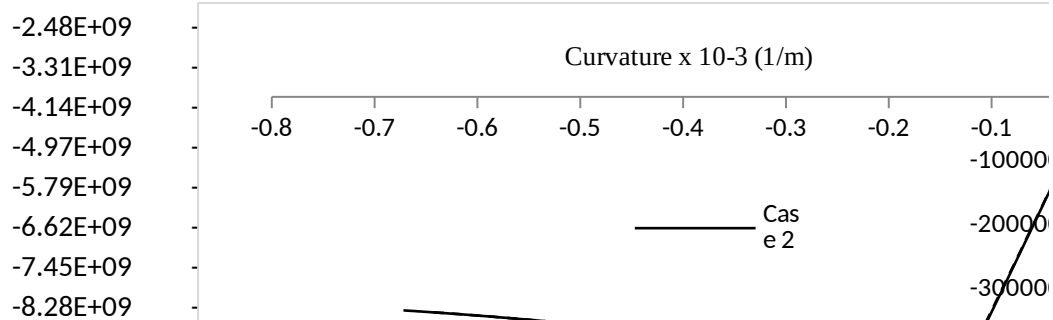
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6.46E+11	6329820	8.18E-04	0.19602395	6.36E+11	6228880
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6.52E+11	6393520	8.38E-04	0.20071856	6.43E+11	6297480
6.54E+11	6409200	8.43E-04	0.20201198	6.46E+11	6331780
6.56E+11	6431740	8.51E-04	0.20385629	6.49E+11	6360200
6.59E+11	6457220	8.61E-04	0.2062515	6.52E+11	6386660
6.60E+11	6469960	8.66E-04	0.20742515	6.52E+11	6389600
6.63E+11	6496420	8.76E-04	0.20982036	6.55E+11	6414100
6.64E+11	6504260	8.79E-04	0.21058683	6.55E+11	6419980
6.66E+11	6524840	8.89E-04	0.21298204	6.57E+11	6436640
6.68E+11	6544440	8.99E-04	0.21537725	6.59E+11	6456240
6.70E+11	6565020	9.09E-04	0.21777246	6.59E+11	6460160
6.72E+11	6584620	9.19E-04	0.22016766	6.61E+11	6478780
6.73E+11	6594420	9.24E-04	0.22131737	6.61E+11	6479760
6.75E+11	6612060	9.34E-04	0.22371257	6.63E+11	6494460
6.76E+11	6625780	9.42E-04	0.22550898	6.64E+11	6511120
6.78E+11	6643420	9.52E-04	0.22790419	6.65E+11	6519940
6.78E+11	6644400	9.52E-04	0.2280479	6.67E+11	6535620
6.79E+11	6657140	9.62E-04	0.23044311	6.68E+11	6543460
6.80E+11	6662040	9.67E-04	0.23149701	6.69E+11	6554240
6.81E+11	6671840	9.77E-04	0.23389222	6.69E+11	6555220
6.82E+11	6680660	9.86E-04	0.23616766	6.70E+11	6564040
6.82E+11	6686540	9.96E-04	0.23856287	6.70E+11	6566000
6.83E+11	6693400	1.01E-03	0.24095808	6.71E+11	6572860
6.84E+11	6701240	1.02E-03	0.24335329	6.71E+11	6578740
6.84E+11	6703200	1.02E-03	0.24383234	6.72E+11	6582660
6.85E+11	6710060	1.03E-03	0.24622754	6.72E+11	6584620
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6.86E+11	6723780	1.05E-03	0.25149701	6.71E+11	6578740
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6.87E+11	6736520	1.07E-03	0.25676647	6.70E+11	6566980
6.88E+11	6741420	1.08E-03	0.25916168	6.69E+11	6559140
6.88E+11	6742400	1.09E-03	0.26011976	6.68E+11	6550320
6.88E+11	6744360	1.10E-03	0.26251497	6.67E+11	6536600
6.88E+11	6745340	1.10E-03	0.26347305	6.66E+11	6526800

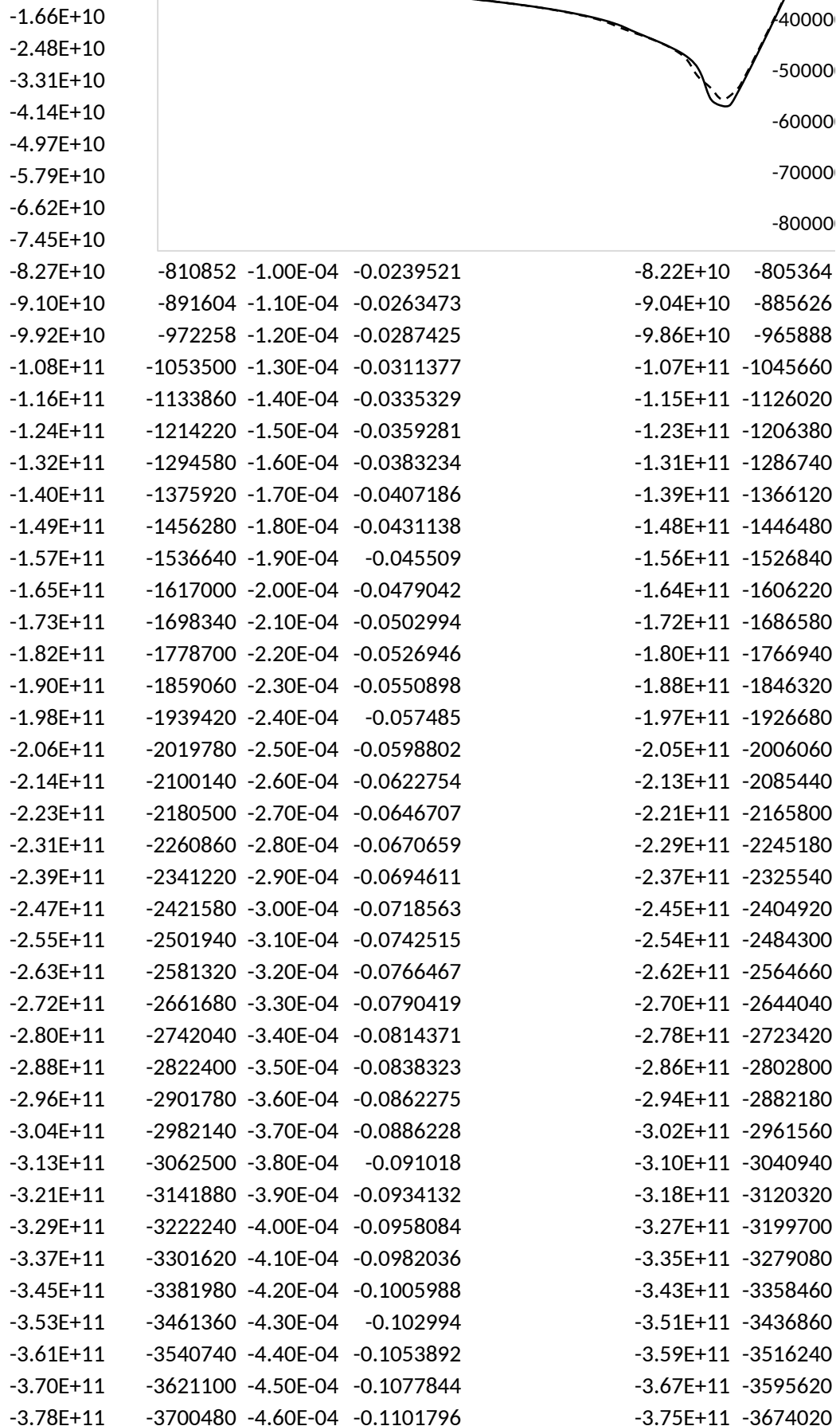
6.88E+11	6746320	1.11E-03	0.26586826	6.65E+11	6517980
6.89E+11	6747300	1.12E-03	0.26754491	6.64E+11	6502300
6.88E+11	6746320	1.13E-03	0.26994012	6.61E+11	6481720
6.88E+11	6742400	1.14E-03	0.27233533	6.60E+11	6468980
6.86E+11	6721820	1.14E-03	0.27353293	6.58E+11	6450360
6.81E+11	6676740	1.15E-03	0.2754491	6.56E+11	6429780
6.78E+11	6640480	1.16E-03	0.27712575	6.54E+11	6405280
6.76E+11	6624800	1.16E-03	0.27784431	6.51E+11	6380780
6.71E+11	6572860	1.17E-03	0.28023952	6.51E+11	6377840
6.69E+11	6559140	1.17E-03	0.28095808	6.48E+11	6353340
6.65E+11	6519940	1.18E-03	0.28311377	6.47E+11	6341580
6.63E+11	6493480	1.19E-03	0.2845509	6.45E+11	6323940
6.59E+11	6461140	1.20E-03	0.28622754	6.44E+11	6307280
6.55E+11	6418020	1.21E-03	0.28862275	6.42E+11	6290620
6.52E+11	6386660	1.21E-03	0.29053892	6.39E+11	6261220
6.47E+11	6337660	1.22E-03	0.29293413	6.38E+11	6248480
6.42E+11	6293560	1.23E-03	0.29532934	6.35E+11	6219080
6.41E+11	6285720	1.24E-03	0.29580838	6.33E+11	6206340
6.38E+11	6247500	1.25E-03	0.29820359	6.31E+11	6181840
6.34E+11	6209280	1.26E-03	0.3005988	6.29E+11	6159300
6.30E+11	6174980	1.27E-03	0.30299401	6.26E+11	6136760
6.27E+11	6143620	1.28E-03	0.30538922	6.24E+11	6115200
6.25E+11	6123040	1.28E-03	0.30682635	6.23E+11	6104420
6.22E+11	6093640	1.29E-03	0.30922156	6.21E+11	6084820
6.19E+11	6064240	1.30E-03	0.31161677	6.19E+11	6066200
6.16E+11	6036800	1.31E-03	0.31401198	6.18E+11	6056400
6.13E+11	6010340	1.32E-03	0.31640719	6.16E+11	6038760
6.11E+11	5986820	1.33E-03	0.3188024	6.14E+11	6017200
6.08E+11	5962320	1.34E-03	0.3211976	6.13E+11	6009360
6.06E+11	5938800	1.35E-03	0.32359281	6.11E+11	5990740
6.04E+11	5916260	1.36E-03	0.32598802	6.10E+11	5978980
6.02E+11	5895680	1.37E-03	0.32838323	6.08E+11	5959380
6.00E+11	5876080	1.38E-03	0.33077844	6.07E+11	5949580
5.98E+11	5856480	1.39E-03	0.33317365	6.05E+11	5929000
5.96E+11	5838840	1.40E-03	0.33556886	6.03E+11	5909400
5.94E+11	5820220	1.41E-03	0.33796407	6.01E+11	5890780
5.93E+11	5814340	1.42E-03	0.33892216	6.00E+11	5881960
5.91E+11	5795720	1.43E-03	0.34131737	5.98E+11	5863340
5.90E+11	5778080	1.44E-03	0.34371257	5.98E+11	5859420
5.89E+11	5767300	1.44E-03	0.34538922	5.96E+11	5835900
5.87E+11	5749660	1.45E-03	0.34778443	5.93E+11	5813360
5.85E+11	5733000	1.46E-03	0.35017964	5.91E+11	5792780
5.83E+11	5716340	1.47E-03	0.35257485	5.89E+11	5773180
5.82E+11	5700660	1.48E-03	0.35497006	5.87E+11	5753580
5.81E+11	5696740	1.48E-03	0.3554491	5.86E+11	5746720

5.79E+11	5678120	1.49E-03	0.35784431	5.84E+11	5727120
5.78E+11	5661460	1.50E-03	0.36023952	5.82E+11	5707520
5.76E+11	5643820	1.51E-03	0.36263473	5.81E+11	5688900
5.74E+11	5628140	1.52E-03	0.36502994	5.79E+11	5671260
5.72E+11	5609520	1.53E-03	0.36742515	5.77E+11	5653620
5.71E+11	5592860	1.54E-03	0.36982036	5.75E+11	5636960
5.69E+11	5576200	1.55E-03	0.37221557	5.74E+11	5620300
5.67E+11	5559540	1.56E-03	0.37461078	5.72E+11	5604620
5.66E+11	5542880	1.57E-03	0.37700599	5.70E+11	5588940
5.64E+11	5528180	1.58E-03	0.3794012	5.69E+11	5574240
5.63E+11	5512500	1.59E-03	0.38179641	5.67E+11	5559540
5.61E+11	5497800	1.60E-03	0.38419162	5.66E+11	5544840
5.60E+11	5483100	1.61E-03	0.38658683	5.64E+11	5531120
5.58E+11	5469380	1.62E-03	0.38898204	5.63E+11	5517400
5.57E+11	5455660	1.63E-03	0.39137725	5.62E+11	5504660
5.56E+11	5450760	1.64E-03	0.39233533	5.60E+11	5491920
5.55E+11	5437040	1.65E-03	0.39473054	5.59E+11	5479180
5.53E+11	5423320	1.66E-03	0.39712575	5.58E+11	5467420
5.52E+11	5410580	1.67E-03	0.39952096	5.57E+11	5454680
5.51E+11	5397840	1.68E-03	0.40191617	5.56E+11	5447820
5.50E+11	5385100	1.69E-03	0.40431138	5.55E+11	5436060
5.48E+11	5372360	1.70E-03	0.40670659	5.54E+11	5424300
5.47E+11	5360600	1.71E-03	0.4091018	5.52E+11	5413520
5.46E+11	5348840	1.72E-03	0.41149701	5.52E+11	5410580
5.45E+11	5337080	1.73E-03	0.41389222	5.51E+11	5399800
5.44E+11	5326300	1.74E-03	0.41628743	5.50E+11	5388040
5.42E+11	5314540	1.75E-03	0.41868263	5.49E+11	5378240
5.41E+11	5303760	1.76E-03	0.42107784	5.48E+11	5367460
5.40E+11	5292980	1.77E-03	0.42347305	5.47E+11	5356680
5.39E+11	5282200	1.78E-03	0.42586826	5.46E+11	5345900
5.38E+11	5272400	1.79E-03	0.42826347	5.45E+11	5342960
5.37E+11	5260640	1.80E-03	0.43065868	5.44E+11	5330220
5.36E+11	5249860	1.81E-03	0.43305389	5.43E+11	5318460
5.35E+11	5239080	1.82E-03	0.4354491	5.42E+11	5306700
5.34E+11	5229280	1.83E-03	0.43784431	5.40E+11	5295920
5.33E+11	5218500	1.84E-03	0.44023952	5.39E+11	5285140
5.31E+11	5207720	1.85E-03	0.44263473	5.38E+11	5273380
5.30E+11	5197920	1.86E-03	0.44502994	5.37E+11	5262600
5.29E+11	5188120	1.87E-03	0.44742515	5.36E+11	5251820
5.28E+11	5178320	1.88E-03	0.44982036	5.35E+11	5241040
5.27E+11	5168520	1.89E-03	0.45221557	5.34E+11	5230260
5.26E+11	5158720	1.90E-03	0.45461078	5.33E+11	5220460
5.26E+11	5149900	1.91E-03	0.45700599	5.32E+11	5209680
5.25E+11	5140100	1.92E-03	0.4594012	5.31E+11	5198900
5.24E+11	5131280	1.93E-03	0.46179641	5.29E+11	5188120

5.23E+11	5122460	1.94E-03	0.46419162	5.28E+11	5178320
5.22E+11	5112660	1.95E-03	0.46658683	5.27E+11	5168520
5.21E+11	5103840	1.96E-03	0.46898204	5.26E+11	5158720
5.20E+11	5096000	1.97E-03	0.47137725	5.25E+11	5147940
5.19E+11	5087180	1.98E-03	0.47377246	5.24E+11	5139120
5.18E+11	5079340	1.99E-03	0.47616766	5.23E+11	5129320
5.17E+11	5070520	2.00E-03	0.47856287	5.22E+11	5119520
5.17E+11	5062680	2.01E-03	0.48095808	5.22E+11	5114620
5.16E+11	5053860	2.02E-03	0.48335329	5.21E+11	5105800
5.15E+11	5046020	2.03E-03	0.4857485	5.20E+11	5096000
5.14E+11	5038180	2.04E-03	0.48814371	5.19E+11	5087180
5.13E+11	5030340	2.05E-03	0.49053892	5.18E+11	5079340
5.13E+11	5022500	2.06E-03	0.49293413	5.17E+11	5070520
5.12E+11	5014660	2.07E-03	0.49532934	5.16E+11	5060720
5.11E+11	5006820	2.08E-03	0.49772455	5.16E+11	5051900
5.10E+11	4998980	2.09E-03	0.50011976	5.15E+11	5043080
5.09E+11	4992120	2.10E-03	0.50251497	5.14E+11	5035240
5.09E+11	4984280	2.11E-03	0.50491018	5.13E+11	5026420
5.08E+11	4977420	2.12E-03	0.50730539	5.12E+11	5017600
5.07E+11	4969580	2.13E-03	0.5097006	5.11E+11	5009760
5.06E+11	4962720	2.14E-03	0.51209581	5.10E+11	5000940
5.06E+11	4954880	2.15E-03	0.51449102	5.10E+11	4993100
5.05E+11	4948020	2.16E-03	0.51688623	5.09E+11	4985260
5.04E+11	4940180	2.17E-03	0.51928144	5.08E+11	4977420
5.03E+11	4933320	2.18E-03	0.52167665	5.07E+11	4969580
5.03E+11	4925480	2.19E-03	0.52407186	5.06E+11	4961740
5.02E+11	4918620	2.20E-03	0.52646707	5.06E+11	4953900
5.01E+11	4911760	2.21E-03	0.52886228	5.05E+11	4946060
5.01E+11	4905880	2.22E-03	0.53125749	5.04E+11	4939200
5.00E+11	4899020	2.23E-03	0.53365269	5.03E+11	4931360
4.99E+11	4892160	2.24E-03	0.5360479	5.03E+11	4924500
4.99E+11	4885300	2.25E-03	0.53844311	5.02E+11	4916660
4.98E+11	4878440	2.26E-03	0.54083832	5.01E+11	4909800
4.97E+11	4871580	2.27E-03	0.54323353	5.00E+11	4902940
4.96E+11	4864720	2.28E-03	0.54562874	5.00E+11	4896080
4.96E+11	4856880	2.29E-03	0.54802395	4.99E+11	4889220
4.95E+11	4850020	2.30E-03	0.55041916	4.98E+11	4882360
4.94E+11	4843160	2.31E-03	0.55281437	4.98E+11	4875500
4.94E+11	4836300	2.32E-03	0.55520958	4.97E+11	4868640
4.93E+11	4829440	2.33E-03	0.55760479	4.96E+11	4861780
4.92E+11	4823560	2.34E-03	0.56	4.95E+11	4854920
4.92E+11	4816700	2.35E-03	0.56239521	4.95E+11	4849040
4.91E+11	4809840	2.36E-03	0.56479042	4.94E+11	4842180
4.90E+11	4803960	2.37E-03	0.56718563	4.93E+11	4835320
4.90E+11	4797100	2.38E-03	0.56958084	4.93E+11	4829440

4.89E+11	4790240	2.39E-03	0.57197605	4.92E+11	4822580
4.88E+11	4783380	2.40E-03	0.57437126	4.92E+11	4816700
4.88E+11	4777500	2.41E-03	0.57676647	4.91E+11	4809840
4.87E+11	4770640	2.42E-03	0.57916168	4.90E+11	4803960
4.86E+11	4763780	2.43E-03	0.58155689	4.90E+11	4797100
4.86E+11	4757900	2.44E-03	0.5839521	4.89E+11	4791220
4.85E+11	4751040	2.45E-03	0.58634731	4.88E+11	4784360
4.84E+11	4744180	2.46E-03	0.58874251	4.88E+11	4778480
4.84E+11	4738300	2.47E-03	0.59113772	4.87E+11	4771620
4.83E+11	4731440	2.48E-03	0.59353293	4.86E+11	4765740
4.82E+11	4725560	2.49E-03	0.59592814	4.86E+11	4758880
4.82E+11	4719680	2.50E-03	0.59832335	4.85E+11	4753000
4.81E+11	4713800	2.51E-03	0.60071856	4.84E+11	4747120
4.80E+11	4707920	2.52E-03	0.60311377	4.84E+11	4740260
4.80E+11	4701060	2.53E-03	0.60550898	4.83E+11	4734380
4.79E+11	4695180	2.54E-03	0.60790419	4.83E+11	4728500
4.79E+11	4689300	2.55E-03	0.6102994	4.82E+11	4722620
4.78E+11	4683420	2.56E-03	0.61269461	4.81E+11	4716740
4.77E+11	4677540	2.57E-03	0.61508982	4.81E+11	4710860
4.77E+11	4671660	2.58E-03	0.61748503	4.80E+11	4704980
4.76E+11	4665780	2.59E-03	0.61988024	4.80E+11	4699100
4.76E+11	4659900	2.60E-03	0.62227545	4.79E+11	4693220
4.75E+11	4654020	2.61E-03	0.62467066	4.78E+11	4687340
4.75E+11	4654020	2.61E-03	0.62491018	4.78E+11	4682440
4.74E+11	4648140	2.62E-03	0.62730539	4.77E+11	4676560
4.74E+11	4642260	2.63E-03	0.6297006	4.77E+11	4670680
4.73E+11	4636380	2.64E-03	0.63209581	4.76E+11	4664800
4.73E+11	4631480	2.65E-03	0.63449102	4.75E+11	4658920
4.72E+11	4625600	2.66E-03	0.63688623	4.75E+11	4654020
4.72E+11	4620700	2.67E-03	0.63928144	4.74E+11	4648140
4.71E+11	4614820	2.68E-03	0.64167665	4.74E+11	4643240
4.70E+11	4609920	2.69E-03	0.64407186	4.73E+11	4637360
4.70E+11	4604040	2.70E-03	0.64646707	4.73E+11	4632460
4.69E+11	4599140	2.71E-03	0.64886228	4.72E+11	4626580
0.00E+00	0	0.00E+00		0.00E+00	0
-8.28E+08	-8118.32	-1.00E-06	-0.0002395	-8.23E+08	-8067.36
-1.66E+09	-16228.8	-2.00E-06	-0.000479	-1.65E+09	-16130.8





-3.86E+11	-3779860	-4.70E-04	-0.1125749	-3.83E+11	-3753400
-3.94E+11	-3859240	-4.80E-04	-0.1149701	-3.91E+11	-3831800
-4.02E+11	-3938620	-4.90E-04	-0.1173653	-3.99E+11	-3911180
-4.10E+11	-4018000	-5.00E-04	-0.1197605	-4.07E+11	-3989580
-4.18E+11	-4097380	-5.10E-04	-0.1221557	-4.15E+11	-4067980
-4.26E+11	-4176760	-5.20E-04	-0.1245509	-4.23E+11	-4145400
-4.34E+11	-4255160	-5.30E-04	-0.1269461	-4.31E+11	-4223800
-4.42E+11	-4333560	-5.40E-04	-0.1293413	-4.39E+11	-4301220
-4.50E+11	-4411960	-5.50E-04	-0.1317365	-4.47E+11	-4378640
-4.58E+11	-4490360	-5.60E-04	-0.1341317	-4.55E+11	-4456060
-4.66E+11	-4567780	-5.70E-04	-0.1365269	-4.63E+11	-4532500
-4.74E+11	-4645200	-5.80E-04	-0.1389222	-4.70E+11	-4608940
-4.82E+11	-4722620	-5.90E-04	-0.1413174	-4.78E+11	-4685380
-4.90E+11	-4799060	-6.00E-04	-0.1437126	-4.86E+11	-4760840
-4.98E+11	-4875500	-6.10E-04	-0.1461078	-4.94E+11	-4836300
-5.05E+11	-4951940	-6.20E-04	-0.148503	-5.01E+11	-4911760
-5.13E+11	-5027400	-6.30E-04	-0.1508982	-5.05E+11	-4951940
-5.21E+11	-5102860	-6.40E-04	-0.1532934	-5.13E+11	-5025440
-5.28E+11	-5178320	-6.50E-04	-0.1556886	-5.20E+11	-5098940
-5.31E+11	-5206740	-6.54E-04	-0.1565988	-5.22E+11	-5114620
-5.39E+11	-5280240	-6.64E-04	-0.158994	-5.29E+11	-5187140
-5.46E+11	-5353740	-6.74E-04	-0.1613892	-5.34E+11	-5229280
-5.51E+11	-5397840	-6.80E-04	-0.1628743	-5.40E+11	-5289060
-5.58E+11	-5469380	-6.90E-04	-0.1652695	-5.43E+11	-5316500
-5.64E+11	-5524260	-6.98E-04	-0.1671617	-5.45E+11	-5336100
-5.69E+11	-5574240	-7.05E-04	-0.1689102	-5.47E+11	-5355700
-5.74E+11	-5623240	-7.13E-04	-0.1708503	-5.49E+11	-5379220
-5.77E+11	-5657540	-7.21E-04	-0.1726707	-5.53E+11	-5417440
-5.79E+11	-5673220	-7.28E-04	-0.1744192	-5.54E+11	-5427240
-5.80E+11	-5680080	-7.35E-04	-0.1759521	-5.56E+11	-5443900
-5.80E+11	-5682040	-7.40E-04	-0.1772216	-5.58E+11	-5471340
-5.80E+11	-5683020	-7.48E-04	-0.1791138	-5.61E+11	-5494860
-5.79E+11	-5676160	-7.58E-04	-0.181509	-5.63E+11	-5513480
-5.78E+11	-5665380	-7.68E-04	-0.1839042	-5.64E+11	-5529160
-5.78E+11	-5663420	-7.70E-04	-0.1843593	-5.65E+11	-5540920
-5.77E+11	-5650680	-7.80E-04	-0.1867545	-5.66E+11	-5547780
-5.76E+11	-5642840	-7.85E-04	-0.1880958	-5.66E+11	-5546800
-5.75E+11	-5631080	-7.91E-04	-0.1894611	-5.66E+11	-5544840
-5.72E+11	-5609520	-8.01E-04	-0.1918563	-5.64E+11	-5531120
-5.70E+11	-5586000	-8.09E-04	-0.1937725	-5.64E+11	-5522300
-5.68E+11	-5569340	-8.13E-04	-0.1947545	-5.60E+11	-5488000
-5.64E+11	-5531120	-8.21E-04	-0.1966228	-5.58E+11	-5472320
-5.60E+11	-5488980	-8.26E-04	-0.1979162	-5.55E+11	-5439980
-5.51E+11	-5398820	-8.36E-04	-0.2003114	-5.52E+11	-5406660
-5.39E+11	-5281220	-8.46E-04	-0.2027066	-5.49E+11	-5378240

-5.31E+11	-5200860	-8.53E-04	-0.2043593	-5.45E+11	-5342960
-5.20E+11	-5096980	-8.63E-04	-0.2067545	-5.41E+11	-5302780
-5.11E+11	-5010740	-8.73E-04	-0.2091497	-5.40E+11	-5290040
-5.04E+11	-4941160	-8.83E-04	-0.2115449	-5.36E+11	-5254760
-4.98E+11	-4882360	-8.93E-04	-0.2139401	-5.36E+11	-5254760
-4.96E+11	-4859820	-8.99E-04	-0.2152096	-5.33E+11	-5224380
-4.94E+11	-4842180	-9.03E-04	-0.2161916	-5.30E+11	-5194000
-4.90E+11	-4799060	-9.13E-04	-0.2185868	-5.27E+11	-5163620
-4.86E+11	-4764760	-9.23E-04	-0.220982	-5.27E+11	-5162640
-4.83E+11	-4732420	-9.33E-04	-0.2233772	-5.23E+11	-5122460
-4.80E+11	-4703020	-9.43E-04	-0.2257725	-5.18E+11	-5077380
-4.77E+11	-4676560	-9.53E-04	-0.2281677	-5.15E+11	-5047980
-4.75E+11	-4650100	-9.63E-04	-0.2305629	-5.13E+11	-5024460
-4.72E+11	-4626580	-9.73E-04	-0.2329581	-5.07E+11	-4967620
-4.70E+11	-4604040	-9.83E-04	-0.2353533	-5.07E+11	-4963700
-4.68E+11	-4583460	-9.93E-04	-0.2377485	-4.99E+11	-4890200
-4.66E+11	-4562880	-1.00E-03	-0.2402395	-4.93E+11	-4827480
-4.64E+11	-4544260	-1.01E-03	-0.2426347	-4.87E+11	-4775540
-4.62E+11	-4525640	-1.02E-03	-0.2450299	-4.86E+11	-4757900
-4.60E+11	-4507020	-1.03E-03	-0.2474251	-4.81E+11	-4717720
-4.58E+11	-4488400	-1.04E-03	-0.2498204	-4.78E+11	-4683420
-4.56E+11	-4470760	-1.05E-03	-0.2522156	-4.75E+11	-4652060
-4.55E+11	-4454100	-1.06E-03	-0.2546108	-4.72E+11	-4625600
-4.53E+11	-4436460	-1.07E-03	-0.257006	-4.70E+11	-4605020
-4.51E+11	-4419800	-1.08E-03	-0.2594012	-4.67E+11	-4580520
-4.49E+11	-4403140	-1.09E-03	-0.2617964	-4.65E+11	-4558960
-4.48E+11	-4387460	-1.10E-03	-0.2641916	-4.65E+11	-4556020
-4.46E+11	-4370800	-1.11E-03	-0.2665868	-4.63E+11	-4534460
-4.44E+11	-4355120	-1.12E-03	-0.268982	-4.61E+11	-4513880
-4.43E+11	-4339440	-1.13E-03	-0.2713772	-4.59E+11	-4494280
-4.41E+11	-4323760	-1.14E-03	-0.2737725	-4.57E+11	-4475660
-4.40E+11	-4308080	-1.15E-03	-0.2761677	-4.55E+11	-4458020
-4.38E+11	-4291420	-1.16E-03	-0.2785629	-4.53E+11	-4440380
-4.36E+11	-4275740	-1.17E-03	-0.2809581	-4.51E+11	-4423720
-4.35E+11	-4260060	-1.18E-03	-0.2833533	-4.50E+11	-4407060
-4.33E+11	-4244380	-1.19E-03	-0.2857485	-4.48E+11	-4391380
-4.31E+11	-4227720	-1.20E-03	-0.2881437	-4.47E+11	-4375700
-4.30E+11	-4211060	-1.21E-03	-0.2905389	-4.45E+11	-4361000
-4.28E+11	-4194400	-1.22E-03	-0.2929341	-4.44E+11	-4346300
-4.26E+11	-4176760	-1.23E-03	-0.2953293	-4.42E+11	-4334540
-4.24E+11	-4159120	-1.24E-03	-0.2977246	-4.41E+11	-4319840
-4.23E+11	-4141480	-1.25E-03	-0.3001198	-4.39E+11	-4306120
-4.21E+11	-4124820	-1.26E-03	-0.302515	-4.38E+11	-4291420
-4.19E+11	-4108160	-1.27E-03	-0.3049102	-4.37E+11	-4277700
-4.18E+11	-4093460	-1.28E-03	-0.3073054	-4.35E+11	-4263980

-4.16E+11	-4078760	-1.29E-03	-0.3097006	-4.34E+11	-4251240
-4.15E+11	-4066020	-1.30E-03	-0.3120958	-4.32E+11	-4236540
-4.14E+11	-4059160	-1.31E-03	-0.3132934	-4.31E+11	-4223800
-4.13E+11	-4046420	-1.32E-03	-0.3156886	-4.30E+11	-4209100
-4.12E+11	-4034660	-1.33E-03	-0.3180838	-4.28E+11	-4195380
-4.10E+11	-4021920	-1.34E-03	-0.320479	-4.27E+11	-4181660
-4.09E+11	-4011140	-1.35E-03	-0.3228743	-4.25E+11	-4166960
-4.08E+11	-4000360	-1.36E-03	-0.3252695	-4.24E+11	-4152260
-4.07E+11	-3990560	-1.37E-03	-0.3276647	-4.22E+11	-4137560
-4.06E+11	-3979780	-1.38E-03	-0.3300599	-4.21E+11	-4122860
-4.05E+11	-3969980	-1.39E-03	-0.3324551	-4.19E+11	-4107180
-4.04E+11	-3959200	-1.40E-03	-0.3348503	-4.17E+11	-4090520
-4.03E+11	-3950380	-1.41E-03	-0.3372455	-4.16E+11	-4073860
-4.02E+11	-3940580	-1.42E-03	-0.3396407	-4.14E+11	-4058180
-4.01E+11	-3931760	-1.43E-03	-0.3420359	-4.13E+11	-4044460
-4.00E+11	-3922940	-1.44E-03	-0.3444311	-4.11E+11	-4029760
-3.99E+11	-3914120	-1.45E-03	-0.3468263	-4.10E+11	-4015060
-3.99E+11	-3905300	-1.46E-03	-0.3492216	-4.09E+11	-4003300
-3.98E+11	-3896480	-1.47E-03	-0.3516168	-4.07E+11	-3992520
-3.97E+11	-3888640	-1.48E-03	-0.354012	-4.06E+11	-3980760
-3.96E+11	-3880800	-1.49E-03	-0.3564072	-4.05E+11	-3969980
-3.95E+11	-3872960	-1.50E-03	-0.3588024	-4.04E+11	-3959200
-3.94E+11	-3865120	-1.51E-03	-0.3611976	-4.03E+11	-3949400
-3.94E+11	-3857280	-1.52E-03	-0.3635928	-4.02E+11	-3939600
-3.93E+11	-3849440	-1.53E-03	-0.365988	-4.01E+11	-3929800
-3.92E+11	-3842580	-1.54E-03	-0.3683832	-4.00E+11	-3920980
-3.91E+11	-3834740	-1.55E-03	-0.3707784	-4.00E+11	-3920980
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-3.90E+11	-3821020	-1.57E-03	-0.3755689	-3.98E+11	-3903340
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-3.89E+11	-3807300	-1.59E-03	-0.3803593	-3.97E+11	-3885700
-3.88E+11	-3800440	-1.60E-03	-0.3827545	-3.96E+11	-3876880
-3.87E+11	-3794560	-1.61E-03	-0.3851497	-3.95E+11	-3869040
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-3.86E+11	-3781820	-1.63E-03	-0.3899401	-3.93E+11	-3853360
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-3.84E+11	-3763200	-1.66E-03	-0.3971257	-3.91E+11	-3830820
-3.83E+11	-3757320	-1.67E-03	-0.399521	-3.90E+11	-3823960
-3.83E+11	-3751440	-1.68E-03	-0.4019162	-3.89E+11	-3816120
-3.82E+11	-3745560	-1.69E-03	-0.4043114	-3.89E+11	-3809260
-3.82E+11	-3739680	-1.70E-03	-0.4067066	-3.88E+11	-3802400
-3.81E+11	-3733800	-1.71E-03	-0.4091018	-3.87E+11	-3795540
-3.81E+11	-3728900	-1.72E-03	-0.411497	-3.87E+11	-3789660
-3.80E+11	-3723020	-1.73E-03	-0.4138922	-3.86E+11	-3782800

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-3.79E+11	-3712240	-1.75E-03	-0.4186826	-3.85E+11	-3770060
-3.78E+11	-3706360	-1.76E-03	-0.4210778	-3.84E+11	-3764180
-3.78E+11	-3701460	-1.77E-03	-0.4234731	-3.83E+11	-3757320
-3.77E+11	-3696560	-1.78E-03	-0.4258683	-3.83E+11	-3751440
-3.77E+11	-3691660	-1.79E-03	-0.4282635	-3.82E+11	-3745560
-3.76E+11	-3685780	-1.80E-03	-0.4306587	-3.82E+11	-3739680
-3.76E+11	-3680880	-1.81E-03	-0.4330539	-3.81E+11	-3733800
-3.75E+11	-3675980	-1.82E-03	-0.4354491	-3.80E+11	-3727920
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-3.74E+11	-3666180	-1.84E-03	-0.4402395	-3.79E+11	-3717140
-3.74E+11	-3661280	-1.85E-03	-0.4426347	-3.79E+11	-3711260
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-3.73E+11	-3652460	-1.87E-03	-0.4474251	-3.78E+11	-3700480
-3.72E+11	-3647560	-1.88E-03	-0.4498204	-3.77E+11	-3695580
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-3.68E+11	-3607380	-1.97E-03	-0.4713772	-3.73E+11	-3652460
-3.68E+11	-3603460	-1.98E-03	-0.4737725	-3.72E+11	-3647560
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-3.66E+11	-3590720	-2.01E-03	-0.4809581	-3.71E+11	-3633840
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-3.66E+11	-3585820	-2.02E-03	-0.4835928	-3.70E+11	-3624040
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-3.65E+11	-3573080	-2.05E-03	-0.4907784	-3.69E+11	-3611300
-3.64E+11	-3569160	-2.06E-03	-0.4931737	-3.68E+11	-3607380
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-3.63E+11	-3561320	-2.08E-03	-0.4979641	-3.67E+11	-3598560
-3.63E+11	-3557400	-2.09E-03	-0.5003593	-3.67E+11	-3593660
-3.63E+11	-3553480	-2.10E-03	-0.5027545	-3.66E+11	-3589740
-3.62E+11	-3549560	-2.11E-03	-0.5051497	-3.66E+11	-3585820
-3.62E+11	-3545640	-2.12E-03	-0.5075449	-3.66E+11	-3581900
-3.61E+11	-3541720	-2.13E-03	-0.5099401	-3.65E+11	-3577980
-3.61E+11	-3537800	-2.14E-03	-0.5123353	-3.65E+11	-3573080
-3.61E+11	-3534860	-2.15E-03	-0.5147305	-3.64E+11	-3569160
-3.60E+11	-3530940	-2.16E-03	-0.5171257	-3.64E+11	-3565240
-3.60E+11	-3527020	-2.17E-03	-0.519521	-3.63E+11	-3561320

-3.60E+11	-3523100	-2.18E-03	-0.5219162	-3.63E+11	-3559360
-3.59E+11	-3520160	-2.19E-03	-0.5243114	-3.63E+11	-3555440
-3.59E+11	-3516240	-2.20E-03	-0.5267066	-3.62E+11	-3551520
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-3.58E+11	-3509380	-2.22E-03	-0.531497	-3.62E+11	-3544660
-3.58E+11	-3505460	-2.23E-03	-0.5338922	-3.61E+11	-3540740
-3.57E+11	-3501540	-2.24E-03	-0.5362874	-3.61E+11	-3536820
-3.57E+11	-3498600	-2.25E-03	-0.5386826	-3.61E+11	-3532900
-3.57E+11	-3494680	-2.26E-03	-0.5410778	-3.60E+11	-3528980
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-3.52E+11	-3447640	-2.41E-03	-0.5760479	-3.55E+11	-3477040
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-3.49E+11	-3423140	-2.49E-03	-0.5952096	-3.52E+11	-3450580
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-3.46E+11	-3385900	-2.62E-03	-0.6263473	-3.48E+11	-3413340

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-3.45E+11	-3378060	-2.65E-03	-0.6335329	-3.47E+11	-3404520
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-3.43E+11	-3361400	-2.71E-03	-0.6479042	-3.46E+11	-3387860
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-3.42E+11	-3351600	-2.75E-03	-0.657485	-3.45E+11	-3376100
-3.42E+11	-3348660	-2.76E-03	-0.6598802	-3.44E+11	-3374140
-3.41E+11	-3345720	-2.77E-03	-0.6622754	-3.44E+11	-3371200
-3.41E+11	-3343760	-2.78E-03	-0.6646707	-3.44E+11	-3368260
-3.41E+11	-3340820	-2.79E-03	-0.6670659	-3.43E+11	-3365320
-3.41E+11	-3338860	-2.80E-03	-0.6694611	-3.43E+11	-3363360
-3.40E+11	-3335920	-2.81E-03	-0.6718563	-3.43E+11	-3360420

Idchk = 2

age

Bulk Carrier (B1) Idchk = 1

20% damage

Bulk C

9.80E-06	1000	frame space =	4.175	9.80E-06	1000	frame space =
Rotation	Curvature	Moment		Rotation	Curvature	Moment
1.00E-06	0.00024	8.14E+08	7981.12	1.00E-06	0.00024	8.05E+08
2.00E-06	0.000479	1.63E+09	15954.4	2.00E-06	0.000479	1.61E+09
3.00E-06	0.000719	2.44E+09	23931.6	3.00E-06	0.000719	2.42E+09
4.00E-06	0.000958	3.26E+09	31908.8	4.00E-06	0.000958	3.22E+09
5.00E-06	0.001198	4.07E+09	39886	5.00E-06	0.001198	4.02E+09
6.00E-06	0.001437	4.88E+09	47863.2	6.00E-06	0.001437	4.83E+09
7.00E-06	0.001677	5.70E+09	55840.4	7.00E-06	0.001677	5.63E+09
8.00E-06	0.001916	6.51E+09	63817.6	8.00E-06	0.001916	6.44E+09
9.00E-06	0.002156	7.33E+09	71794.8	9.00E-06	0.002156	7.24E+09
1.00E-05	0.002395	8.14E+09	79762.2	1.00E-05	0.002395	8.05E+09
2.00E-05	0.00479	1.63E+10	159544	2.00E-05	0.00479	1.61E+10
3.00E-05	0.007186	2.44E+10	239316	3.00E-05	0.007186	2.41E+10
4.00E-05	0.009581	3.26E+10	319088	4.00E-05	0.009581	3.22E+10
5.00E-05	0.011976	4.07E+10	398860	5.00E-05	0.011976	4.02E+10
6.00E-05	0.014371	4.88E+10	478534	6.00E-05	0.014371	4.83E+10
7.00E-05	0.016766	5.70E+10	558306	7.00E-05	0.016766	5.63E+10
8.00E-05	0.019162	6.51E+10	638078	8.00E-05	0.019162	6.44E+10
9.00E-05	0.021557	7.33E+10	717850	9.00E-05	0.021557	7.24E+10
1.00E-04	0.023952	8.14E+10	797622	1.00E-04	0.023952	8.05E+10
1.10E-04	0.026347	8.95E+10	877394	1.10E-04	0.026347	8.85E+10
1.20E-04	0.028743	9.77E+10	957166	1.20E-04	0.028743	9.66E+10
1.30E-04	0.031138	1.06E+11	1036840	1.30E-04	0.031138	1.05E+11
1.40E-04	0.033533	1.14E+11	1116220	1.40E-04	0.033533	1.13E+11
1.50E-04	0.035928	1.22E+11	1196580	1.50E-04	0.035928	1.21E+11
1.60E-04	0.038323	1.30E+11	1275960	1.60E-04	0.038323	1.29E+11
1.70E-04	0.040719	1.38E+11	1356320	1.70E-04	0.040719	1.37E+11
1.80E-04	0.043114	1.47E+11	1435700	1.80E-04	0.043114	1.45E+11
1.90E-04	0.045509	1.55E+11	1515080	1.90E-04	0.045509	1.53E+11
2.00E-04	0.047904	1.63E+11	1595440	2.00E-04	0.047904	1.61E+11
2.10E-04	0.050299	1.71E+11	1674820	2.10E-04	0.050299	1.69E+11
2.20E-04	0.052695	1.79E+11	1755180	2.20E-04	0.052695	1.77E+11
2.30E-04	0.05509	1.87E+11	1834560	2.30E-04	0.05509	1.85E+11
2.40E-04	0.057485	1.95E+11	1913940	2.40E-04	0.057485	1.93E+11
2.50E-04	0.05988	2.04E+11	1994300	2.50E-04	0.05988	2.01E+11
2.60E-04	0.062275	2.12E+11	2073680	2.60E-04	0.062275	2.09E+11
2.70E-04	0.064671	2.20E+11	2153060	2.70E-04	0.064671	2.17E+11
2.80E-04	0.067066	2.28E+11	2233420	2.80E-04	0.067066	2.25E+11
2.90E-04	0.069461	2.36E+11	2312800	2.90E-04	0.069461	2.33E+11
3.00E-04	0.071856	2.44E+11	2393160	3.00E-04	0.071856	2.41E+11
3.10E-04	0.074251	2.52E+11	2472540	3.10E-04	0.074251	2.49E+11

3.20E-04	0.076647	2.60E+11	2551920	3.20E-04	0.076647	2.57E+11
3.30E-04	0.079042	2.69E+11	2632280	3.30E-04	0.079042	2.66E+11
3.40E-04	0.081437	2.77E+11	2711660	3.40E-04	0.081437	2.74E+11
3.50E-04	0.083832	2.85E+11	2791040	3.50E-04	0.083832	2.82E+11
3.60E-04	0.086228	2.93E+11	2871400	3.60E-04	0.086228	2.90E+11
3.70E-04	0.088623	3.01E+11	2950780	3.70E-04	0.088623	2.98E+11
3.80E-04	0.091018	3.09E+11	3030160	3.80E-04	0.091018	3.06E+11
3.90E-04	0.093413	3.17E+11	3110520	3.90E-04	0.093413	3.14E+11
4.00E-04	0.095808	3.26E+11	3189900	4.00E-04	0.095808	3.22E+11
4.10E-04	0.098204	3.34E+11	3269280	4.10E-04	0.098204	3.30E+11
4.20E-04	0.100599	3.42E+11	3349640	4.20E-04	0.100599	3.38E+11
4.30E-04	0.102994	3.50E+11	3429020	4.30E-04	0.102994	3.46E+11
4.40E-04	0.105389	3.58E+11	3508400	4.40E-04	0.105389	3.54E+11
4.50E-04	0.107784	3.66E+11	3588760	4.50E-04	0.107784	3.62E+11
4.60E-04	0.11018	3.74E+11	3668140	4.60E-04	0.11018	3.70E+11
4.70E-04	0.112575	3.82E+11	3747520	4.70E-04	0.112575	3.78E+11
4.80E-04	0.11497	3.91E+11	3826900	4.80E-04	0.11497	3.86E+11
4.90E-04	0.117365	3.99E+11	3907260	4.90E-04	0.117365	3.94E+11
5.00E-04	0.11976	4.07E+11	3986640	5.00E-04	0.11976	4.02E+11
5.10E-04	0.122156	4.15E+11	4066020	5.10E-04	0.122156	4.10E+11
5.20E-04	0.124551	4.23E+11	4146380	5.20E-04	0.124551	4.18E+11
5.30E-04	0.126946	4.31E+11	4225760	5.30E-04	0.126946	4.26E+11
5.40E-04	0.129341	4.39E+11	4305140	5.40E-04	0.129341	4.34E+11
5.50E-04	0.131737	4.47E+11	4384520	5.50E-04	0.131737	4.42E+11
5.60E-04	0.134132	4.56E+11	4464880	5.60E-04	0.134132	4.50E+11
5.70E-04	0.136527	4.64E+11	4544260	5.70E-04	0.136527	4.58E+11
5.80E-04	0.138922	4.72E+11	4623640	5.80E-04	0.138922	4.66E+11
5.90E-04	0.141317	4.80E+11	4703020	5.90E-04	0.141317	4.74E+11
6.00E-04	0.143713	4.88E+11	4782400	6.00E-04	0.143713	4.82E+11
6.10E-04	0.146108	4.96E+11	4861780	6.10E-04	0.146108	4.90E+11
6.20E-04	0.148503	5.04E+11	4941160	6.20E-04	0.148503	4.98E+11
6.30E-04	0.150898	5.12E+11	5019560	6.30E-04	0.150898	5.06E+11
6.40E-04	0.153293	5.20E+11	5098940	6.40E-04	0.153293	5.14E+11
6.50E-04	0.155689	5.28E+11	5177340	6.50E-04	0.155689	5.22E+11
6.60E-04	0.158084	5.36E+11	5255740	6.60E-04	0.158084	5.30E+11
6.70E-04	0.160479	5.44E+11	5335120	6.70E-04	0.160479	5.38E+11
6.80E-04	0.162874	5.52E+11	5411560	6.80E-04	0.162874	5.45E+11
6.90E-04	0.165269	5.60E+11	5488980	6.90E-04	0.165269	5.47E+11
7.00E-04	0.167665	5.68E+11	5566400	7.00E-04	0.167665	5.52E+11
7.10E-04	0.17006	5.76E+11	5641860	7.10E-04	0.17006	5.56E+11
7.10E-04	0.17006	5.84E+11	5718300	7.20E-04	0.172455	5.62E+11
7.20E-04	0.172455	5.91E+11	5793760	7.30E-04	0.17485	5.68E+11
7.24E-04	0.173389	5.93E+11	5806500	7.32E-04	0.175257	5.73E+11
7.34E-04	0.175784	5.98E+11	5864320	7.40E-04	0.177222	5.79E+11
7.44E-04	0.17818	6.03E+11	5908420	7.47E-04	0.178994	5.81E+11

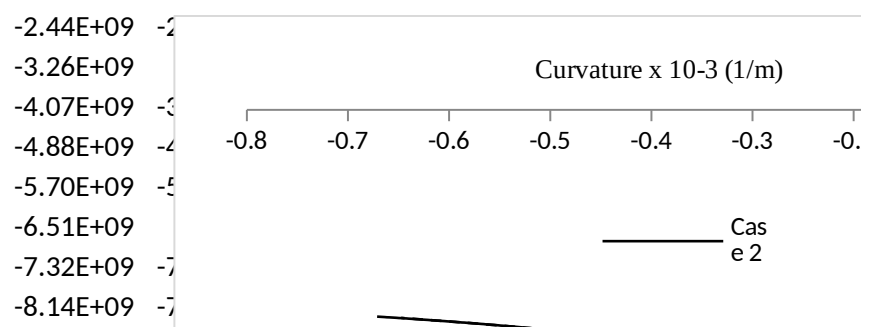
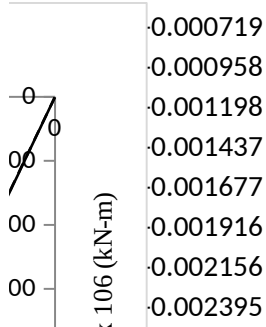
7.46E-04	0.178587	6.07E+11	5949580	7.55E-04	0.180886	5.87E+11
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7.58E-04	0.181653	6.13E+11	6008380	7.69E-04	0.184216	5.93E+11
7.67E-04	0.183641	6.17E+11	6047580	7.79E-04	0.186611	5.97E+11
7.74E-04	0.185461	6.20E+11	6079920	7.87E-04	0.188599	6.02E+11
7.83E-04	0.187521	6.24E+11	6117160	7.97E-04	0.190994	6.02E+11
7.92E-04	0.189749	6.27E+11	6140680	8.04E-04	0.192623	6.05E+11
8.00E-04	0.191569	6.30E+11	6174000	8.14E-04	0.195018	6.09E+11
8.08E-04	0.193581	6.30E+11	6174980	8.14E-04	0.195066	6.13E+11
8.17E-04	0.19576	6.33E+11	6204380	8.24E-04	0.197461	6.16E+11
8.26E-04	0.197844	6.34E+11	6210260	8.27E-04	0.197964	6.19E+11
8.36E-04	0.200216	6.36E+11	6232800	8.35E-04	0.2	6.22E+11
8.45E-04	0.202491	6.39E+11	6258280	8.45E-04	0.202395	6.25E+11
8.55E-04	0.204886	6.41E+11	6282780	8.55E-04	0.20479	6.27E+11
8.56E-04	0.205102	6.43E+11	6300420	8.62E-04	0.206539	6.29E+11
8.66E-04	0.207497	6.45E+11	6321000	8.72E-04	0.208934	6.31E+11
8.69E-04	0.208168	6.47E+11	6341580	8.82E-04	0.211329	6.31E+11
8.76E-04	0.209844	6.49E+11	6362160	8.92E-04	0.213725	6.34E+11
8.86E-04	0.21224	6.51E+11	6378820	9.01E-04	0.215737	6.34E+11
8.88E-04	0.212647	6.53E+11	6397440	9.11E-04	0.218132	6.36E+11
8.98E-04	0.215042	6.55E+11	6416060	9.21E-04	0.220527	6.38E+11
8.98E-04	0.215186	6.56E+11	6426840	9.27E-04	0.221964	6.38E+11
9.06E-04	0.217102	6.57E+11	6442520	9.37E-04	0.224359	6.40E+11
9.16E-04	0.219497	6.57E+11	6442520	9.37E-04	0.224431	6.40E+11
9.22E-04	0.220766	6.59E+11	6456240	9.47E-04	0.226826	6.41E+11
9.32E-04	0.223162	6.60E+11	6469960	9.57E-04	0.229222	6.41E+11
9.37E-04	0.224359	6.62E+11	6483680	9.67E-04	0.231617	6.42E+11
9.47E-04	0.226754	6.63E+11	6497400	9.77E-04	0.233988	6.43E+11
9.47E-04	0.22685	6.64E+11	6509160	9.87E-04	0.236383	6.44E+11
9.57E-04	0.229246	6.65E+11	6513080	9.91E-04	0.237341	6.45E+11
9.59E-04	0.229796	6.66E+11	6523860	1.00E-03	0.23976	6.45E+11
9.68E-04	0.231784	6.67E+11	6532680	1.01E-03	0.241916	6.46E+11
9.76E-04	0.233772	6.68E+11	6541500	1.02E-03	0.244311	6.46E+11
9.84E-04	0.235713	6.68E+11	6546400	1.03E-03	0.245988	6.47E+11
9.94E-04	0.238108	6.69E+11	6552280	1.04E-03	0.248383	6.47E+11
9.94E-04	0.238156	6.69E+11	6558160	1.05E-03	0.250778	6.47E+11
1.00E-03	0.24024	6.70E+11	6562080	1.06E-03	0.252934	6.47E+11
1.01E-03	0.242635	6.70E+11	6565020	1.07E-03	0.255329	6.47E+11
1.01E-03	0.242874	6.70E+11	6566980	1.08E-03	0.257485	6.47E+11
1.02E-03	0.244551	6.70E+11	6569920	1.09E-03	0.25988	6.47E+11
1.03E-03	0.246228	6.71E+11	6572860	1.09E-03	0.262036	6.47E+11
1.04E-03	0.248144	6.71E+11	6575800	1.10E-03	0.264431	6.47E+11
1.04E-03	0.24982	6.71E+11	6575800	1.11E-03	0.264671	6.46E+11
1.05E-03	0.252216	6.71E+11	6578740	1.12E-03	0.267066	6.46E+11
1.06E-03	0.253892	6.72E+11	6581680	1.13E-03	0.269461	6.46E+11

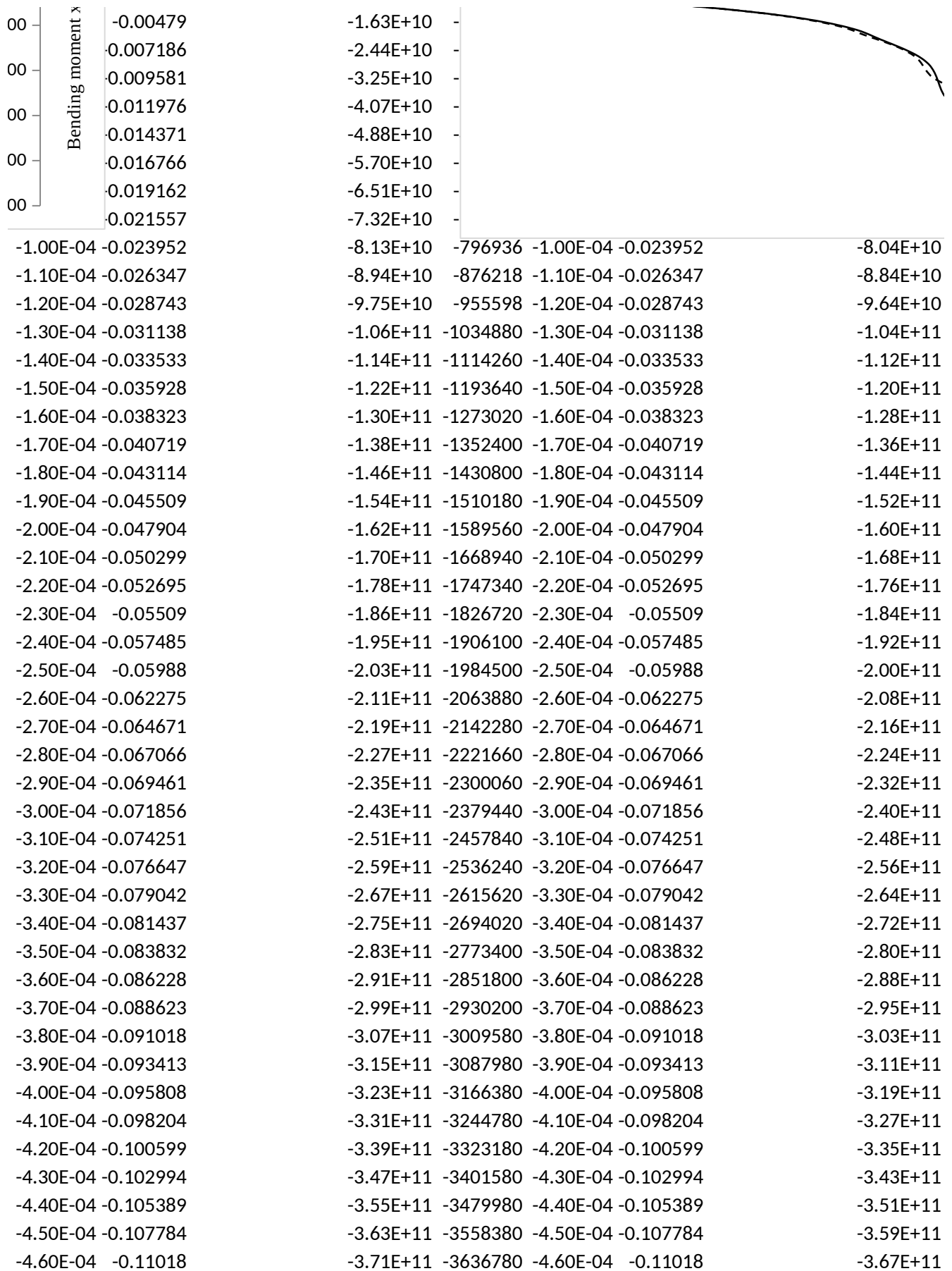
1.07E-03	0.25509	6.72E+11	6584620	1.14E-03	0.271856	6.45E+11
1.07E-03	0.257246	6.72E+11	6586580	1.14E-03	0.273293	6.45E+11
1.08E-03	0.259641	6.72E+11	6588540	1.15E-03	0.275689	6.45E+11
1.09E-03	0.261317	6.73E+11	6590500	1.16E-03	0.277126	6.44E+11
1.10E-03	0.263234	6.73E+11	6593440	1.17E-03	0.279521	6.44E+11
1.11E-03	0.265389	6.73E+11	6596380	1.18E-03	0.281916	6.43E+11
1.12E-03	0.267784	6.73E+11	6599320	1.19E-03	0.284311	6.42E+11
1.13E-03	0.27018	6.73E+11	6599320	1.19E-03	0.284551	6.42E+11
1.13E-03	0.270419	6.74E+11	6602260	1.20E-03	0.286946	6.40E+11
1.14E-03	0.272814	6.74E+11	6605200	1.21E-03	0.289341	6.40E+11
1.14E-03	0.274012	6.74E+11	6606180	1.22E-03	0.291737	6.39E+11
1.15E-03	0.275449	6.74E+11	6606180	1.22E-03	0.292216	6.38E+11
1.16E-03	0.276886	6.74E+11	6607160	1.23E-03	0.294611	6.37E+11
1.16E-03	0.278323	6.74E+11	6608140	1.24E-03	0.296287	6.35E+11
1.17E-03	0.280719	6.74E+11	6609120	1.25E-03	0.298683	6.34E+11
1.18E-03	0.281677	6.74E+11	6609120	1.25E-03	0.299401	6.34E+11
1.19E-03	0.284072	6.74E+11	6608140	1.26E-03	0.301796	6.32E+11
1.19E-03	0.285269	6.73E+11	6597360	1.27E-03	0.304192	6.32E+11
1.20E-03	0.287425	6.73E+11	6595400	1.27E-03	0.304431	6.31E+11
1.21E-03	0.28982	6.71E+11	6573840	1.28E-03	0.305868	6.29E+11
1.22E-03	0.292216	6.67E+11	6539540	1.28E-03	0.307545	6.28E+11
1.23E-03	0.294611	6.65E+11	6517000	1.29E-03	0.308503	6.27E+11
1.24E-03	0.295808	6.60E+11	6470940	1.30E-03	0.310898	6.27E+11
1.25E-03	0.298204	6.58E+11	6450360	1.30E-03	0.312335	6.25E+11
1.26E-03	0.300599	6.56E+11	6428800	1.31E-03	0.313533	6.24E+11
1.26E-03	0.302036	6.52E+11	6392540	1.32E-03	0.315689	6.23E+11
1.27E-03	0.304192	6.48E+11	6349420	1.33E-03	0.318084	6.21E+11
1.28E-03	0.306587	6.47E+11	6344520	1.33E-03	0.318323	6.20E+11
1.29E-03	0.307784	6.44E+11	6312180	1.34E-03	0.320479	6.18E+11
1.30E-03	0.31018	6.40E+11	6275920	1.35E-03	0.322874	6.17E+11
1.30E-03	0.311856	6.37E+11	6241620	1.36E-03	0.325269	6.16E+11
1.31E-03	0.314251	6.34E+11	6216140	1.37E-03	0.327186	6.14E+11
1.32E-03	0.315449	6.30E+11	6177920	1.38E-03	0.329581	6.12E+11
1.33E-03	0.317844	6.28E+11	6149500	1.38E-03	0.331497	6.11E+11
1.34E-03	0.32024	6.24E+11	6119120	1.39E-03	0.333892	6.09E+11
1.35E-03	0.322635	6.21E+11	6089720	1.40E-03	0.336287	6.07E+11
1.35E-03	0.323593	6.18E+11	6060320	1.41E-03	0.338683	6.06E+11
1.36E-03	0.325988	6.15E+11	6029940	1.42E-03	0.341078	6.04E+11
1.36E-03	0.326707	6.13E+11	6003480	1.43E-03	0.343473	6.03E+11
1.37E-03	0.329102	6.12E+11	5993680	1.44E-03	0.344431	6.01E+11
1.38E-03	0.331497	6.09E+11	5967220	1.45E-03	0.346826	6.00E+11
1.39E-03	0.333892	6.06E+11	5941740	1.46E-03	0.349222	5.99E+11
1.40E-03	0.336287	6.04E+11	5918220	1.47E-03	0.351617	5.97E+11
1.41E-03	0.338683	6.01E+11	5893720	1.48E-03	0.354012	5.97E+11
1.42E-03	0.339401	5.99E+11	5870200	1.49E-03	0.356407	5.95E+11

1.43E-03	0.341796	5.97E+11	5848640	1.50E-03	0.358802	5.94E+11
1.44E-03	0.344192	5.95E+11	5828060	1.51E-03	0.361198	5.93E+11
1.45E-03	0.346587	5.93E+11	5808460	1.52E-03	0.363593	5.91E+11
1.46E-03	0.348982	5.91E+11	5788860	1.53E-03	0.365988	5.90E+11
1.47E-03	0.351377	5.89E+11	5771220	1.54E-03	0.368383	5.89E+11
1.48E-03	0.353772	5.87E+11	5753580	1.55E-03	0.370778	5.88E+11
1.49E-03	0.356168	5.85E+11	5736920	1.56E-03	0.373174	5.86E+11
1.50E-03	0.358563	5.84E+11	5720260	1.57E-03	0.375569	5.85E+11
1.51E-03	0.360958	5.82E+11	5704580	1.58E-03	0.377964	5.84E+11
1.52E-03	0.363353	5.81E+11	5689880	1.59E-03	0.380359	5.83E+11
1.53E-03	0.365749	5.80E+11	5679100	1.60E-03	0.382036	5.82E+11
1.54E-03	0.368144	5.78E+11	5663420	1.61E-03	0.384431	5.81E+11
1.55E-03	0.370539	5.76E+11	5648720	1.62E-03	0.386826	5.80E+11
1.56E-03	0.372934	5.76E+11	5643820	1.62E-03	0.387545	5.79E+11
1.57E-03	0.375329	5.75E+11	5630100	1.63E-03	0.38994	5.77E+11
1.58E-03	0.377725	5.73E+11	5616380	1.64E-03	0.392335	5.77E+11
1.59E-03	0.38012	5.72E+11	5602660	1.65E-03	0.394731	5.76E+11
1.60E-03	0.382515	5.72E+11	5602660	1.65E-03	0.394731	5.75E+11
1.61E-03	0.38491	5.70E+11	5586980	1.66E-03	0.397126	5.73E+11
1.61E-03	0.386347	5.69E+11	5572280	1.67E-03	0.399521	5.72E+11
1.62E-03	0.388743	5.67E+11	5558560	1.68E-03	0.401916	5.71E+11
1.63E-03	0.391138	5.66E+11	5543860	1.69E-03	0.404311	5.70E+11
1.64E-03	0.393533	5.65E+11	5537000	1.69E-03	0.405509	5.69E+11
1.65E-03	0.394012	5.63E+11	5518380	1.70E-03	0.407904	5.68E+11
1.66E-03	0.396407	5.62E+11	5504660	1.71E-03	0.410299	5.67E+11
1.67E-03	0.398802	5.60E+11	5489960	1.72E-03	0.412695	5.65E+11
1.68E-03	0.401198	5.59E+11	5475260	1.73E-03	0.41509	5.64E+11
1.69E-03	0.403593	5.57E+11	5460560	1.74E-03	0.417485	5.64E+11
1.70E-03	0.405988	5.56E+11	5446840	1.75E-03	0.41988	5.62E+11
1.71E-03	0.408383	5.54E+11	5433120	1.76E-03	0.422275	5.61E+11
1.71E-03	0.409102	5.53E+11	5419400	1.77E-03	0.424671	5.59E+11
1.72E-03	0.411497	5.52E+11	5405680	1.78E-03	0.427066	5.58E+11
1.73E-03	0.413892	5.50E+11	5391960	1.79E-03	0.429461	5.57E+11
1.74E-03	0.416287	5.49E+11	5379220	1.80E-03	0.431856	5.55E+11
1.75E-03	0.418683	5.48E+11	5365500	1.81E-03	0.434251	5.54E+11
1.76E-03	0.421078	5.46E+11	5353740	1.82E-03	0.436647	5.53E+11
1.77E-03	0.423473	5.45E+11	5341000	1.83E-03	0.439042	5.52E+11
1.78E-03	0.425868	5.44E+11	5329240	1.84E-03	0.441437	5.50E+11
1.79E-03	0.428263	5.43E+11	5317480	1.85E-03	0.443832	5.49E+11
1.80E-03	0.430659	5.42E+11	5311600	1.86E-03	0.445269	5.48E+11
1.81E-03	0.433054	5.41E+11	5299840	1.87E-03	0.447665	5.47E+11
1.82E-03	0.435449	5.40E+11	5288080	1.88E-03	0.45006	5.46E+11
1.83E-03	0.437844	5.39E+11	5277300	1.89E-03	0.452455	5.45E+11
1.84E-03	0.44024	5.37E+11	5265540	1.90E-03	0.45485	5.44E+11
1.85E-03	0.442635	5.36E+11	5254760	1.91E-03	0.457246	5.43E+11

1.86E-03	0.44503	5.35E+11	5244960	1.92E-03	0.459641	5.42E+11
1.87E-03	0.447425	5.34E+11	5234180	1.93E-03	0.462036	5.41E+11
1.88E-03	0.44982	5.33E+11	5224380	1.94E-03	0.464431	5.39E+11
1.89E-03	0.452216	5.32E+11	5213600	1.95E-03	0.466826	5.38E+11
1.90E-03	0.454611	5.31E+11	5203800	1.96E-03	0.469222	5.37E+11
1.91E-03	0.457006	5.30E+11	5194000	1.97E-03	0.471617	5.36E+11
1.92E-03	0.459401	5.29E+11	5185180	1.98E-03	0.474012	5.35E+11
1.92E-03	0.460599	5.28E+11	5175380	1.99E-03	0.476407	5.34E+11
1.93E-03	0.462994	5.27E+11	5165580	2.00E-03	0.478802	5.33E+11
1.94E-03	0.465389	5.26E+11	5156760	2.01E-03	0.481198	5.32E+11
1.95E-03	0.467784	5.25E+11	5147940	2.02E-03	0.483593	5.31E+11
1.96E-03	0.46994	5.24E+11	5139120	2.03E-03	0.485988	5.31E+11
1.97E-03	0.472335	5.24E+11	5130300	2.04E-03	0.488383	5.30E+11
1.98E-03	0.474731	5.23E+11	5121480	2.05E-03	0.490778	5.29E+11
1.99E-03	0.477126	5.22E+11	5113640	2.06E-03	0.493174	5.28E+11
2.00E-03	0.479521	5.21E+11	5104820	2.07E-03	0.495569	5.28E+11
2.01E-03	0.481916	5.20E+11	5096980	2.08E-03	0.497964	5.27E+11
2.02E-03	0.484311	5.19E+11	5088160	2.09E-03	0.500359	5.26E+11
2.03E-03	0.486707	5.18E+11	5080320	2.10E-03	0.502754	5.25E+11
2.04E-03	0.489102	5.18E+11	5072480	2.11E-03	0.50515	5.25E+11
2.05E-03	0.491497	5.17E+11	5064640	2.12E-03	0.507545	5.24E+11
2.06E-03	0.493892	5.16E+11	5056800	2.13E-03	0.50994	5.23E+11
2.07E-03	0.496287	5.15E+11	5049940	2.14E-03	0.512335	5.22E+11
2.08E-03	0.498683	5.15E+11	5042100	2.15E-03	0.514731	5.22E+11
2.09E-03	0.501078	5.14E+11	5034260	2.16E-03	0.517126	5.21E+11
2.10E-03	0.503473	5.13E+11	5025440	2.17E-03	0.519521	5.20E+11
2.11E-03	0.505868	5.12E+11	5017600	2.18E-03	0.521916	5.19E+11
2.12E-03	0.508263	5.11E+11	5008780	2.19E-03	0.524311	5.18E+11
2.13E-03	0.510659	5.10E+11	5000940	2.20E-03	0.526707	5.17E+11
2.14E-03	0.513054	5.10E+11	4993100	2.21E-03	0.529102	5.17E+11
2.15E-03	0.515449	5.09E+11	4986240	2.22E-03	0.531497	5.16E+11
2.16E-03	0.517844	5.08E+11	4978400	2.23E-03	0.533892	5.15E+11
2.17E-03	0.52024	5.07E+11	4970560	2.24E-03	0.536287	5.14E+11
2.18E-03	0.522635	5.07E+11	4963700	2.25E-03	0.538683	5.13E+11
2.19E-03	0.52503	5.06E+11	4955860	2.26E-03	0.541078	5.12E+11
2.20E-03	0.527425	5.05E+11	4948020	2.27E-03	0.543473	5.12E+11
2.21E-03	0.52982	5.04E+11	4941160	2.28E-03	0.545868	5.11E+11
2.22E-03	0.532216	5.03E+11	4933320	2.29E-03	0.548263	5.10E+11
2.23E-03	0.534611	5.03E+11	4926460	2.30E-03	0.550659	5.09E+11
2.24E-03	0.537006	5.02E+11	4918620	2.31E-03	0.553054	5.08E+11
2.25E-03	0.539401	5.01E+11	4911760	2.32E-03	0.555449	5.08E+11
2.26E-03	0.541796	5.01E+11	4904900	2.33E-03	0.557844	5.07E+11
2.27E-03	0.544192	5.00E+11	4898040	2.34E-03	0.56024	5.06E+11
2.28E-03	0.546587	4.99E+11	4891180	2.35E-03	0.562635	5.05E+11
2.29E-03	0.548982	4.98E+11	4884320	2.36E-03	0.56503	5.05E+11

2.30E-03	0.551377	4.98E+11	4877460	2.37E-03	0.567425	5.04E+11
2.31E-03	0.553772	4.97E+11	4870600	2.38E-03	0.56982	5.03E+11
2.32E-03	0.556168	4.96E+11	4863740	2.39E-03	0.572216	5.02E+11
2.33E-03	0.558563	4.96E+11	4856880	2.40E-03	0.574611	5.02E+11
2.34E-03	0.560958	4.95E+11	4850020	2.41E-03	0.577006	5.01E+11
2.35E-03	0.563353	4.94E+11	4843160	2.42E-03	0.579401	5.00E+11
2.36E-03	0.565749	4.94E+11	4837280	2.43E-03	0.581796	4.99E+11
2.37E-03	0.568144	4.93E+11	4830420	2.44E-03	0.584192	4.99E+11
2.38E-03	0.570539	4.92E+11	4823560	2.45E-03	0.586587	4.98E+11
2.39E-03	0.572934	4.92E+11	4817680	2.46E-03	0.588982	4.97E+11
2.40E-03	0.575329	4.91E+11	4810820	2.47E-03	0.591377	4.96E+11
2.41E-03	0.577725	4.90E+11	4804940	2.48E-03	0.593772	4.96E+11
2.42E-03	0.58012	4.90E+11	4799060	2.49E-03	0.596168	4.95E+11
2.43E-03	0.582515	4.89E+11	4793180	2.50E-03	0.598563	4.94E+11
2.44E-03	0.58491	4.89E+11	4787300	2.51E-03	0.600958	4.94E+11
2.45E-03	0.587305	4.88E+11	4781420	2.52E-03	0.603353	4.94E+11
2.46E-03	0.589701	4.87E+11	4775540	2.53E-03	0.605749	4.93E+11
2.47E-03	0.592096	4.87E+11	4769660	2.54E-03	0.608144	4.92E+11
2.48E-03	0.594491	4.86E+11	4763780	2.55E-03	0.610539	4.91E+11
2.49E-03	0.596886	4.86E+11	4757900	2.56E-03	0.612934	4.91E+11
2.50E-03	0.599281	4.85E+11	4752020	2.57E-03	0.615329	4.90E+11
2.51E-03	0.601677	4.84E+11	4746140	2.58E-03	0.617725	4.89E+11
2.52E-03	0.604072	4.84E+11	4740260	2.59E-03	0.62012	4.89E+11
2.53E-03	0.606467	4.83E+11	4734380	2.60E-03	0.622515	4.88E+11
2.54E-03	0.608862	4.83E+11	4729480	2.61E-03	0.62491	4.88E+11
2.55E-03	0.611257	4.82E+11	4723600	2.62E-03	0.627305	4.87E+11
2.56E-03	0.613653	4.81E+11	4717720	2.63E-03	0.629701	4.86E+11
2.57E-03	0.616048	4.81E+11	4712820	2.64E-03	0.632096	4.86E+11
2.58E-03	0.618443	4.80E+11	4706940	2.65E-03	0.634491	4.85E+11
2.59E-03	0.620838	4.80E+11	4701060	2.66E-03	0.636886	4.84E+11
2.60E-03	0.623234	4.79E+11	4696160	2.67E-03	0.639281	4.84E+11
2.61E-03	0.625629	4.79E+11	4690280	2.68E-03	0.641677	4.83E+11
2.62E-03	0.628024	4.78E+11	4684400	2.69E-03	0.644072	4.83E+11
2.63E-03	0.630419	4.77E+11	4678520	2.70E-03	0.646467	4.82E+11
0.00E+00		0.00E+00	0	0.00E+00		0.00E+00
-1.00E-06	-0.00024	-8.14E+08	-7981.12	-1.00E-06	-0.00024	-8.05E+08
-2.00E-06	-0.000479	-1.63E+09	-15954.4	-2.00E-06	-0.000479	-1.61E+09





-4.70E-04 -0.112575	-3.79E+11 -3715180	-4.70E-04 -0.112575	-3.74E+11
-4.80E-04 -0.11497	-3.87E+11 -3793580	-4.80E-04 -0.11497	-3.82E+11
-4.90E-04 -0.117365	-3.95E+11 -3871980	-4.90E-04 -0.117365	-3.90E+11
-5.00E-04 -0.11976	-4.03E+11 -3949400	-5.00E-04 -0.11976	-3.98E+11
-5.10E-04 -0.122156	-4.11E+11 -4027800	-5.10E-04 -0.122156	-4.06E+11
-5.20E-04 -0.124551	-4.19E+11 -4105220	-5.20E-04 -0.124551	-4.14E+11
-5.30E-04 -0.126946	-4.27E+11 -4182640	-5.30E-04 -0.126946	-4.21E+11
-5.40E-04 -0.129341	-4.35E+11 -4260060	-5.40E-04 -0.129341	-4.29E+11
-5.50E-04 -0.131737	-4.43E+11 -4336500	-5.50E-04 -0.131737	-4.37E+11
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-5.80E-04 -0.138922	-4.66E+11 -4564840	-5.80E-04 -0.138922	-4.59E+11
-5.90E-04 -0.141317	-4.74E+11 -4641280	-5.90E-04 -0.141317	-4.67E+11
-6.00E-04 -0.143713	-4.81E+11 -4716740	-6.00E-04 -0.143713	-4.75E+11
-6.10E-04 -0.146108	-4.89E+11 -4791220	-6.10E-04 -0.146108	-4.81E+11
-6.20E-04 -0.148503	-4.97E+11 -4865700	-6.20E-04 -0.148503	-4.88E+11
-6.25E-04 -0.149796	-5.04E+11 -4939200	-6.30E-04 -0.150898	-4.95E+11
-6.35E-04 -0.152192	-5.12E+11 -5013680	-6.40E-04 -0.153293	-4.96E+11
-6.45E-04 -0.154587	-5.16E+11 -5057780	-6.46E-04 -0.154778	-5.03E+11
-6.48E-04 -0.155114	-5.24E+11 -5130300	-6.56E-04 -0.157174	-5.04E+11
-6.58E-04 -0.157509	-5.31E+11 -5202820	-6.66E-04 -0.159569	-5.09E+11
-6.64E-04 -0.158946	-5.35E+11 -5242020	-6.72E-04 -0.16091	-5.13E+11
-6.72E-04 -0.16103	-5.42E+11 -5312580	-6.82E-04 -0.163305	-5.16E+11
-6.78E-04 -0.162419	-5.47E+11 -5357660	-6.88E-04 -0.164886	-5.18E+11
-6.83E-04 -0.163545	-5.52E+11 -5408620	-6.96E-04 -0.166707	-5.21E+11
-6.87E-04 -0.164647	-5.56E+11 -5448800	-7.03E-04 -0.168311	-5.23E+11
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-7.19E-04 -0.172263	-5.62E+11 -5510540	-7.31E-04 -0.17509	-5.32E+11
-7.27E-04 -0.174108	-5.62E+11 -5508580	-7.37E-04 -0.176551	-5.34E+11
-7.34E-04 -0.175784	-5.61E+11 -5497800	-7.47E-04 -0.178946	-5.35E+11
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-7.70E-04 -0.184479	-5.53E+11 -5415480	-7.89E-04 -0.18891	-5.30E+11
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-7.94E-04 -0.190108	-5.42E+11 -5308660	-8.12E-04 -0.194491	-5.23E+11
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-8.06E-04 -0.193078	-5.24E+11 -5134220	-8.32E-04 -0.199281	-5.19E+11

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-8.38E-04 -0.200743	-4.88E+11 -4781420 -8.71E-04 -0.208623	-5.13E+11
-8.38E-04 -0.200766	-4.82E+11 -4725560 -8.81E-04 -0.211018	-5.12E+11
-8.48E-04 -0.203162	-4.80E+11 -4699100 -8.87E-04 -0.212335	-5.09E+11
-8.58E-04 -0.205557	-4.75E+11 -4657940 -8.97E-04 -0.214731	-5.07E+11
-8.68E-04 -0.207952	-4.72E+11 -4620700 -9.07E-04 -0.217126	-5.04E+11
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-9.39E-04 -0.224982	-4.47E+11 -4383540 -1.01E-03 -0.241198	-4.72E+11
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-9.74E-04 -0.233222	-4.40E+11 -4313960 -1.05E-03 -0.250778	-4.57E+11
-9.84E-04 -0.235617	-4.39E+11 -4298280 -1.06E-03 -0.253174	-4.55E+11
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-1.06E-03 -0.254611	-4.24E+11 -4158140 -1.15E-03 -0.274731	-4.38E+11
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-1.09E-03 -0.261796	-4.20E+11 -4113060 -1.18E-03 -0.281916	-4.34E+11
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-2.46E-03 -0.589461	-3.36E+11 -3293780	-2.55E-03 -0.611257	-3.39E+11
-2.47E-03 -0.591856	-3.36E+11 -3290840	-2.56E-03 -0.613653	-3.38E+11
-2.48E-03 -0.592814	-3.36E+11 -3287900	-2.57E-03 -0.616048	-3.38E+11
-2.49E-03 -0.59521	-3.35E+11 -3285940	-2.58E-03 -0.618443	-3.38E+11
-2.50E-03 -0.597605	-3.35E+11 -3283000	-2.59E-03 -0.620838	-3.38E+11
-2.51E-03 -0.6	-3.35E+11 -3280060	-2.60E-03 -0.623234	-3.37E+11
-2.52E-03 -0.602395	-3.35E+11 -3278100	-2.61E-03 -0.625629	-3.37E+11

-2.53E-03 -0.60479	-3.34E+11 -3275160 -2.62E-03 -0.628024	-3.37E+11
-2.54E-03 -0.607186	-3.34E+11 -3272220 -2.63E-03 -0.630419	-3.37E+11
-2.55E-03 -0.609581	-3.34E+11 -3270260 -2.64E-03 -0.632814	-3.36E+11
-2.56E-03 -0.611976	-3.33E+11 -3267320 -2.65E-03 -0.63521	-3.36E+11
-2.57E-03 -0.614371	-3.33E+11 -3265360 -2.66E-03 -0.637605	-3.36E+11
-2.58E-03 -0.616766	-3.33E+11 -3262420 -2.67E-03 -0.64	-3.36E+11
-2.59E-03 -0.619162	-3.33E+11 -3259480 -2.68E-03 -0.642395	-3.35E+11
-2.60E-03 -0.621557	-3.32E+11 -3257520 -2.69E-03 -0.64479	-3.35E+11
-2.61E-03 -0.623952	-3.32E+11 -3254580 -2.70E-03 -0.647186	-3.35E+11
-2.62E-03 -0.626347	-3.32E+11 -3252620 -2.71E-03 -0.649581	-3.34E+11
-2.63E-03 -0.628743	-3.32E+11 -3249680 -2.72E-03 -0.651976	-3.34E+11
-2.64E-03 -0.631138	-3.31E+11 -3247720 -2.73E-03 -0.654371	-3.34E+11
-2.65E-03 -0.633533	-3.31E+11 -3244780 -2.74E-03 -0.656766	-3.33E+11
-2.66E-03 -0.635928	-3.31E+11 -3242820 -2.75E-03 -0.659162	-3.33E+11
-2.67E-03 -0.638323	-3.31E+11 -3240860 -2.76E-03 -0.661557	-3.33E+11
-2.68E-03 -0.640719	-3.30E+11 -3237920 -2.77E-03 -0.663952	-3.33E+11
-2.69E-03 -0.643114	-3.30E+11 -3235960 -2.78E-03 -0.666347	-3.32E+11
-2.70E-03 -0.645509	-3.30E+11 -3233020 -2.79E-03 -0.668743	-3.32E+11
-2.71E-03 -0.647904	-3.30E+11 -3231060 -2.80E-03 -0.671138	-3.32E+11

Carrier (B1) Idchk = 2
20% damage

4.175	9.80E-06	1000
Rotation	Curvature	
7891.94	1.00E-06	0.00024
15778	2.00E-06	0.000479
23667	3.00E-06	0.000719
31556	4.00E-06	0.000958
39435.2	5.00E-06	0.001198
47324.2	6.00E-06	0.001437
55213.2	7.00E-06	0.001677
63092.4	8.00E-06	0.001916
70981.4	9.00E-06	0.002156
78870.4	1.00E-05	0.002395
157780	2.00E-05	0.00479
236572	3.00E-05	0.007186
315462	4.00E-05	0.009581
394352	5.00E-05	0.011976
473144	6.00E-05	0.014371
552034	7.00E-05	0.016766
630924	8.00E-05	0.019162
709814	9.00E-05	0.021557
788606	1.00E-04	0.023952
867496	1.10E-04	0.026347
946386	1.20E-04	0.028743
1025080	1.30E-04	0.031138
1104460	1.40E-04	0.033533
1182860	1.50E-04	0.035928
1262240	1.60E-04	0.038323
1340640	1.70E-04	0.040719
1420020	1.80E-04	0.043114
1498420	1.90E-04	0.045509
1576820	2.00E-04	0.047904
1656200	2.10E-04	0.050299
1734600	2.20E-04	0.052695
1813980	2.30E-04	0.05509
1892380	2.40E-04	0.057485
1971760	2.50E-04	0.05988
2050160	2.60E-04	0.062275
2128560	2.70E-04	0.064671
2207940	2.80E-04	0.067066
2286340	2.90E-04	0.069461
2365720	3.00E-04	0.071856
2444120	3.10E-04	0.074251

Bulk Carrier (B1) Idchk = 1
40% damage

frame spa	4.175	9.80E-06	1000
Moment	Rotation	Curvature	
8.07E+08	7911.54	1.00E-06	0.00024
1.61E+09	15817.2	2.00E-06	0.000479
2.42E+09	23725.8	3.00E-06	0.000719
3.23E+09	31634.4	4.00E-06	0.000958
4.04E+09	39543	5.00E-06	0.001198
4.84E+09	47441.8	6.00E-06	0.001437
5.65E+09	55350.4	7.00E-06	0.001677
6.46E+09	63259	8.00E-06	0.001916
7.26E+09	71167.6	9.00E-06	0.002156
8.07E+09	79076.2	1.00E-05	0.002395
1.61E+10	158172	2.00E-05	0.00479
2.42E+10	237160	3.00E-05	0.007186
3.23E+10	316246	4.00E-05	0.009581
4.03E+10	395332	5.00E-05	0.011976
4.84E+10	474418	6.00E-05	0.014371
5.65E+10	553504	7.00E-05	0.016766
6.46E+10	632590	8.00E-05	0.019162
7.26E+10	711578	9.00E-05	0.021557
8.07E+10	790664	1.00E-04	0.023952
8.88E+10	869750	1.10E-04	0.026347
9.68E+10	948836	1.20E-04	0.028743
1.05E+11	1028020	1.30E-04	0.031138
1.13E+11	1107400	1.40E-04	0.033533
1.21E+11	1185800	1.50E-04	0.035928
1.29E+11	1265180	1.60E-04	0.038323
1.37E+11	1344560	1.70E-04	0.040719
1.45E+11	1422960	1.80E-04	0.043114
1.53E+11	1502340	1.90E-04	0.045509
1.61E+11	1581720	2.00E-04	0.047904
1.69E+11	1660120	2.10E-04	0.050299
1.78E+11	1739500	2.20E-04	0.052695
1.86E+11	1818880	2.30E-04	0.05509
1.94E+11	1897280	2.40E-04	0.057485
2.02E+11	1976660	2.50E-04	0.05988
2.10E+11	2056040	2.60E-04	0.062275
2.18E+11	2134440	2.70E-04	0.064671
2.26E+11	2213820	2.80E-04	0.067066
2.34E+11	2293200	2.90E-04	0.069461
2.42E+11	2371600	3.00E-04	0.071856
2.50E+11	2450980	3.10E-04	0.074251

Bul

frame spa
Moment
7.93E+08
1.59E+09
2.38E+09
3.17E+09
3.96E+09
4.76E+09
5.55E+09
6.34E+09
7.14E+09
7.93E+09
1.59E+10
2.38E+10
3.17E+10
3.96E+10
4.76E+10
5.55E+10
6.34E+10
7.13E+10
7.93E+10
8.72E+10
9.51E+10
1.03E+11
1.11E+11
1.19E+11
1.27E+11
1.35E+11
1.43E+11
1.51E+11
1.59E+11
1.67E+11
1.74E+11
1.82E+11
1.90E+11
1.98E+11
2.06E+11
2.14E+11
2.22E+11
2.30E+11
2.38E+11
2.46E+11

2522520	3.20E-04	0.076647	2.58E+11	2530360	3.20E-04	0.076647	2.54E+11
2601900	3.30E-04	0.079042	2.66E+11	2608760	3.30E-04	0.079042	2.62E+11
2680300	3.40E-04	0.081437	2.74E+11	2688140	3.40E-04	0.081437	2.69E+11
2758700	3.50E-04	0.083832	2.82E+11	2767520	3.50E-04	0.083832	2.77E+11
2838080	3.60E-04	0.086228	2.90E+11	2845920	3.60E-04	0.086228	2.85E+11
2916480	3.70E-04	0.088623	2.99E+11	2925300	3.70E-04	0.088623	2.93E+11
2995860	3.80E-04	0.091018	3.07E+11	3004680	3.80E-04	0.091018	3.01E+11
3074260	3.90E-04	0.093413	3.15E+11	3083080	3.90E-04	0.093413	3.09E+11
3152660	4.00E-04	0.095808	3.23E+11	3162460	4.00E-04	0.095808	3.17E+11
3232040	4.10E-04	0.098204	3.31E+11	3240860	4.10E-04	0.098204	3.25E+11
3310440	4.20E-04	0.100599	3.39E+11	3320240	4.20E-04	0.100599	3.33E+11
3389820	4.30E-04	0.102994	3.47E+11	3399620	4.30E-04	0.102994	3.41E+11
3468220	4.40E-04	0.105389	3.55E+11	3478020	4.40E-04	0.105389	3.49E+11
3546620	4.50E-04	0.107784	3.63E+11	3557400	4.50E-04	0.107784	3.57E+11
3626000	4.60E-04	0.11018	3.71E+11	3635800	4.60E-04	0.11018	3.64E+11
3704400	4.70E-04	0.112575	3.79E+11	3715180	4.70E-04	0.112575	3.72E+11
3782800	4.80E-04	0.11497	3.87E+11	3794560	4.80E-04	0.11497	3.80E+11
3862180	4.90E-04	0.117365	3.95E+11	3872960	4.90E-04	0.117365	3.88E+11
3940580	5.00E-04	0.11976	4.03E+11	3952340	5.00E-04	0.11976	3.96E+11
4018980	5.10E-04	0.122156	4.11E+11	4030740	5.10E-04	0.122156	4.04E+11
4098360	5.20E-04	0.124551	4.19E+11	4110120	5.20E-04	0.124551	4.12E+11
4176760	5.30E-04	0.126946	4.28E+11	4189500	5.30E-04	0.126946	4.20E+11
4255160	5.40E-04	0.129341	4.36E+11	4267900	5.40E-04	0.129341	4.28E+11
4334540	5.50E-04	0.131737	4.44E+11	4347280	5.50E-04	0.131737	4.36E+11
4412940	5.60E-04	0.134132	4.52E+11	4425680	5.60E-04	0.134132	4.44E+11
4491340	5.70E-04	0.136527	4.60E+11	4505060	5.70E-04	0.136527	4.51E+11
4569740	5.80E-04	0.138922	4.68E+11	4583460	5.80E-04	0.138922	4.59E+11
4648140	5.90E-04	0.141317	4.76E+11	4662840	5.90E-04	0.141317	4.67E+11
4726540	6.00E-04	0.143713	4.84E+11	4741240	6.00E-04	0.143713	4.75E+11
4803960	6.10E-04	0.146108	4.92E+11	4819640	6.10E-04	0.146108	4.83E+11
4882360	6.20E-04	0.148503	5.00E+11	4899020	6.20E-04	0.148503	4.91E+11
4959780	6.30E-04	0.150898	5.08E+11	4977420	6.30E-04	0.150898	4.99E+11
5037200	6.40E-04	0.153293	5.16E+11	5055820	6.40E-04	0.153293	5.06E+11
5114620	6.50E-04	0.155689	5.24E+11	5133240	6.50E-04	0.155689	5.14E+11
5192040	6.60E-04	0.158084	5.32E+11	5211640	6.60E-04	0.158084	5.18E+11
5268480	6.70E-04	0.160479	5.40E+11	5290040	6.70E-04	0.160479	5.24E+11
5344920	6.80E-04	0.162874	5.48E+11	5367460	6.80E-04	0.162874	5.28E+11
5357660	6.82E-04	0.163281	5.56E+11	5443900	6.90E-04	0.165269	5.34E+11
5410580	6.89E-04	0.164958	5.63E+11	5521320	7.00E-04	0.167665	5.38E+11
5450760	6.96E-04	0.166587	5.71E+11	5597760	7.10E-04	0.17006	5.43E+11
5506620	7.05E-04	0.168814	5.79E+11	5673220	7.20E-04	0.172455	5.45E+11
5565420	7.15E-04	0.17121	5.82E+11	5701640	7.24E-04	0.173365	5.51E+11
5616380	7.24E-04	0.173317	5.88E+11	5757500	7.32E-04	0.175257	5.52E+11
5674200	7.34E-04	0.175713	5.92E+11	5800620	7.39E-04	0.176982	5.57E+11
5696740	7.38E-04	0.176671	5.96E+11	5839820	7.47E-04	0.178826	5.62E+11

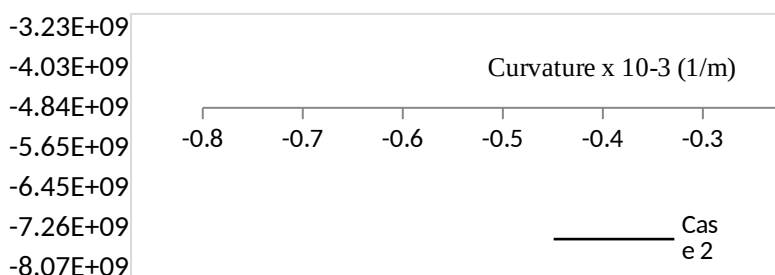
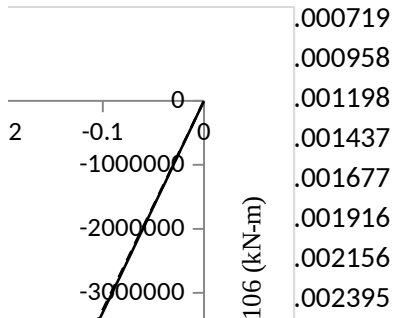
5750640	7.48E-04	0.179066	5.99E+11	5868240	7.53E-04	0.180431	5.67E+11
5803560	7.58E-04	0.181461	6.02E+11	5895680	7.60E-04	0.182036	5.72E+11
5808460	7.59E-04	0.181701	6.06E+11	5933900	7.70E-04	0.184431	5.72E+11
5848640	7.67E-04	0.183593	6.09E+11	5963300	7.78E-04	0.186251	5.76E+11
5894700	7.77E-04	0.185988	6.12E+11	5998580	7.88E-04	0.188647	5.78E+11
5896660	7.77E-04	0.186084	6.14E+11	6016220	7.93E-04	0.189868	5.81E+11
5924100	7.83E-04	0.187593	6.17E+11	6049540	8.03E-04	0.192263	5.85E+11
5965260	7.93E-04	0.189916	6.18E+11	6051500	8.03E-04	0.192407	5.88E+11
6004460	8.03E-04	0.192287	6.21E+11	6080900	8.13E-04	0.194802	5.91E+11
6036800	8.12E-04	0.194371	6.21E+11	6089720	8.17E-04	0.195593	5.94E+11
6067180	8.20E-04	0.196503	6.24E+11	6114220	8.27E-04	0.197988	5.95E+11
6097560	8.30E-04	0.198707	6.26E+11	6136760	8.37E-04	0.200383	5.97E+11
6121080	8.38E-04	0.200719	6.29E+11	6160280	8.47E-04	0.202778	6.00E+11
6147540	8.48E-04	0.203066	6.29E+11	6164200	8.48E-04	0.20321	6.02E+11
6165180	8.55E-04	0.20479	6.31E+11	6183800	8.58E-04	0.205605	6.04E+11
6187720	8.65E-04	0.207186	6.33E+11	6202420	8.68E-04	0.208	6.05E+11
6187720	8.65E-04	0.20721	6.35E+11	6222020	8.78E-04	0.210395	6.07E+11
6208300	8.75E-04	0.209605	6.36E+11	6231820	8.84E-04	0.211617	6.08E+11
6215160	8.78E-04	0.210347	6.38E+11	6249460	8.94E-04	0.214012	6.10E+11
6232800	8.88E-04	0.212695	6.39E+11	6266120	9.04E-04	0.216407	6.10E+11
6249460	8.98E-04	0.21509	6.40E+11	6274940	9.09E-04	0.217701	6.12E+11
6255340	9.02E-04	0.216048	6.42E+11	6286700	9.17E-04	0.219617	6.12E+11
6270040	9.12E-04	0.218443	6.43E+11	6300420	9.27E-04	0.222012	6.13E+11
6271020	9.13E-04	0.218659	6.44E+11	6314140	9.37E-04	0.224407	6.13E+11
6283760	9.23E-04	0.221054	6.46E+11	6326880	9.47E-04	0.226802	6.14E+11
6283760	9.23E-04	0.22115	6.46E+11	6334720	9.52E-04	0.228048	6.15E+11
6294540	9.32E-04	0.223305	6.48E+11	6345500	9.62E-04	0.230443	6.16E+11
6305320	9.42E-04	0.225701	6.48E+11	6350400	9.66E-04	0.231353	6.16E+11
6308260	9.45E-04	0.226228	6.49E+11	6359220	9.76E-04	0.233749	6.17E+11
6316100	9.52E-04	0.228096	6.50E+11	6367060	9.84E-04	0.235665	6.17E+11
6324920	9.62E-04	0.230491	6.51E+11	6374900	9.94E-04	0.23806	6.18E+11
6326880	9.65E-04	0.23121	6.51E+11	6377840	9.98E-04	0.23897	6.18E+11
6333740	9.75E-04	0.233509	6.51E+11	6383720	1.01E-03	0.241437	6.19E+11
6338640	9.85E-04	0.235904	6.52E+11	6389600	1.02E-03	0.243832	6.19E+11
6338640	9.86E-04	0.236216	6.53E+11	6396460	1.03E-03	0.246228	6.20E+11
6341580	9.96E-04	0.238611	6.53E+11	6398420	1.03E-03	0.246946	6.20E+11
6341580	1.00E-03	0.23976	6.54E+11	6404300	1.04E-03	0.249341	6.20E+11
6342560	1.01E-03	0.241916	6.54E+11	6409200	1.05E-03	0.251737	6.20E+11
6342560	1.02E-03	0.244311	6.54E+11	6410180	1.05E-03	0.252216	6.20E+11
6342560	1.02E-03	0.244551	6.55E+11	6415080	1.06E-03	0.254611	6.20E+11
6341580	1.03E-03	0.245988	6.55E+11	6419000	1.07E-03	0.257006	6.20E+11
6336680	1.04E-03	0.248383	6.56E+11	6423900	1.08E-03	0.259401	6.20E+11
6334720	1.04E-03	0.249581	6.56E+11	6426840	1.09E-03	0.261557	6.20E+11
6329820	1.05E-03	0.251976	6.56E+11	6431740	1.10E-03	0.263952	6.20E+11
6328840	1.05E-03	0.252455	6.57E+11	6435660	1.11E-03	0.266347	6.20E+11

6322960	1.06E-03	0.25485	6.57E+11	6438600	1.12E-03	0.268743	6.20E+11
6322960	1.07E-03	0.25509	6.57E+11	6439580	1.13E-03	0.26994	6.20E+11
6316100	1.07E-03	0.257246	6.57E+11	6442520	1.14E-03	0.272335	6.19E+11
6306300	1.08E-03	0.259641	6.58E+11	6444480	1.15E-03	0.274731	6.19E+11
6306300	1.08E-03	0.259641	6.58E+11	6445460	1.15E-03	0.275928	6.19E+11
6298460	1.09E-03	0.261557	6.58E+11	6447420	1.16E-03	0.278323	6.18E+11
6288660	1.10E-03	0.263952	6.58E+11	6447420	1.17E-03	0.280479	6.18E+11
6286700	1.10E-03	0.264192	6.58E+11	6448400	1.18E-03	0.282874	6.18E+11
6275920	1.11E-03	0.266587	6.58E+11	6450360	1.19E-03	0.285269	6.17E+11
6272980	1.12E-03	0.267305	6.58E+11	6450360	1.19E-03	0.285509	6.17E+11
6265140	1.12E-03	0.268743	6.58E+11	6451340	1.20E-03	0.287904	6.17E+11
6253380	1.13E-03	0.270898	6.59E+11	6453300	1.21E-03	0.290299	6.16E+11
6241620	1.14E-03	0.273054	6.59E+11	6455260	1.22E-03	0.292216	6.16E+11
6226920	1.15E-03	0.275449	6.59E+11	6456240	1.23E-03	0.294611	6.15E+11
6212220	1.16E-03	0.277844	6.59E+11	6458200	1.24E-03	0.297006	6.14E+11
6210260	1.16E-03	0.278323	6.59E+11	6460160	1.25E-03	0.299401	6.14E+11
6195560	1.17E-03	0.280719	6.60E+11	6463100	1.26E-03	0.301796	6.13E+11
6194580	1.17E-03	0.280719	6.60E+11	6465060	1.27E-03	0.304192	6.12E+11
6181840	1.18E-03	0.282635	6.60E+11	6465060	1.27E-03	0.304671	6.12E+11
6168120	1.19E-03	0.284551	6.60E+11	6467020	1.28E-03	0.307066	6.11E+11
6158320	1.19E-03	0.285988	6.60E+11	6469960	1.29E-03	0.309461	6.10E+11
6141660	1.20E-03	0.288383	6.60E+11	6471920	1.30E-03	0.311856	6.10E+11
6140680	1.20E-03	0.288383	6.61E+11	6473880	1.31E-03	0.314251	6.09E+11
6127940	1.21E-03	0.290299	6.61E+11	6475840	1.32E-03	0.316647	6.08E+11
6112260	1.22E-03	0.292695	6.61E+11	6476820	1.33E-03	0.317844	6.07E+11
6102460	1.23E-03	0.294371	6.61E+11	6479760	1.34E-03	0.32024	6.06E+11
6089720	1.24E-03	0.296287	6.61E+11	6481720	1.35E-03	0.322635	6.06E+11
6076980	1.25E-03	0.298204	6.62E+11	6482700	1.35E-03	0.324311	6.05E+11
6059340	1.26E-03	0.300599	6.62E+11	6483680	1.36E-03	0.326707	6.04E+11
6046600	1.26E-03	0.302515	6.62E+11	6484660	1.37E-03	0.329102	6.03E+11
6032880	1.27E-03	0.304192	6.62E+11	6484660	1.38E-03	0.33006	6.03E+11
6017200	1.28E-03	0.306347	6.62E+11	6485640	1.39E-03	0.332455	6.02E+11
5994660	1.29E-03	0.308743	6.62E+11	6485640	1.40E-03	0.33485	6.01E+11
5986820	1.29E-03	0.309701	6.62E+11	6486620	1.41E-03	0.337246	6.00E+11
5966240	1.30E-03	0.312096	6.62E+11	6486620	1.42E-03	0.339641	5.99E+11
5952520	1.31E-03	0.313533	6.62E+11	6486620	1.42E-03	0.34012	5.98E+11
5934880	1.32E-03	0.315689	6.62E+11	6486620	1.43E-03	0.342515	5.97E+11
5915280	1.33E-03	0.318084	6.62E+11	6485640	1.44E-03	0.34491	5.97E+11
5912340	1.33E-03	0.318563	6.62E+11	6485640	1.45E-03	0.347305	5.96E+11
5893720	1.34E-03	0.320958	6.62E+11	6485640	1.46E-03	0.349701	5.96E+11
5876080	1.35E-03	0.323353	6.62E+11	6485640	1.47E-03	0.352096	5.94E+11
5867260	1.36E-03	0.324551	6.62E+11	6485640	1.47E-03	0.352575	5.94E+11
5851580	1.37E-03	0.326946	6.62E+11	6484660	1.48E-03	0.35497	5.93E+11
5846680	1.37E-03	0.327665	6.61E+11	6480740	1.49E-03	0.355928	5.92E+11
5831980	1.38E-03	0.33006	6.61E+11	6478780	1.50E-03	0.358323	5.91E+11

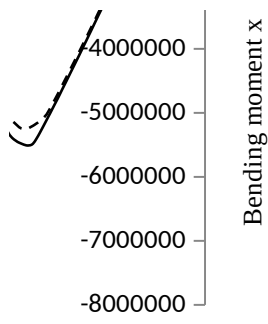
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5791800	1.41E-03	0.336527	6.62E+11	6482700	1.53E-03	0.365509	5.89E+11
5778080	1.42E-03	0.338922	6.62E+11	6483680	1.54E-03	0.367904	5.88E+11
5774160	1.42E-03	0.339641	6.65E+11	6513080	1.55E-03	0.370299	5.87E+11
5760440	1.43E-03	0.342036	6.65E+11	6512100	1.56E-03	0.372695	5.87E+11
5746720	1.44E-03	0.344431	6.65E+11	6512100	1.57E-03	0.37509	5.86E+11
5733980	1.45E-03	0.346826	6.65E+11	6512100	1.57E-03	0.37509	5.85E+11
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5690860	1.48E-03	0.35521	6.61E+11	6474860	1.60E-03	0.382036	5.81E+11
5681060	1.49E-03	0.357126	6.57E+11	6439580	1.60E-03	0.384192	5.80E+11
5669300	1.50E-03	0.359521	6.52E+11	6393520	1.61E-03	0.386587	5.79E+11
5657540	1.51E-03	0.361916	6.52E+11	6389600	1.62E-03	0.386826	5.78E+11
5654600	1.51E-03	0.362635	6.49E+11	6360200	1.63E-03	0.389222	5.77E+11
5642840	1.52E-03	0.36503	6.48E+11	6353340	1.63E-03	0.38994	5.76E+11
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5593840	1.56E-03	0.374371	6.42E+11	6288660	1.65E-03	0.395689	5.73E+11
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5575220	1.58E-03	0.377964	6.36E+11	6230840	1.67E-03	0.4	5.71E+11
5563460	1.59E-03	0.380359	6.33E+11	6202420	1.68E-03	0.402395	5.71E+11
5551700	1.60E-03	0.382754	6.33E+11	6199480	1.68E-03	0.402395	5.70E+11
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5468400	1.66E-03	0.397365	6.17E+11	6048560	1.74E-03	0.417485	5.65E+11
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5360600	1.75E-03	0.418922	6.01E+11	5884900	1.82E-03	0.436647	5.58E+11
5349820	1.76E-03	0.421317	5.99E+11	5868240	1.83E-03	0.439042	5.57E+11
5339040	1.77E-03	0.423713	5.97E+11	5850600	1.84E-03	0.441437	5.56E+11
5328260	1.78E-03	0.426108	5.95E+11	5833940	1.85E-03	0.443832	5.55E+11
5318460	1.79E-03	0.428503	5.94E+11	5818260	1.86E-03	0.446228	5.54E+11

5307680	1.80E-03	0.430898	5.92E+11	5802580	1.87E-03	0.448623	5.53E+11
5296900	1.81E-03	0.433293	5.91E+11	5786900	1.88E-03	0.451018	5.53E+11
5286120	1.82E-03	0.435689	5.89E+11	5772200	1.89E-03	0.453413	5.52E+11
5275340	1.83E-03	0.438084	5.88E+11	5758480	1.90E-03	0.455808	5.51E+11
5265540	1.84E-03	0.440479	5.86E+11	5745740	1.91E-03	0.458204	5.50E+11
5255740	1.85E-03	0.442874	5.85E+11	5730060	1.92E-03	0.460599	5.49E+11
5245940	1.86E-03	0.445269	5.83E+11	5715360	1.93E-03	0.462994	5.49E+11
5236140	1.87E-03	0.447665	5.82E+11	5700660	1.94E-03	0.465389	5.48E+11
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5216540	1.89E-03	0.452455	5.79E+11	5673220	1.96E-03	0.47018	5.47E+11
5207720	1.90E-03	0.45485	5.78E+11	5660480	1.97E-03	0.472575	5.46E+11
5198900	1.91E-03	0.457246	5.76E+11	5647740	1.98E-03	0.47497	5.45E+11
5190080	1.92E-03	0.459641	5.75E+11	5635000	1.99E-03	0.477365	5.45E+11
5181260	1.93E-03	0.462036	5.74E+11	5623240	2.00E-03	0.47976	5.44E+11
5172440	1.94E-03	0.464431	5.73E+11	5611480	2.01E-03	0.482156	5.43E+11
5169500	1.94E-03	0.46491	5.72E+11	5600700	2.02E-03	0.484551	5.43E+11
5160680	1.95E-03	0.467305	5.71E+11	5594820	2.03E-03	0.485749	5.42E+11
5151860	1.96E-03	0.469701	5.70E+11	5583060	2.04E-03	0.488144	5.41E+11
5143040	1.97E-03	0.472096	5.69E+11	5580120	2.04E-03	0.488623	5.40E+11
5142060	1.97E-03	0.472575	5.68E+11	5565420	2.05E-03	0.491018	5.40E+11
5133240	1.98E-03	0.47497	5.67E+11	5553660	2.06E-03	0.493413	5.39E+11
5124420	1.99E-03	0.477365	5.65E+11	5540920	2.07E-03	0.495808	5.38E+11
5116580	2.00E-03	0.47976	5.64E+11	5530140	2.08E-03	0.498204	5.38E+11
5115600	2.00E-03	0.47976	5.63E+11	5518380	2.09E-03	0.500599	5.37E+11
5105800	2.01E-03	0.482156	5.62E+11	5511520	2.10E-03	0.502036	5.37E+11
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5087180	2.03E-03	0.486946	5.60E+11	5485060	2.12E-03	0.506826	5.35E+11
5079340	2.04E-03	0.489341	5.59E+11	5473300	2.13E-03	0.509222	5.35E+11
5070520	2.05E-03	0.491737	5.57E+11	5462520	2.14E-03	0.511617	5.34E+11
5061700	2.06E-03	0.494132	5.56E+11	5451740	2.15E-03	0.514012	5.34E+11
5053860	2.07E-03	0.496527	5.55E+11	5440960	2.16E-03	0.516407	5.33E+11
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5037200	2.09E-03	0.501317	5.53E+11	5420380	2.18E-03	0.521198	5.32E+11
5029360	2.10E-03	0.503713	5.52E+11	5409600	2.19E-03	0.523593	5.31E+11
5021520	2.11E-03	0.506108	5.51E+11	5398820	2.20E-03	0.525988	5.30E+11
5013680	2.12E-03	0.508503	5.50E+11	5387060	2.21E-03	0.528383	5.30E+11
5005840	2.13E-03	0.510898	5.49E+11	5377260	2.22E-03	0.530778	5.29E+11
4998000	2.14E-03	0.513293	5.48E+11	5366480	2.23E-03	0.533174	5.29E+11
4990160	2.15E-03	0.515689	5.47E+11	5355700	2.24E-03	0.535569	5.28E+11
4982320	2.16E-03	0.518084	5.45E+11	5344920	2.25E-03	0.537964	5.27E+11
4974480	2.17E-03	0.520479	5.44E+11	5334140	2.26E-03	0.540359	5.27E+11
4966640	2.18E-03	0.522874	5.43E+11	5323360	2.27E-03	0.542754	5.26E+11
4959780	2.19E-03	0.525269	5.42E+11	5312580	2.28E-03	0.54515	5.25E+11
4951940	2.20E-03	0.527665	5.41E+11	5302780	2.29E-03	0.547545	5.25E+11
4944100	2.21E-03	0.53006	5.40E+11	5292980	2.30E-03	0.54994	5.24E+11

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4929400	2.23E-03	0.53485	5.38E+11	5272400	2.32E-03	0.554731	5.23E+11
4922540	2.24E-03	0.537246	5.37E+11	5261620	2.33E-03	0.557126	5.22E+11
4914700	2.25E-03	0.539641	5.36E+11	5251820	2.34E-03	0.559521	5.21E+11
4906860	2.26E-03	0.542036	5.35E+11	5242020	2.35E-03	0.561916	5.21E+11
4900000	2.27E-03	0.544431	5.34E+11	5232220	2.36E-03	0.564311	5.20E+11
4892160	2.28E-03	0.546826	5.33E+11	5222420	2.37E-03	0.566707	5.19E+11
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4878440	2.30E-03	0.551617	5.31E+11	5203800	2.39E-03	0.571497	5.18E+11
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4856880	2.33E-03	0.558802	5.29E+11	5184200	2.41E-03	0.576527	5.16E+11
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4843160	2.35E-03	0.563593	5.27E+11	5165580	2.43E-03	0.581317	5.15E+11
4837280	2.36E-03	0.565988	5.26E+11	5156760	2.44E-03	0.583713	5.14E+11
4836300	2.37E-03	0.566467	5.25E+11	5147940	2.45E-03	0.586108	5.13E+11
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4815720	2.40E-03	0.573653	5.23E+11	5121480	2.48E-03	0.593293	5.11E+11
4808860	2.41E-03	0.576048	5.22E+11	5113640	2.49E-03	0.595689	5.10E+11
4802980	2.42E-03	0.578443	5.21E+11	5104820	2.50E-03	0.598084	5.09E+11
4796120	2.43E-03	0.580838	5.20E+11	5096980	2.51E-03	0.600479	5.09E+11
4790240	2.44E-03	0.583234	5.19E+11	5088160	2.52E-03	0.602874	5.08E+11
4783380	2.45E-03	0.585629	5.18E+11	5080320	2.53E-03	0.605269	5.07E+11
4777500	2.46E-03	0.588024	5.18E+11	5072480	2.54E-03	0.607665	5.07E+11
4770640	2.47E-03	0.590419	5.17E+11	5064640	2.55E-03	0.61006	5.06E+11
4764760	2.48E-03	0.592814	5.16E+11	5056800	2.56E-03	0.612455	5.05E+11
4758880	2.49E-03	0.59521	5.15E+11	5048960	2.57E-03	0.61485	5.05E+11
4753000	2.50E-03	0.597605	5.14E+11	5041120	2.58E-03	0.617246	5.04E+11
4747120	2.51E-03	0.6	5.14E+11	5033280	2.59E-03	0.619641	5.04E+11
4741240	2.52E-03	0.602395	5.13E+11	5025440	2.60E-03	0.622036	5.03E+11
4735360	2.53E-03	0.60479	5.12E+11	5018580	2.61E-03	0.624431	5.02E+11
4729480	2.54E-03	0.607186	5.11E+11	5010740	2.62E-03	0.626826	5.02E+11
4723600	2.55E-03	0.609581	5.11E+11	5003880	2.63E-03	0.629222	5.01E+11
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Cas
e 2



Bending moment x

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-4.03E+10
-4.84E+10
-5.65E+10
-6.45E+10
-7.26E+10
-8.06E+10



-787430	-1.00E-04	-0.023952	-8.06E+10				
-865928	-1.10E-04	-0.026347	-8.87E+10	-868770	-1.10E-04	-0.026347	-8.71E+10
-944328	-1.20E-04	-0.028743	-9.67E+10	-947562	-1.20E-04	-0.028743	-9.51E+10
-1023120	-1.30E-04	-0.031138	-1.05E+11	-1026060	-1.30E-04	-0.031138	-1.03E+11
-1101520	-1.40E-04	-0.033533	-1.13E+11	-1105440	-1.40E-04	-0.033533	-1.11E+11
-1179920	-1.50E-04	-0.035928	-1.21E+11	-1183840	-1.50E-04	-0.035928	-1.19E+11
-1257340	-1.60E-04	-0.038323	-1.29E+11	-1262240	-1.60E-04	-0.038323	-1.27E+11
-1335740	-1.70E-04	-0.040719	-1.37E+11	-1341620	-1.70E-04	-0.040719	-1.35E+11
-1414140	-1.80E-04	-0.043114	-1.45E+11	-1420020	-1.80E-04	-0.043114	-1.43E+11
-1492540	-1.90E-04	-0.045509	-1.53E+11	-1498420	-1.90E-04	-0.045509	-1.50E+11
-1570940	-2.00E-04	-0.047904	-1.61E+11	-1576820	-2.00E-04	-0.047904	-1.58E+11
-1648360	-2.10E-04	-0.050299	-1.69E+11	-1656200	-2.10E-04	-0.050299	-1.66E+11
-1726760	-2.20E-04	-0.052695	-1.77E+11	-1734600	-2.20E-04	-0.052695	-1.74E+11
-1804180	-2.30E-04	-0.05509	-1.85E+11	-1813000	-2.30E-04	-0.05509	-1.82E+11
-1882580	-2.40E-04	-0.057485	-1.93E+11	-1891400	-2.40E-04	-0.057485	-1.90E+11
-1960980	-2.50E-04	-0.05988	-2.01E+11	-1969800	-2.50E-04	-0.05988	-1.98E+11
-2038400	-2.60E-04	-0.062275	-2.09E+11	-2048200	-2.60E-04	-0.062275	-2.05E+11
-2116800	-2.70E-04	-0.064671	-2.17E+11	-2126600	-2.70E-04	-0.064671	-2.13E+11
-2194220	-2.80E-04	-0.067066	-2.25E+11	-2205000	-2.80E-04	-0.067066	-2.21E+11
-2272620	-2.90E-04	-0.069461	-2.33E+11	-2283400	-2.90E-04	-0.069461	-2.29E+11
-2350040	-3.00E-04	-0.071856	-2.41E+11	-2361800	-3.00E-04	-0.071856	-2.37E+11
-2428440	-3.10E-04	-0.074251	-2.49E+11	-2440200	-3.10E-04	-0.074251	-2.45E+11
-2505860	-3.20E-04	-0.076647	-2.57E+11	-2517620	-3.20E-04	-0.076647	-2.53E+11
-2584260	-3.30E-04	-0.079042	-2.65E+11	-2596020	-3.30E-04	-0.079042	-2.60E+11
-2661680	-3.40E-04	-0.081437	-2.73E+11	-2674420	-3.40E-04	-0.081437	-2.68E+11
-2739100	-3.50E-04	-0.083832	-2.81E+11	-2752820	-3.50E-04	-0.083832	-2.76E+11
-2817500	-3.60E-04	-0.086228	-2.89E+11	-2831220	-3.60E-04	-0.086228	-2.84E+11
-2894920	-3.70E-04	-0.088623	-2.97E+11	-2909620	-3.70E-04	-0.088623	-2.92E+11
-2972340	-3.80E-04	-0.091018	-3.05E+11	-2987040	-3.80E-04	-0.091018	-3.00E+11
-3049760	-3.90E-04	-0.093413	-3.13E+11	-3065440	-3.90E-04	-0.093413	-3.08E+11
-3127180	-4.00E-04	-0.095808	-3.21E+11	-3143840	-4.00E-04	-0.095808	-3.15E+11
-3205580	-4.10E-04	-0.098204	-3.29E+11	-3221260	-4.10E-04	-0.098204	-3.23E+11
-3283000	-4.20E-04	-0.100599	-3.37E+11	-3299660	-4.20E-04	-0.100599	-3.31E+11
-3360420	-4.30E-04	-0.102994	-3.45E+11	-3377080	-4.30E-04	-0.102994	-3.39E+11
-3437840	-4.40E-04	-0.105389	-3.53E+11	-3455480	-4.40E-04	-0.105389	-3.47E+11
-3515260	-4.50E-04	-0.107784	-3.61E+11	-3533880	-4.50E-04	-0.107784	-3.55E+11
-3592680	-4.60E-04	-0.11018	-3.69E+11	-3611300	-4.60E-04	-0.11018	-3.62E+11

-3669120	-4.70E-04	-0.112575	-3.77E+11	-3689700	-4.70E-04	-0.112575	-3.70E+11
-3746540	-4.80E-04	-0.11497	-3.84E+11	-3767120	-4.80E-04	-0.11497	-3.78E+11
-3822980	-4.90E-04	-0.117365	-3.92E+11	-3844540	-4.90E-04	-0.117365	-3.86E+11
-3899420	-5.00E-04	-0.11976	-4.00E+11	-3922940	-5.00E-04	-0.11976	-3.93E+11
-3975860	-5.10E-04	-0.122156	-4.08E+11	-3999380	-5.10E-04	-0.122156	-4.01E+11
-4052300	-5.20E-04	-0.124551	-4.16E+11	-4076800	-5.20E-04	-0.124551	-4.09E+11
-4127760	-5.30E-04	-0.126946	-4.24E+11	-4154220	-5.30E-04	-0.126946	-4.16E+11
-4203220	-5.40E-04	-0.129341	-4.32E+11	-4230660	-5.40E-04	-0.129341	-4.24E+11
-4278680	-5.50E-04	-0.131737	-4.39E+11	-4306120	-5.50E-04	-0.131737	-4.32E+11
-4354140	-5.60E-04	-0.134132	-4.47E+11	-4382560	-5.60E-04	-0.134132	-4.39E+11
-4428620	-5.70E-04	-0.136527	-4.55E+11	-4458020	-5.70E-04	-0.136527	-4.47E+11
-4502120	-5.80E-04	-0.138922	-4.63E+11	-4533480	-5.80E-04	-0.138922	-4.54E+11
-4576600	-5.90E-04	-0.141317	-4.70E+11	-4608940	-5.90E-04	-0.141317	-4.62E+11
-4650100	-6.00E-04	-0.143713	-4.78E+11	-4683420	-6.00E-04	-0.143713	-4.66E+11
-4708900	-6.08E-04	-0.145653	-4.85E+11	-4756920	-6.10E-04	-0.146108	-4.73E+11
-4780440	-6.18E-04	-0.148048	-4.93E+11	-4831400	-6.20E-04	-0.148503	-4.78E+11
-4851980	-6.28E-04	-0.150443	-5.01E+11	-4904900	-6.30E-04	-0.150898	-4.86E+11
-4855900	-6.29E-04	-0.150587	-5.08E+11	-4977420	-6.40E-04	-0.153293	-4.88E+11
-4925480	-6.39E-04	-0.152982	-5.09E+11	-4987220	-6.41E-04	-0.153629	-4.92E+11
-4943120	-6.41E-04	-0.153581	-5.16E+11	-5059740	-6.51E-04	-0.156024	-4.96E+11
-4985260	-6.48E-04	-0.15509	-5.24E+11	-5131280	-6.61E-04	-0.158419	-4.99E+11
-5025440	-6.54E-04	-0.156575	-5.27E+11	-5168520	-6.67E-04	-0.159689	-5.02E+11
-5054840	-6.61E-04	-0.158228	-5.35E+11	-5238100	-6.77E-04	-0.162084	-5.03E+11
-5078360	-6.67E-04	-0.159665	-5.39E+11	-5277300	-6.83E-04	-0.163473	-5.05E+11
-5107760	-6.75E-04	-0.161701	-5.44E+11	-5329240	-6.90E-04	-0.165341	-5.07E+11
-5129320	-6.82E-04	-0.163353	-5.48E+11	-5371380	-6.97E-04	-0.166946	-5.09E+11
-5151860	-6.90E-04	-0.165198	-5.52E+11	-5409600	-7.05E-04	-0.168886	-5.11E+11
-5167540	-6.96E-04	-0.166683	-5.54E+11	-5426260	-7.12E-04	-0.170515	-5.12E+11
-5188120	-7.04E-04	-0.168575	-5.54E+11	-5430180	-7.18E-04	-0.171928	-5.13E+11
-5203800	-7.10E-04	-0.170156	-5.54E+11	-5430180	-7.26E-04	-0.173796	-5.14E+11
-5215560	-7.16E-04	-0.171569	-5.54E+11	-5427240	-7.31E-04	-0.174994	-5.16E+11
-5236140	-7.26E-04	-0.173964	-5.53E+11	-5415480	-7.41E-04	-0.177389	-5.18E+11
-5240060	-7.29E-04	-0.174491	-5.51E+11	-5398820	-7.51E-04	-0.179784	-5.19E+11
-5248880	-7.35E-04	-0.176096	-5.51E+11	-5396860	-7.51E-04	-0.179928	-5.19E+11
-5251820	-7.40E-04	-0.177246	-5.49E+11	-5379220	-7.61E-04	-0.182323	-5.19E+11
-5254760	-7.49E-04	-0.179425	-5.48E+11	-5366480	-7.68E-04	-0.18388	-5.17E+11
-5244960	-7.58E-04	-0.181533	-5.45E+11	-5340020	-7.78E-04	-0.186275	-5.15E+11
-5224380	-7.67E-04	-0.183713	-5.42E+11	-5311600	-7.88E-04	-0.188671	-5.13E+11
-5192040	-7.77E-04	-0.186012	-5.41E+11	-5305720	-7.89E-04	-0.189006	-5.11E+11
-5154800	-7.87E-04	-0.188407	-5.37E+11	-5260640	-7.99E-04	-0.191401	-5.09E+11
-5154800	-7.87E-04	-0.188431	-5.37E+11	-5257700	-8.00E-04	-0.191521	-5.07E+11
-5124420	-7.97E-04	-0.190826	-5.33E+11	-5224380	-8.05E-04	-0.192814	-5.06E+11
-5121480	-7.98E-04	-0.191066	-5.25E+11	-5148920	-8.15E-04	-0.19521	-5.05E+11
-5100900	-8.06E-04	-0.192934	-5.15E+11	-5048960	-8.25E-04	-0.197605	-5.05E+11
-5085220	-8.13E-04	-0.194611	-5.06E+11	-4958800	-8.33E-04	-0.199569	-5.03E+11

-5066600	-8.20E-04	-0.196503	-4.96E+11	-4856880	-8.43E-04	-0.201964	-5.02E+11
-5051900	-8.28E-04	-0.198204	-4.87E+11	-4769660	-8.53E-04	-0.204359	-5.01E+11
-5031320	-8.38E-04	-0.200599	-4.79E+11	-4695180	-8.63E-04	-0.206754	-5.00E+11
-5024460	-8.42E-04	-0.201557	-4.73E+11	-4636380	-8.73E-04	-0.20915	-4.98E+11
-5013680	-8.46E-04	-0.202731	-4.71E+11	-4612860	-8.78E-04	-0.210299	-4.98E+11
-4991140	-8.56E-04	-0.205126	-4.66E+11	-4569740	-8.88E-04	-0.212695	-4.95E+11
-4967620	-8.66E-04	-0.207521	-4.62E+11	-4530540	-8.98E-04	-0.21509	-4.93E+11
-4939200	-8.76E-04	-0.209916	-4.59E+11	-4498200	-9.08E-04	-0.217485	-4.90E+11
-4937240	-8.77E-04	-0.210108	-4.56E+11	-4467820	-9.18E-04	-0.21988	-4.89E+11
-4914700	-8.85E-04	-0.21188	-4.53E+11	-4439400	-9.28E-04	-0.222275	-4.86E+11
-4875500	-8.95E-04	-0.214275	-4.50E+11	-4413920	-9.38E-04	-0.224671	-4.82E+11
-4829440	-9.05E-04	-0.216671	-4.48E+11	-4390400	-9.48E-04	-0.227066	-4.78E+11
-4829440	-9.05E-04	-0.216695	-4.46E+11	-4367860	-9.58E-04	-0.229461	-4.75E+11
-4802980	-9.10E-04	-0.217964	-4.44E+11	-4347280	-9.68E-04	-0.231856	-4.70E+11
-4751040	-9.20E-04	-0.220359	-4.42E+11	-4326700	-9.78E-04	-0.234251	-4.69E+11
-4743200	-9.22E-04	-0.220719	-4.40E+11	-4307100	-9.88E-04	-0.236647	-4.63E+11
-4681460	-9.32E-04	-0.223114	-4.38E+11	-4289460	-9.98E-04	-0.239042	-4.58E+11
-4624620	-9.42E-04	-0.225509	-4.36E+11	-4270840	-1.01E-03	-0.241437	-4.54E+11
-4577580	-9.52E-04	-0.227904	-4.34E+11	-4253200	-1.02E-03	-0.243832	-4.50E+11
-4547200	-9.59E-04	-0.229725	-4.32E+11	-4235560	-1.03E-03	-0.246228	-4.50E+11
-4511920	-9.69E-04	-0.23212	-4.31E+11	-4218900	-1.04E-03	-0.248623	-4.47E+11
-4482520	-9.79E-04	-0.234515	-4.29E+11	-4202240	-1.05E-03	-0.251018	-4.44E+11
-4455080	-9.89E-04	-0.23691	-4.27E+11	-4186560	-1.06E-03	-0.253413	-4.42E+11
-4430580	-9.99E-04	-0.239305	-4.26E+11	-4169900	-1.07E-03	-0.255808	-4.39E+11
-4410980	-1.01E-03	-0.241437	-4.24E+11	-4155200	-1.08E-03	-0.258204	-4.39E+11
-4389420	-1.02E-03	-0.243832	-4.22E+11	-4139520	-1.09E-03	-0.260599	-4.37E+11
-4369820	-1.03E-03	-0.246228	-4.21E+11	-4123840	-1.10E-03	-0.262994	-4.35E+11
-4360020	-1.03E-03	-0.247186	-4.19E+11	-4108160	-1.11E-03	-0.265389	-4.33E+11
-4341400	-1.04E-03	-0.249581	-4.18E+11	-4092480	-1.12E-03	-0.267784	-4.32E+11
-4322780	-1.05E-03	-0.251976	-4.16E+11	-4077780	-1.13E-03	-0.27018	-4.30E+11
-4306120	-1.06E-03	-0.254371	-4.15E+11	-4063080	-1.14E-03	-0.272575	-4.28E+11
-4288480	-1.07E-03	-0.256766	-4.13E+11	-4047400	-1.15E-03	-0.27497	-4.26E+11
-4286520	-1.07E-03	-0.257006	-4.11E+11	-4031720	-1.16E-03	-0.277365	-4.25E+11
-4270840	-1.08E-03	-0.259401	-4.10E+11	-4017020	-1.17E-03	-0.27976	-4.23E+11
-4255160	-1.09E-03	-0.261796	-4.08E+11	-4001340	-1.18E-03	-0.282156	-4.22E+11
-4239480	-1.10E-03	-0.264192	-4.07E+11	-3985660	-1.19E-03	-0.284551	-4.20E+11
-4224780	-1.11E-03	-0.266587	-4.05E+11	-3969980	-1.20E-03	-0.286946	-4.19E+11
-4210080	-1.12E-03	-0.268982	-4.04E+11	-3954300	-1.21E-03	-0.289341	-4.17E+11
-4196360	-1.13E-03	-0.271377	-4.02E+11	-3938620	-1.22E-03	-0.291737	-4.16E+11
-4182640	-1.14E-03	-0.273772	-4.00E+11	-3921960	-1.23E-03	-0.294132	-4.15E+11
-4168920	-1.15E-03	-0.276168	-3.98E+11	-3904320	-1.24E-03	-0.296527	-4.13E+11
-4155200	-1.16E-03	-0.278563	-3.97E+11	-3888640	-1.25E-03	-0.298922	-4.12E+11
-4142460	-1.17E-03	-0.280958	-3.95E+11	-3873940	-1.26E-03	-0.301317	-4.11E+11
-4129720	-1.18E-03	-0.283353	-3.94E+11	-3859240	-1.27E-03	-0.303713	-4.09E+11
-4116000	-1.19E-03	-0.285749	-3.93E+11	-3849440	-1.28E-03	-0.305389	-4.08E+11

-4103260	-1.20E-03	-0.288144	-3.91E+11	-3835720	-1.29E-03	-0.307784	-4.07E+11
-4090520	-1.21E-03	-0.290539	-3.90E+11	-3823960	-1.30E-03	-0.31018	-4.06E+11
-4077780	-1.22E-03	-0.292934	-3.89E+11	-3812200	-1.31E-03	-0.312575	-4.04E+11
-4065040	-1.23E-03	-0.295329	-3.88E+11	-3800440	-1.32E-03	-0.31497	-4.03E+11
-4052300	-1.24E-03	-0.297725	-3.87E+11	-3788680	-1.33E-03	-0.317365	-4.02E+11
-4039560	-1.25E-03	-0.30012	-3.86E+11	-3777900	-1.34E-03	-0.31976	-4.01E+11
-4025840	-1.26E-03	-0.302515	-3.85E+11	-3768100	-1.35E-03	-0.322156	-3.99E+11
-4012120	-1.27E-03	-0.30491	-3.84E+11	-3758300	-1.36E-03	-0.324551	-3.98E+11
-3998400	-1.28E-03	-0.307305	-3.83E+11	-3748500	-1.37E-03	-0.326946	-3.97E+11
-3984680	-1.29E-03	-0.309701	-3.82E+11	-3738700	-1.38E-03	-0.329341	-3.95E+11
-3970960	-1.30E-03	-0.312096	-3.81E+11	-3728900	-1.39E-03	-0.331737	-3.94E+11
-3954300	-1.31E-03	-0.314491	-3.80E+11	-3720080	-1.40E-03	-0.334132	-3.92E+11
-3938620	-1.32E-03	-0.316886	-3.79E+11	-3711260	-1.41E-03	-0.336527	-3.91E+11
-3922940	-1.33E-03	-0.319281	-3.78E+11	-3703420	-1.42E-03	-0.338922	-3.89E+11
-3908240	-1.34E-03	-0.321677	-3.77E+11	-3694600	-1.43E-03	-0.341317	-3.88E+11
-3894520	-1.35E-03	-0.324072	-3.76E+11	-3685780	-1.44E-03	-0.343713	-3.86E+11
-3880800	-1.36E-03	-0.326467	-3.75E+11	-3677940	-1.45E-03	-0.346108	-3.85E+11
-3869040	-1.37E-03	-0.328862	-3.75E+11	-3670100	-1.46E-03	-0.348503	-3.84E+11
-3857280	-1.38E-03	-0.331257	-3.74E+11	-3662260	-1.47E-03	-0.350898	-3.83E+11
-3846500	-1.39E-03	-0.333653	-3.73E+11	-3654420	-1.48E-03	-0.353293	-3.81E+11
-3835720	-1.40E-03	-0.336048	-3.72E+11	-3647560	-1.49E-03	-0.355689	-3.80E+11
-3824940	-1.41E-03	-0.338443	-3.72E+11	-3640700	-1.50E-03	-0.358084	-3.79E+11
-3816120	-1.42E-03	-0.340838	-3.71E+11	-3632860	-1.51E-03	-0.360479	-3.78E+11
-3806320	-1.43E-03	-0.343234	-3.70E+11	-3626000	-1.52E-03	-0.362874	-3.78E+11
-3797500	-1.44E-03	-0.345629	-3.69E+11	-3619140	-1.53E-03	-0.365269	-3.77E+11
-3788680	-1.45E-03	-0.348024	-3.69E+11	-3612280	-1.54E-03	-0.367665	-3.76E+11
-3779860	-1.46E-03	-0.350419	-3.68E+11	-3605420	-1.55E-03	-0.37006	-3.75E+11
-3771040	-1.47E-03	-0.352814	-3.67E+11	-3599540	-1.56E-03	-0.372455	-3.74E+11
-3766140	-1.48E-03	-0.354491	-3.67E+11	-3592680	-1.57E-03	-0.37485	-3.73E+11
-3757320	-1.49E-03	-0.356886	-3.66E+11	-3586800	-1.58E-03	-0.377246	-3.73E+11
-3749480	-1.50E-03	-0.359281	-3.65E+11	-3579940	-1.59E-03	-0.379641	-3.72E+11
-3741640	-1.51E-03	-0.361677	-3.65E+11	-3574060	-1.60E-03	-0.382036	-3.71E+11
-3733800	-1.52E-03	-0.364072	-3.64E+11	-3568180	-1.61E-03	-0.384431	-3.70E+11
-3725960	-1.53E-03	-0.366467	-3.64E+11	-3562300	-1.62E-03	-0.386826	-3.70E+11
-3719100	-1.54E-03	-0.368862	-3.63E+11	-3556420	-1.63E-03	-0.389222	-3.69E+11
-3711260	-1.55E-03	-0.371257	-3.62E+11	-3550540	-1.64E-03	-0.391617	-3.68E+11
-3704400	-1.56E-03	-0.373653	-3.62E+11	-3544660	-1.65E-03	-0.394012	-3.68E+11
-3697540	-1.57E-03	-0.376048	-3.61E+11	-3539760	-1.66E-03	-0.396407	-3.67E+11
-3690680	-1.58E-03	-0.378443	-3.61E+11	-3533880	-1.67E-03	-0.398802	-3.66E+11
-3683820	-1.59E-03	-0.380838	-3.60E+11	-3528980	-1.68E-03	-0.401198	-3.66E+11
-3676960	-1.60E-03	-0.383234	-3.60E+11	-3523100	-1.69E-03	-0.403593	-3.65E+11
-3670100	-1.61E-03	-0.385629	-3.59E+11	-3518200	-1.70E-03	-0.405988	-3.64E+11
-3664220	-1.62E-03	-0.388024	-3.58E+11	-3512320	-1.71E-03	-0.408383	-3.64E+11
-3658340	-1.63E-03	-0.390419	-3.58E+11	-3507420	-1.72E-03	-0.410778	-3.63E+11
-3651480	-1.64E-03	-0.392814	-3.57E+11	-3502520	-1.73E-03	-0.413174	-3.62E+11

-3645600 -1.65E-03 -0.39521	-3.57E+11 -3497620 -1.74E-03 -0.415569	-3.62E+11
-3639720 -1.66E-03 -0.397605	-3.56E+11 -3492720 -1.75E-03 -0.417964	-3.61E+11
-3633840 -1.67E-03 -0.4	-3.56E+11 -3487820 -1.76E-03 -0.420359	-3.61E+11
-3626980 -1.68E-03 -0.402395	-3.55E+11 -3482920 -1.77E-03 -0.422754	-3.60E+11
-3622080 -1.69E-03 -0.40479	-3.55E+11 -3478020 -1.78E-03 -0.42515	-3.59E+11
-3616200 -1.70E-03 -0.407186	-3.54E+11 -3473120 -1.79E-03 -0.427545	-3.59E+11
-3610320 -1.71E-03 -0.409581	-3.54E+11 -3468220 -1.80E-03 -0.42994	-3.58E+11
-3605420 -1.72E-03 -0.411976	-3.53E+11 -3463320 -1.81E-03 -0.432335	-3.58E+11
-3600520 -1.73E-03 -0.413892	-3.53E+11 -3459400 -1.82E-03 -0.434731	-3.57E+11
-3595620 -1.74E-03 -0.416287	-3.53E+11 -3454500 -1.83E-03 -0.437126	-3.57E+11
-3589740 -1.75E-03 -0.418683	-3.52E+11 -3450580 -1.84E-03 -0.439521	-3.56E+11
-3584840 -1.76E-03 -0.421078	-3.52E+11 -3445680 -1.85E-03 -0.441916	-3.56E+11
-3578960 -1.77E-03 -0.423473	-3.51E+11 -3441760 -1.86E-03 -0.444311	-3.55E+11
-3574060 -1.78E-03 -0.425868	-3.51E+11 -3436860 -1.87E-03 -0.446707	-3.55E+11
-3569160 -1.79E-03 -0.428263	-3.50E+11 -3432940 -1.88E-03 -0.449102	-3.54E+11
-3564260 -1.80E-03 -0.430659	-3.50E+11 -3428040 -1.89E-03 -0.451497	-3.54E+11
-3559360 -1.81E-03 -0.433054	-3.49E+11 -3424120 -1.90E-03 -0.453892	-3.53E+11
-3554460 -1.82E-03 -0.435449	-3.49E+11 -3420200 -1.91E-03 -0.456287	-3.53E+11
-3549560 -1.83E-03 -0.437844	-3.49E+11 -3416280 -1.92E-03 -0.458683	-3.52E+11
-3544660 -1.84E-03 -0.44024	-3.48E+11 -3411380 -1.93E-03 -0.461078	-3.52E+11
-3539760 -1.85E-03 -0.442635	-3.48E+11 -3407460 -1.94E-03 -0.463473	-3.51E+11
-3534860 -1.86E-03 -0.44503	-3.47E+11 -3403540 -1.95E-03 -0.465868	-3.51E+11
-3530940 -1.87E-03 -0.447425	-3.47E+11 -3399620 -1.96E-03 -0.468263	-3.50E+11
-3526040 -1.88E-03 -0.44982	-3.47E+11 -3395700 -1.96E-03 -0.470419	-3.50E+11
-3521140 -1.89E-03 -0.452216	-3.46E+11 -3391780 -1.97E-03 -0.472814	-3.50E+11
-3517220 -1.90E-03 -0.454611	-3.46E+11 -3387860 -1.98E-03 -0.47521	-3.49E+11
-3512320 -1.91E-03 -0.457006	-3.45E+11 -3383940 -1.99E-03 -0.477605	-3.49E+11
-3508400 -1.92E-03 -0.459401	-3.45E+11 -3380020 -2.00E-03 -0.48	-3.48E+11
-3504480 -1.93E-03 -0.461796	-3.45E+11 -3376100 -2.01E-03 -0.482395	-3.48E+11
-3499580 -1.94E-03 -0.464192	-3.44E+11 -3372180 -2.02E-03 -0.48479	-3.47E+11
-3495660 -1.95E-03 -0.466587	-3.44E+11 -3368260 -2.03E-03 -0.487186	-3.47E+11
-3491740 -1.96E-03 -0.468982	-3.43E+11 -3365320 -2.04E-03 -0.489581	-3.47E+11
-3487820 -1.97E-03 -0.471377	-3.43E+11 -3361400 -2.05E-03 -0.491976	-3.46E+11
-3482920 -1.98E-03 -0.473772	-3.43E+11 -3357480 -2.06E-03 -0.494371	-3.46E+11
-3479000 -1.99E-03 -0.476168	-3.42E+11 -3353560 -2.07E-03 -0.496766	-3.45E+11
-3479000 -1.99E-03 -0.476407	-3.42E+11 -3349640 -2.08E-03 -0.499162	-3.45E+11
-3475080 -2.00E-03 -0.478802	-3.42E+11 -3346700 -2.09E-03 -0.501557	-3.45E+11
-3470180 -2.01E-03 -0.481198	-3.41E+11 -3342780 -2.10E-03 -0.503952	-3.44E+11
-3466260 -2.02E-03 -0.483593	-3.41E+11 -3339840 -2.11E-03 -0.506347	-3.44E+11
-3462340 -2.03E-03 -0.485988	-3.40E+11 -3335920 -2.12E-03 -0.508743	-3.43E+11
-3458420 -2.04E-03 -0.488383	-3.40E+11 -3332980 -2.13E-03 -0.511138	-3.43E+11
-3455480 -2.05E-03 -0.490778	-3.40E+11 -3329060 -2.14E-03 -0.513533	-3.43E+11
-3451560 -2.06E-03 -0.493174	-3.39E+11 -3326120 -2.15E-03 -0.515928	-3.42E+11
-3447640 -2.07E-03 -0.495569	-3.39E+11 -3322200 -2.16E-03 -0.518323	-3.42E+11
-3443720 -2.08E-03 -0.497964	-3.39E+11 -3319260 -2.17E-03 -0.520719	-3.42E+11

-3439800	-2.09E-03	-0.500359	-3.38E+11	-3315340	-2.18E-03	-0.523114	-3.41E+11
-3436860	-2.10E-03	-0.502754	-3.38E+11	-3312400	-2.19E-03	-0.525509	-3.41E+11
-3432940	-2.11E-03	-0.50515	-3.38E+11	-3308480	-2.20E-03	-0.527904	-3.41E+11
-3429020	-2.12E-03	-0.507545	-3.37E+11	-3305540	-2.21E-03	-0.530299	-3.40E+11
-3426080	-2.13E-03	-0.50994	-3.37E+11	-3302600	-2.22E-03	-0.532695	-3.40E+11
-3422160	-2.14E-03	-0.512335	-3.37E+11	-3299660	-2.23E-03	-0.53509	-3.39E+11
-3418240	-2.15E-03	-0.514731	-3.37E+11	-3297700	-2.24E-03	-0.536048	-3.39E+11
-3415300	-2.16E-03	-0.517126	-3.36E+11	-3294760	-2.25E-03	-0.538443	-3.39E+11
-3411380	-2.17E-03	-0.519521	-3.36E+11	-3291820	-2.26E-03	-0.540838	-3.38E+11
-3408440	-2.18E-03	-0.521916	-3.36E+11	-3288880	-2.27E-03	-0.543234	-3.38E+11
-3404520	-2.19E-03	-0.524311	-3.35E+11	-3284960	-2.28E-03	-0.545629	-3.38E+11
-3401580	-2.20E-03	-0.526707	-3.35E+11	-3282020	-2.29E-03	-0.548024	-3.37E+11
-3397660	-2.21E-03	-0.529102	-3.35E+11	-3279080	-2.30E-03	-0.550419	-3.37E+11
-3394720	-2.22E-03	-0.531497	-3.34E+11	-3276140	-2.31E-03	-0.552814	-3.37E+11
-3390800	-2.23E-03	-0.533892	-3.34E+11	-3273200	-2.32E-03	-0.55521	-3.36E+11
-3390800	-2.23E-03	-0.533892	-3.34E+11	-3270260	-2.33E-03	-0.557605	-3.36E+11
-3387860	-2.24E-03	-0.536287	-3.33E+11	-3267320	-2.34E-03	-0.56	-3.36E+11
-3384920	-2.25E-03	-0.538683	-3.33E+11	-3264380	-2.35E-03	-0.562395	-3.36E+11
-3381000	-2.26E-03	-0.541078	-3.33E+11	-3261440	-2.36E-03	-0.56479	-3.35E+11
-3378060	-2.27E-03	-0.543473	-3.33E+11	-3258500	-2.37E-03	-0.567186	-3.35E+11
-3374140	-2.28E-03	-0.545868	-3.32E+11	-3255560	-2.38E-03	-0.569581	-3.35E+11
-3371200	-2.29E-03	-0.548263	-3.32E+11	-3252620	-2.39E-03	-0.571976	-3.34E+11
-3368260	-2.30E-03	-0.550659	-3.32E+11	-3249680	-2.40E-03	-0.574371	-3.34E+11
-3364340	-2.31E-03	-0.553054	-3.31E+11	-3246740	-2.41E-03	-0.576766	-3.34E+11
-3361400	-2.32E-03	-0.555449	-3.31E+11	-3243800	-2.42E-03	-0.579162	-3.33E+11
-3358460	-2.33E-03	-0.557844	-3.31E+11	-3240860	-2.43E-03	-0.581557	-3.33E+11
-3355520	-2.34E-03	-0.56024	-3.30E+11	-3237920	-2.44E-03	-0.583952	-3.33E+11
-3352580	-2.35E-03	-0.562635	-3.30E+11	-3235960	-2.45E-03	-0.586347	-3.33E+11
-3349640	-2.36E-03	-0.56503	-3.30E+11	-3233020	-2.46E-03	-0.588743	-3.32E+11
-3345720	-2.37E-03	-0.567425	-3.30E+11	-3230080	-2.47E-03	-0.591138	-3.32E+11
-3342780	-2.38E-03	-0.56982	-3.29E+11	-3227140	-2.48E-03	-0.593533	-3.32E+11
-3339840	-2.39E-03	-0.572216	-3.29E+11	-3224200	-2.49E-03	-0.595928	-3.31E+11
-3336900	-2.40E-03	-0.574611	-3.29E+11	-3221260	-2.50E-03	-0.598323	-3.31E+11
-3333960	-2.41E-03	-0.577006	-3.29E+11	-3219300	-2.51E-03	-0.600719	-3.31E+11
-3331020	-2.42E-03	-0.579401	-3.28E+11	-3216360	-2.52E-03	-0.603114	-3.31E+11
-3328080	-2.43E-03	-0.581796	-3.28E+11	-3213420	-2.53E-03	-0.605509	-3.30E+11
-3325140	-2.44E-03	-0.584192	-3.28E+11	-3210480	-2.54E-03	-0.607904	-3.30E+11
-3322200	-2.45E-03	-0.586587	-3.27E+11	-3208520	-2.55E-03	-0.610299	-3.30E+11
-3319260	-2.46E-03	-0.588982	-3.27E+11	-3205580	-2.56E-03	-0.612695	-3.29E+11
-3316320	-2.47E-03	-0.591377	-3.27E+11	-3203620	-2.57E-03	-0.61509	-3.29E+11
-3313380	-2.48E-03	-0.593772	-3.27E+11	-3200680	-2.58E-03	-0.617485	-3.29E+11
-3310440	-2.49E-03	-0.596168	-3.26E+11	-3197740	-2.59E-03	-0.61988	-3.28E+11
-3307500	-2.50E-03	-0.598563	-3.26E+11	-3195780	-2.60E-03	-0.622275	-3.28E+11
-3305540	-2.51E-03	-0.600958	-3.26E+11	-3192840	-2.61E-03	-0.624671	-3.28E+11
-3303580	-2.52E-03	-0.602635	-3.26E+11	-3190880	-2.62E-03	-0.627066	-3.28E+11

-3300640	-2.53E-03	-0.60503	-3.25E+11	-3187940	-2.63E-03	-0.629461	-3.27E+11
-3297700	-2.54E-03	-0.607425	-3.25E+11	-3185980	-2.64E-03	-0.631856	-3.27E+11
-3294760	-2.55E-03	-0.60982	-3.25E+11	-3183040	-2.65E-03	-0.634251	-3.27E+11
-3292800	-2.56E-03	-0.612216	-3.25E+11	-3181080	-2.66E-03	-0.636647	-3.26E+11
-3289860	-2.57E-03	-0.614611	-3.24E+11	-3178140	-2.67E-03	-0.639042	-3.26E+11
-3287900	-2.57E-03	-0.616287	-3.24E+11	-3176180	-2.68E-03	-0.641437	-3.26E+11
-3284960	-2.58E-03	-0.618683	-3.24E+11	-3173240	-2.69E-03	-0.643832	-3.26E+11
-3282020	-2.59E-03	-0.621078	-3.24E+11	-3171280	-2.70E-03	-0.646228	-3.25E+11
-3279080	-2.60E-03	-0.623473	-3.23E+11	-3168340	-2.71E-03	-0.648623	-3.25E+11
-3276140	-2.61E-03	-0.625868	-3.23E+11	-3166380	-2.72E-03	-0.651018	-3.25E+11
-3273200	-2.62E-03	-0.628263	-3.23E+11	-3163440	-2.73E-03	-0.653413	-3.24E+11
-3270260	-2.63E-03	-0.630659	-3.23E+11	-3161480	-2.74E-03	-0.655808	-3.24E+11
-3267320	-2.64E-03	-0.633054	-3.22E+11	-3159520	-2.75E-03	-0.658204	-3.24E+11
-3264380	-2.65E-03	-0.635449	-3.22E+11	-3156580	-2.76E-03	-0.660599	-3.24E+11
-3261440	-2.66E-03	-0.637844	-3.22E+11	-3154620	-2.77E-03	-0.662994	-3.23E+11
-3258500	-2.67E-03	-0.64024	-3.22E+11	-3152660	-2.78E-03	-0.665389	-3.23E+11
-3256540	-2.68E-03	-0.642635	-3.21E+11	-3149720	-2.79E-03	-0.667784	-3.23E+11
-3253600	-2.69E-03	-0.64503	-3.21E+11	-3147760	-2.80E-03	-0.67018	-3.23E+11
-3250660	-2.70E-03	-0.647425	-3.21E+11	-3144820	-2.81E-03	-0.672575	-3.22E+11

lk Carrier (B1) ldchk = 2

40% damage

4.175 9.80E-06 1000

Rotation Curvature

7773.36	1.00E-06	0.00024
15542.8	2.00E-06	0.000479
23314.2	3.00E-06	0.000719
31075.8	4.00E-06	0.000958
38847.2	5.00E-06	0.001198
46618.6	6.00E-06	0.001437
54380.2	7.00E-06	0.001677
62151.6	8.00E-06	0.001916
69923	9.00E-06	0.002156
77684.6	1.00E-05	0.002395
155330	2.00E-05	0.00479
233044	3.00E-05	0.007186
310758	4.00E-05	0.009581
388374	5.00E-05	0.011976
466088	6.00E-05	0.014371
543802	7.00E-05	0.016766
621418	8.00E-05	0.019162
699132	9.00E-05	0.021557
776846	1.00E-04	0.023952
854462	1.10E-04	0.026347
932176	1.20E-04	0.028743
1009400	1.30E-04	0.031138
1087800	1.40E-04	0.033533
1165220	1.50E-04	0.035928
1242640	1.60E-04	0.038323
1321040	1.70E-04	0.040719
1398460	1.80E-04	0.043114
1475880	1.90E-04	0.045509
1553300	2.00E-04	0.047904
1631700	2.10E-04	0.050299
1709120	2.20E-04	0.052695
1786540	2.30E-04	0.05509
1863960	2.40E-04	0.057485
1941380	2.50E-04	0.05988
2018800	2.60E-04	0.062275
2097200	2.70E-04	0.064671
2174620	2.80E-04	0.067066
2252040	2.90E-04	0.069461
2329460	3.00E-04	0.071856
2406880	3.10E-04	0.074251

Bulk Carrier (B1) ldchk = 1

70% damage

frame spa 4.175 9.80E-06 1000

Moment Rotation Curvature

8.07E+08	7906.64	1.00E-06	0.00024
1.61E+09	15807.4	2.00E-06	0.000479
2.42E+09	23706.2	3.00E-06	0.000719
3.23E+09	31614.8	4.00E-06	0.000958
4.03E+09	39513.6	5.00E-06	0.001198
4.84E+09	47412.4	6.00E-06	0.001437
5.65E+09	55321	7.00E-06	0.001677
6.45E+09	63219.8	8.00E-06	0.001916
7.26E+09	71118.6	9.00E-06	0.002156
8.06E+09	79027.2	1.00E-05	0.002395
1.61E+10	158074	2.00E-05	0.00479
2.42E+10	237062	3.00E-05	0.007186
3.23E+10	316050	4.00E-05	0.009581
4.03E+10	395136	5.00E-05	0.011976
4.84E+10	474124	6.00E-05	0.014371
5.64E+10	553112	7.00E-05	0.016766
6.45E+10	632198	8.00E-05	0.019162
7.26E+10	711186	9.00E-05	0.021557
8.06E+10	790174	1.00E-04	0.023952
8.87E+10	869162	1.10E-04	0.026347
9.68E+10	948248	1.20E-04	0.028743
1.05E+11	1027040	1.30E-04	0.031138
1.13E+11	1106420	1.40E-04	0.033533
1.21E+11	1184820	1.50E-04	0.035928
1.29E+11	1264200	1.60E-04	0.038323
1.37E+11	1343580	1.70E-04	0.040719
1.45E+11	1421980	1.80E-04	0.043114
1.53E+11	1501360	1.90E-04	0.045509
1.61E+11	1580740	2.00E-04	0.047904
1.69E+11	1659140	2.10E-04	0.050299
1.77E+11	1738520	2.20E-04	0.052695
1.86E+11	1817900	2.30E-04	0.05509
1.94E+11	1896300	2.40E-04	0.057485
2.02E+11	1975680	2.50E-04	0.05988
2.10E+11	2054080	2.60E-04	0.062275
2.18E+11	2133460	2.70E-04	0.064671
2.26E+11	2212840	2.80E-04	0.067066
2.34E+11	2291240	2.90E-04	0.069461
2.42E+11	2370620	3.00E-04	0.071856
2.50E+11	2450000	3.10E-04	0.074251

Bul

frame spa

Moment

7.92E+08
1.58E+09
2.38E+09
3.17E+09
3.96E+09
4.75E+09
5.54E+09
6.33E+09
7.12E+09
7.92E+09
1.58E+10
2.37E+10
3.17E+10
3.96E+10
4.75E+10
5.54E+10
6.33E+10
7.12E+10
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9.50E+10
1.03E+11
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1.66E+11
1.74E+11
1.82E+11
1.90E+11
1.98E+11
2.06E+11
2.14E+11
2.22E+11
2.29E+11
2.37E+11
2.45E+11

2485280	3.20E-04	0.076647	2.58E+11	2528400	3.20E-04	0.076647	2.53E+11
2562700	3.30E-04	0.079042	2.66E+11	2607780	3.30E-04	0.079042	2.61E+11
2640120	3.40E-04	0.081437	2.74E+11	2686180	3.40E-04	0.081437	2.69E+11
2717540	3.50E-04	0.083832	2.82E+11	2765560	3.50E-04	0.083832	2.77E+11
2794960	3.60E-04	0.086228	2.90E+11	2844940	3.60E-04	0.086228	2.85E+11
2872380	3.70E-04	0.088623	2.98E+11	2923340	3.70E-04	0.088623	2.93E+11
2950780	3.80E-04	0.091018	3.06E+11	3002720	3.80E-04	0.091018	3.01E+11
3028200	3.90E-04	0.093413	3.14E+11	3081120	3.90E-04	0.093413	3.09E+11
3105620	4.00E-04	0.095808	3.23E+11	3160500	4.00E-04	0.095808	3.16E+11
3183040	4.10E-04	0.098204	3.31E+11	3239880	4.10E-04	0.098204	3.24E+11
3260460	4.20E-04	0.100599	3.39E+11	3318280	4.20E-04	0.100599	3.32E+11
3337880	4.30E-04	0.102994	3.47E+11	3397660	4.30E-04	0.102994	3.40E+11
3416280	4.40E-04	0.105389	3.55E+11	3476060	4.40E-04	0.105389	3.48E+11
3493700	4.50E-04	0.107784	3.63E+11	3555440	4.50E-04	0.107784	3.56E+11
3571120	4.60E-04	0.11018	3.71E+11	3633840	4.60E-04	0.11018	3.64E+11
3648540	4.70E-04	0.112575	3.79E+11	3713220	4.70E-04	0.112575	3.72E+11
3725960	4.80E-04	0.11497	3.87E+11	3792600	4.80E-04	0.11497	3.80E+11
3803380	4.90E-04	0.117365	3.95E+11	3871000	4.90E-04	0.117365	3.88E+11
3880800	5.00E-04	0.11976	4.03E+11	3950380	5.00E-04	0.11976	3.95E+11
3958220	5.10E-04	0.122156	4.11E+11	4028780	5.10E-04	0.122156	4.03E+11
4036620	5.20E-04	0.124551	4.19E+11	4108160	5.20E-04	0.124551	4.11E+11
4114040	5.30E-04	0.126946	4.27E+11	4186560	5.30E-04	0.126946	4.19E+11
4191460	5.40E-04	0.129341	4.35E+11	4265940	5.40E-04	0.129341	4.27E+11
4268880	5.50E-04	0.131737	4.43E+11	4345320	5.50E-04	0.131737	4.35E+11
4346300	5.60E-04	0.134132	4.51E+11	4423720	5.60E-04	0.134132	4.43E+11
4423720	5.70E-04	0.136527	4.59E+11	4502120	5.70E-04	0.136527	4.51E+11
4500160	5.80E-04	0.138922	4.68E+11	4581500	5.80E-04	0.138922	4.59E+11
4577580	5.90E-04	0.141317	4.76E+11	4659900	5.90E-04	0.141317	4.66E+11
4655000	6.00E-04	0.143713	4.84E+11	4739280	6.00E-04	0.143713	4.74E+11
4731440	6.10E-04	0.146108	4.92E+11	4817680	6.10E-04	0.146108	4.82E+11
4808860	6.20E-04	0.148503	5.00E+11	4896080	6.20E-04	0.148503	4.90E+11
4885300	6.30E-04	0.150898	5.08E+11	4975460	6.30E-04	0.150898	4.98E+11
4961740	6.40E-04	0.153293	5.16E+11	5052880	6.40E-04	0.153293	5.06E+11
5037200	6.50E-04	0.155689	5.24E+11	5131280	6.50E-04	0.155689	5.11E+11
5074440	6.55E-04	0.156838	5.32E+11	5209680	6.60E-04	0.158084	5.17E+11
5131280	6.62E-04	0.158635	5.40E+11	5287100	6.70E-04	0.160479	5.22E+11
5175380	6.69E-04	0.160192	5.48E+11	5365500	6.80E-04	0.162874	5.28E+11
5233200	6.79E-04	0.162587	5.55E+11	5441940	6.90E-04	0.165269	5.32E+11
5268480	6.85E-04	0.164024	5.63E+11	5518380	7.00E-04	0.167665	5.38E+11
5325320	6.95E-04	0.166419	5.71E+11	5594820	7.10E-04	0.17006	5.41E+11
5341000	6.98E-04	0.16709	5.79E+11	5670280	7.20E-04	0.172455	5.45E+11
5396860	7.08E-04	0.169485	5.82E+11	5700660	7.24E-04	0.173437	5.48E+11
5408620	7.10E-04	0.169988	5.88E+11	5757500	7.32E-04	0.175353	5.53E+11
5460560	7.20E-04	0.172383	5.92E+11	5800620	7.39E-04	0.177054	5.54E+11
5509560	7.29E-04	0.174587	5.96E+11	5838840	7.47E-04	0.178898	5.59E+11

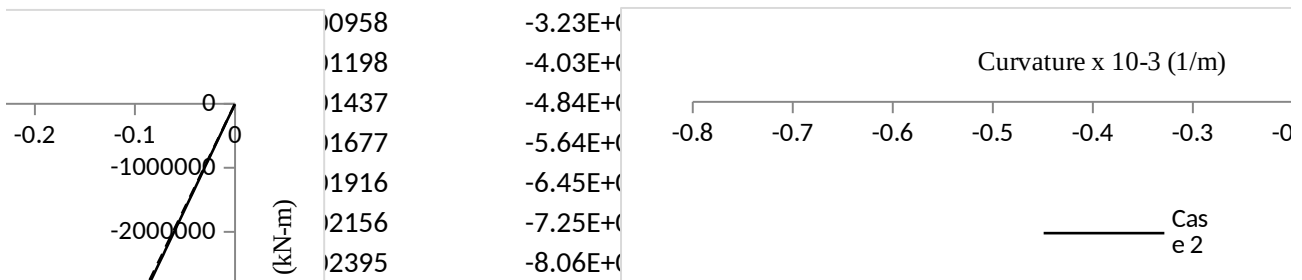
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5601680	7.48E-04	0.17921	6.02E+11	5894700	7.60E-04	0.182084	5.63E+11
5603640	7.49E-04	0.179329	6.05E+11	5932920	7.70E-04	0.184479	5.68E+11
5648720	7.59E-04	0.181725	6.08E+11	5961340	7.78E-04	0.186275	5.71E+11
5664400	7.62E-04	0.182539	6.12E+11	5996620	7.88E-04	0.188671	5.75E+11
5691840	7.68E-04	0.184048	6.14E+11	6014260	7.93E-04	0.189892	5.76E+11
5729080	7.78E-04	0.186251	6.17E+11	6047580	8.03E-04	0.192287	5.79E+11
5760440	7.86E-04	0.188263	6.17E+11	6048560	8.03E-04	0.192407	5.82E+11
5790820	7.94E-04	0.190251	6.20E+11	6076980	8.13E-04	0.194802	5.85E+11
5825120	8.04E-04	0.192647	6.21E+11	6085800	8.16E-04	0.195545	5.88E+11
5826100	8.04E-04	0.192671	6.23E+11	6109320	8.26E-04	0.19794	5.89E+11
5853540	8.14E-04	0.19485	6.26E+11	6132840	8.36E-04	0.200335	5.91E+11
5879020	8.23E-04	0.19703	6.28E+11	6155380	8.46E-04	0.202731	5.94E+11
5899600	8.31E-04	0.198922	6.28E+11	6158320	8.48E-04	0.20309	5.96E+11
5922140	8.41E-04	0.201317	6.30E+11	6177920	8.58E-04	0.205485	5.97E+11
5926060	8.42E-04	0.201725	6.32E+11	6192620	8.66E-04	0.207401	5.98E+11
5946640	8.52E-04	0.20412	6.34E+11	6211240	8.76E-04	0.209796	5.99E+11
5957420	8.58E-04	0.205389	6.35E+11	6223980	8.82E-04	0.211353	6.01E+11
5975060	8.68E-04	0.207784	6.37E+11	6240640	8.92E-04	0.213749	6.02E+11
5978980	8.70E-04	0.208335	6.39E+11	6257300	9.02E-04	0.216144	6.03E+11
5992700	8.80E-04	0.210731	6.39E+11	6265140	9.08E-04	0.217365	6.04E+11
5993680	8.80E-04	0.210754	6.41E+11	6276900	9.15E-04	0.219234	6.05E+11
6005440	8.90E-04	0.21315	6.42E+11	6289640	9.25E-04	0.221629	6.05E+11
6010340	8.94E-04	0.214108	6.43E+11	6302380	9.35E-04	0.224024	6.06E+11
6021120	9.04E-04	0.216503	6.44E+11	6315120	9.45E-04	0.226419	6.06E+11
6027980	9.10E-04	0.217892	6.45E+11	6321000	9.50E-04	0.227497	6.07E+11
6037780	9.20E-04	0.220287	6.46E+11	6331780	9.60E-04	0.229892	6.07E+11
6039740	9.21E-04	0.220695	6.47E+11	6335700	9.64E-04	0.230778	6.08E+11
6048560	9.31E-04	0.22309	6.48E+11	6345500	9.74E-04	0.233174	6.08E+11
6048560	9.32E-04	0.223257	6.48E+11	6351380	9.81E-04	0.234946	6.09E+11
6057380	9.42E-04	0.225653	6.49E+11	6359220	9.91E-04	0.237341	6.09E+11
6060320	9.46E-04	0.226659	6.49E+11	6362160	9.94E-04	0.238108	6.09E+11
6066200	9.55E-04	0.228719	6.50E+11	6367060	1.00E-03	0.240479	6.09E+11
6070120	9.65E-04	0.231114	6.50E+11	6372940	1.01E-03	0.242874	6.09E+11
6074040	9.75E-04	0.233509	6.51E+11	6378820	1.02E-03	0.245269	6.09E+11
6074040	9.76E-04	0.233701	6.51E+11	6380780	1.03E-03	0.245749	6.09E+11
6076000	9.86E-04	0.236096	6.52E+11	6385680	1.04E-03	0.248144	6.10E+11
6076980	9.90E-04	0.23715	6.52E+11	6390580	1.05E-03	0.250539	6.09E+11
6077960	1.00E-03	0.239521	6.52E+11	6390580	1.05E-03	0.251018	6.09E+11
6077960	1.01E-03	0.240719	6.53E+11	6394500	1.06E-03	0.253413	6.09E+11
6077960	1.01E-03	0.242156	6.53E+11	6398420	1.07E-03	0.255808	6.09E+11
6077960	1.02E-03	0.244311	6.53E+11	6401360	1.08E-03	0.258204	6.09E+11
6076980	1.03E-03	0.246707	6.54E+11	6405280	1.09E-03	0.260599	6.09E+11
6076000	1.03E-03	0.247665	6.54E+11	6409200	1.10E-03	0.262994	6.09E+11
6075020	1.04E-03	0.249341	6.54E+11	6413120	1.11E-03	0.265389	6.09E+11

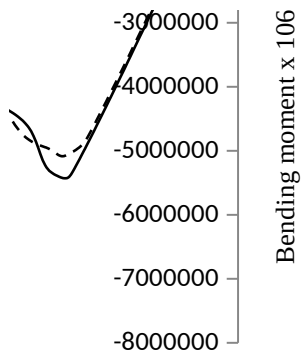
6073060	1.05E-03	0.251737	6.55E+11	6416060	1.12E-03	0.267305	6.09E+11
6072080	1.05E-03	0.252216	6.55E+11	6419980	1.13E-03	0.269701	6.08E+11
6070120	1.06E-03	0.254611	6.55E+11	6422920	1.14E-03	0.272096	6.08E+11
6068160	1.07E-03	0.255808	6.56E+11	6425860	1.15E-03	0.274491	6.08E+11
6064240	1.08E-03	0.257964	6.56E+11	6427820	1.16E-03	0.276886	6.07E+11
6059340	1.09E-03	0.260359	6.56E+11	6428800	1.16E-03	0.277844	6.07E+11
6059340	1.09E-03	0.260359	6.56E+11	6430760	1.17E-03	0.28024	6.07E+11
6054440	1.10E-03	0.262515	6.56E+11	6432720	1.18E-03	0.282635	6.07E+11
6047580	1.11E-03	0.26491	6.57E+11	6433700	1.19E-03	0.284311	6.06E+11
6047580	1.11E-03	0.26515	6.57E+11	6434680	1.20E-03	0.286707	6.06E+11
6041700	1.12E-03	0.267545	6.57E+11	6434680	1.21E-03	0.289102	6.05E+11
6040720	1.12E-03	0.267784	6.57E+11	6435660	1.22E-03	0.291497	6.05E+11
6034840	1.13E-03	0.26994	6.57E+11	6436640	1.22E-03	0.293174	6.05E+11
6027000	1.14E-03	0.272335	6.57E+11	6438600	1.23E-03	0.295569	6.05E+11
6020140	1.15E-03	0.274731	6.57E+11	6439580	1.24E-03	0.297964	6.04E+11
6012300	1.16E-03	0.277126	6.57E+11	6441540	1.25E-03	0.300359	6.03E+11
6004460	1.17E-03	0.279521	6.57E+11	6441540	1.26E-03	0.300599	6.03E+11
6001520	1.17E-03	0.28024	6.58E+11	6443500	1.27E-03	0.302994	6.02E+11
5993680	1.18E-03	0.282395	6.58E+11	6444480	1.28E-03	0.305389	6.02E+11
5986820	1.19E-03	0.284311	6.58E+11	6446440	1.29E-03	0.307784	6.01E+11
5977020	1.20E-03	0.286707	6.58E+11	6448400	1.30E-03	0.31018	6.00E+11
5976040	1.20E-03	0.286946	6.58E+11	6450360	1.31E-03	0.312575	6.00E+11
5965260	1.21E-03	0.289341	6.58E+11	6452320	1.31E-03	0.314731	5.99E+11
5960360	1.21E-03	0.290539	6.59E+11	6453300	1.32E-03	0.317126	5.98E+11
5949580	1.22E-03	0.292934	6.59E+11	6454280	1.33E-03	0.318084	5.98E+11
5939780	1.23E-03	0.295329	6.59E+11	6455260	1.34E-03	0.320479	5.97E+11
5935860	1.24E-03	0.296287	6.59E+11	6455260	1.35E-03	0.322874	5.97E+11
5927040	1.25E-03	0.298683	6.59E+11	6455260	1.36E-03	0.325269	5.96E+11
5917240	1.26E-03	0.301078	6.59E+11	6456240	1.37E-03	0.327665	5.95E+11
5908420	1.27E-03	0.303473	6.59E+11	6456240	1.38E-03	0.33006	5.94E+11
5904500	1.27E-03	0.304671	6.59E+11	6456240	1.39E-03	0.332455	5.94E+11
5895680	1.28E-03	0.307066	6.59E+11	6457220	1.40E-03	0.33485	5.93E+11
5889800	1.29E-03	0.308503	6.59E+11	6457220	1.40E-03	0.33485	5.93E+11
5877060	1.30E-03	0.310898	6.59E+11	6457220	1.41E-03	0.337246	5.92E+11
5871180	1.30E-03	0.312096	6.59E+11	6458200	1.42E-03	0.339641	5.91E+11
5861380	1.31E-03	0.314491	6.59E+11	6458200	1.43E-03	0.342036	5.90E+11
5849620	1.32E-03	0.316886	6.59E+11	6459180	1.44E-03	0.344431	5.89E+11
5849620	1.32E-03	0.316886	6.59E+11	6459180	1.45E-03	0.346826	5.88E+11
5837860	1.33E-03	0.319281	6.59E+11	6459180	1.46E-03	0.349222	5.88E+11
5836880	1.33E-03	0.319521	6.59E+11	6459180	1.47E-03	0.351617	5.87E+11
5825120	1.34E-03	0.321916	6.59E+11	6459180	1.47E-03	0.351856	5.86E+11
5825120	1.34E-03	0.321916	6.59E+11	6460160	1.48E-03	0.354251	5.85E+11
5814340	1.35E-03	0.324311	6.59E+11	6460160	1.49E-03	0.356647	5.85E+11
5802580	1.36E-03	0.326707	6.59E+11	6460160	1.50E-03	0.359042	5.84E+11
5791800	1.37E-03	0.329102	6.59E+11	6460160	1.51E-03	0.360958	5.84E+11

5790820	1.38E-03	0.329341	6.59E+11	6460160	1.52E-03	0.363353	5.84E+11
5779060	1.39E-03	0.331737	6.59E+11	6460160	1.53E-03	0.365749	5.83E+11
5771220	1.39E-03	0.333653	6.59E+11	6460160	1.54E-03	0.368144	5.83E+11
5762400	1.40E-03	0.335569	6.59E+11	6459180	1.55E-03	0.370539	5.82E+11
5752600	1.41E-03	0.337964	6.59E+11	6459180	1.56E-03	0.372934	5.81E+11
5750640	1.41E-03	0.338204	6.59E+11	6459180	1.57E-03	0.375329	5.80E+11
5739860	1.42E-03	0.340599	6.59E+11	6459180	1.58E-03	0.377725	5.80E+11
5730060	1.43E-03	0.342994	6.59E+11	6458200	1.59E-03	0.38012	5.79E+11
5725160	1.44E-03	0.344192	6.59E+11	6458200	1.59E-03	0.380359	5.78E+11
5714380	1.45E-03	0.346587	6.59E+11	6457220	1.60E-03	0.382754	5.77E+11
5703600	1.46E-03	0.348982	6.59E+11	6458200	1.61E-03	0.38515	5.76E+11
5692820	1.47E-03	0.351377	6.59E+11	6458200	1.61E-03	0.385389	5.76E+11
5685960	1.47E-03	0.352814	6.58E+11	6451340	1.62E-03	0.387784	5.75E+11
5675180	1.48E-03	0.35521	6.56E+11	6426840	1.63E-03	0.389701	5.75E+11
5664400	1.49E-03	0.357605	6.52E+11	6389600	1.63E-03	0.391377	5.74E+11
5653620	1.50E-03	0.36	6.47E+11	6337660	1.64E-03	0.393772	5.73E+11
5647740	1.51E-03	0.361437	6.46E+11	6330800	1.65E-03	0.394251	5.72E+11
5636960	1.52E-03	0.363832	6.42E+11	6295520	1.66E-03	0.396647	5.72E+11
5633040	1.52E-03	0.364551	6.42E+11	6292580	1.66E-03	0.396886	5.71E+11
5622260	1.53E-03	0.366946	6.40E+11	6275920	1.66E-03	0.398323	5.70E+11
5617360	1.54E-03	0.367904	6.38E+11	6248480	1.67E-03	0.400719	5.70E+11
5608540	1.54E-03	0.36982	6.37E+11	6242600	1.68E-03	0.401198	5.70E+11
5597760	1.55E-03	0.372216	6.34E+11	6214180	1.68E-03	0.403353	5.69E+11
5597760	1.55E-03	0.372216	6.30E+11	6173020	1.69E-03	0.405749	5.69E+11
5586980	1.56E-03	0.374611	6.28E+11	6154400	1.70E-03	0.406946	5.68E+11
5575220	1.57E-03	0.377006	6.25E+11	6120100	1.71E-03	0.409341	5.68E+11
5571300	1.58E-03	0.377964	6.24E+11	6119120	1.71E-03	0.409581	5.67E+11
5560520	1.59E-03	0.380359	6.21E+11	6086780	1.72E-03	0.411976	5.66E+11
5550720	1.60E-03	0.382754	6.18E+11	6057380	1.73E-03	0.414371	5.65E+11
5550720	1.60E-03	0.382754	6.15E+11	6026020	1.74E-03	0.416766	5.65E+11
5540920	1.61E-03	0.38515	6.12E+11	5999560	1.75E-03	0.419162	5.65E+11
5539940	1.61E-03	0.385389	6.10E+11	5974080	1.76E-03	0.421557	5.64E+11
5530140	1.62E-03	0.387784	6.09E+11	5966240	1.76E-03	0.422275	5.63E+11
5520340	1.63E-03	0.39018	6.07E+11	5946640	1.77E-03	0.423952	5.63E+11
5511520	1.64E-03	0.392575	6.04E+11	5919200	1.78E-03	0.426347	5.62E+11
5503680	1.65E-03	0.394491	6.01E+11	5890780	1.79E-03	0.428743	5.62E+11
5493880	1.66E-03	0.396886	5.98E+11	5864320	1.80E-03	0.431138	5.61E+11
5485060	1.67E-03	0.399281	5.96E+11	5839820	1.81E-03	0.433533	5.60E+11
5476240	1.68E-03	0.401677	5.94E+11	5817280	1.82E-03	0.435928	5.60E+11
5467420	1.69E-03	0.404072	5.91E+11	5793760	1.83E-03	0.438323	5.59E+11
5465460	1.69E-03	0.40479	5.90E+11	5777100	1.84E-03	0.44024	5.58E+11
5456640	1.70E-03	0.407186	5.87E+11	5755540	1.85E-03	0.442635	5.58E+11
5447820	1.71E-03	0.409581	5.85E+11	5733980	1.86E-03	0.44503	5.57E+11
5439000	1.72E-03	0.411976	5.83E+11	5713400	1.87E-03	0.447425	5.56E+11
5431160	1.73E-03	0.414371	5.81E+11	5692820	1.88E-03	0.44982	5.55E+11

5422340	1.74E-03	0.416766	5.79E+11	5673220	1.89E-03	0.452216	5.55E+11
5415480	1.75E-03	0.418683	5.77E+11	5654600	1.90E-03	0.454611	5.54E+11
5407640	1.76E-03	0.421078	5.75E+11	5636960	1.91E-03	0.457006	5.54E+11
5399800	1.77E-03	0.423473	5.73E+11	5618340	1.92E-03	0.459401	5.53E+11
5391960	1.78E-03	0.425868	5.72E+11	5601680	1.93E-03	0.461796	5.52E+11
5384120	1.79E-03	0.428263	5.70E+11	5586000	1.94E-03	0.464192	5.51E+11
5376280	1.80E-03	0.430659	5.68E+11	5569340	1.95E-03	0.466587	5.50E+11
5368440	1.81E-03	0.433054	5.67E+11	5552680	1.96E-03	0.468982	5.50E+11
5367460	1.81E-03	0.433533	5.65E+11	5536020	1.97E-03	0.471377	5.50E+11
5359620	1.82E-03	0.435928	5.63E+11	5521320	1.98E-03	0.473772	5.49E+11
5351780	1.83E-03	0.438323	5.62E+11	5506620	1.99E-03	0.476168	5.48E+11
5344920	1.84E-03	0.440719	5.60E+11	5491920	2.00E-03	0.478563	5.47E+11
5337080	1.85E-03	0.443114	5.59E+11	5477220	2.01E-03	0.480958	5.46E+11
5330220	1.86E-03	0.445509	5.58E+11	5463500	2.02E-03	0.483353	5.46E+11
5323360	1.87E-03	0.447904	5.56E+11	5449780	2.03E-03	0.485749	5.45E+11
5316500	1.88E-03	0.45006	5.55E+11	5436060	2.04E-03	0.488144	5.44E+11
5310620	1.89E-03	0.452216	5.54E+11	5425280	2.05E-03	0.49006	5.43E+11
5302780	1.90E-03	0.454611	5.52E+11	5411560	2.06E-03	0.492455	5.43E+11
5295920	1.91E-03	0.457006	5.51E+11	5394900	2.07E-03	0.49485	5.42E+11
5289060	1.92E-03	0.459401	5.49E+11	5380200	2.08E-03	0.497246	5.41E+11
5282200	1.93E-03	0.461796	5.48E+11	5366480	2.09E-03	0.499641	5.41E+11
5275340	1.94E-03	0.464192	5.46E+11	5352760	2.10E-03	0.502036	5.40E+11
5268480	1.95E-03	0.466587	5.45E+11	5340020	2.11E-03	0.504431	5.39E+11
5265540	1.95E-03	0.467545	5.44E+11	5334140	2.11E-03	0.505629	5.39E+11
5258680	1.96E-03	0.46994	5.43E+11	5318460	2.12E-03	0.508024	5.38E+11
5251820	1.97E-03	0.472335	5.41E+11	5304740	2.13E-03	0.510419	5.37E+11
5244960	1.98E-03	0.474731	5.40E+11	5291020	2.14E-03	0.512814	5.37E+11
5238100	1.99E-03	0.477126	5.39E+11	5277300	2.15E-03	0.51521	5.36E+11
5232220	2.00E-03	0.479521	5.37E+11	5265540	2.16E-03	0.517605	5.35E+11
5231240	2.00E-03	0.47976	5.36E+11	5252800	2.17E-03	0.52	5.35E+11
5225360	2.01E-03	0.482156	5.35E+11	5241040	2.18E-03	0.522395	5.35E+11
5218500	2.02E-03	0.484551	5.34E+11	5228300	2.19E-03	0.52479	5.34E+11
5211640	2.03E-03	0.486946	5.32E+11	5216540	2.20E-03	0.527186	5.33E+11
5204780	2.04E-03	0.489341	5.31E+11	5204780	2.21E-03	0.529581	5.33E+11
5197920	2.05E-03	0.491737	5.30E+11	5193020	2.22E-03	0.531976	5.32E+11
5192040	2.06E-03	0.494132	5.29E+11	5181260	2.23E-03	0.534371	5.31E+11
5185180	2.07E-03	0.496527	5.28E+11	5170480	2.24E-03	0.536766	5.31E+11
5180280	2.08E-03	0.498683	5.26E+11	5158720	2.25E-03	0.539162	5.30E+11
5174400	2.09E-03	0.500838	5.25E+11	5146960	2.26E-03	0.541557	5.30E+11
5167540	2.10E-03	0.503234	5.24E+11	5136180	2.27E-03	0.543952	5.30E+11
5160680	2.11E-03	0.505629	5.23E+11	5124420	2.28E-03	0.546347	5.29E+11
5154800	2.12E-03	0.508024	5.22E+11	5113640	2.29E-03	0.548743	5.28E+11
5147940	2.13E-03	0.510419	5.21E+11	5103840	2.30E-03	0.551138	5.28E+11
5141080	2.14E-03	0.512814	5.20E+11	5093060	2.31E-03	0.553533	5.27E+11
5134220	2.15E-03	0.51521	5.19E+11	5082280	2.32E-03	0.555928	5.27E+11

5127360	2.16E-03	0.517605	5.18E+11	5071500	2.33E-03	0.558323	5.26E+11
5120500	2.17E-03	0.52	5.17E+11	5061700	2.34E-03	0.560719	5.26E+11
5113640	2.18E-03	0.522395	5.15E+11	5050920	2.35E-03	0.563114	5.25E+11
5107760	2.19E-03	0.52479	5.14E+11	5041120	2.36E-03	0.565509	5.25E+11
5100900	2.20E-03	0.527186	5.13E+11	5031320	2.37E-03	0.567904	5.24E+11
5095020	2.21E-03	0.529581	5.12E+11	5021520	2.38E-03	0.570299	5.24E+11
5089140	2.22E-03	0.531976	5.12E+11	5012700	2.39E-03	0.572695	5.23E+11
5083260	2.23E-03	0.534371	5.11E+11	5005840	2.40E-03	0.574611	5.23E+11
5077380	2.24E-03	0.536766	5.10E+11	4996040	2.41E-03	0.577006	5.22E+11
5071500	2.25E-03	0.539162	5.09E+11	4986240	2.42E-03	0.579401	5.22E+11
5065620	2.26E-03	0.541557	5.08E+11	4977420	2.43E-03	0.581796	5.21E+11
5060720	2.27E-03	0.543713	5.07E+11	4968600	2.44E-03	0.584192	5.21E+11
5055820	2.28E-03	0.545629	5.06E+11	4959780	2.45E-03	0.586587	5.21E+11
5045040	2.29E-03	0.548024	5.05E+11	4950960	2.46E-03	0.588982	5.20E+11
5037200	2.30E-03	0.550419	5.04E+11	4942140	2.47E-03	0.591377	5.20E+11
5028380	2.31E-03	0.552814	5.03E+11	4933320	2.48E-03	0.593772	5.19E+11
5020540	2.32E-03	0.55521	5.03E+11	4924500	2.49E-03	0.596168	5.19E+11
5012700	2.33E-03	0.557605	5.02E+11	4916660	2.50E-03	0.598563	5.18E+11
5004860	2.34E-03	0.56	5.01E+11	4907840	2.51E-03	0.600958	5.18E+11
4998000	2.35E-03	0.562395	5.00E+11	4900000	2.52E-03	0.603353	5.17E+11
4991140	2.36E-03	0.56479	4.99E+11	4892160	2.53E-03	0.605749	5.17E+11
4984280	2.37E-03	0.567186	4.98E+11	4883340	2.54E-03	0.608144	5.16E+11
4977420	2.38E-03	0.569581	4.98E+11	4875500	2.55E-03	0.610539	5.16E+11
4971540	2.39E-03	0.571976	4.97E+11	4868640	2.56E-03	0.612934	5.16E+11
4964680	2.40E-03	0.574371	4.96E+11	4860800	2.57E-03	0.615329	5.15E+11
4958800	2.41E-03	0.576766	4.95E+11	4852960	2.58E-03	0.617725	5.15E+11
4952920	2.42E-03	0.579162	4.94E+11	4845120	2.59E-03	0.62012	5.14E+11
4947040	2.43E-03	0.581557	4.94E+11	4837280	2.60E-03	0.622515	5.14E+11
4941160	2.44E-03	0.583952	4.93E+11	4829440	2.61E-03	0.62491	5.13E+11
4935280	2.45E-03	0.586347	4.92E+11	4822580	2.62E-03	0.627305	5.13E+11
4929400	2.46E-03	0.588743	4.91E+11	4814740	2.63E-03	0.629701	5.12E+11
4923520	2.47E-03	0.591138	4.91E+11	4807880	2.64E-03	0.632096	5.12E+11
4917640	2.48E-03	0.593533	4.90E+11	4800040	2.65E-03	0.634491	5.12E+11
4912740	2.49E-03	0.595928	4.89E+11	4793180	2.66E-03	0.636886	5.11E+11
0	0.00E+00		0.00E+00	0	0.00E+00		0.00E+00
-7773.36	-1.00E-06	-0.00024	-8.07E+08	-7906.64	-1.00E-06	-0.00024	-7.92E+08
-15542.8	-2.00E-06	-0.000479	-1.61E+09	-15807.4	-2.00E-06	-0.000479	-1.58E+09
-23304.4	-3.00E-06	-0.000719	-2.42E+09	-23706.2	-3.00E-06	-0.000719	-2.37E+09

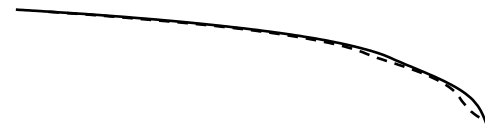




Bending moment x 10⁶

00479
07186
09581
11976
14371
16766
19162
21557
23952

-1.61E+
-2.42E+
-3.22E+
-4.03E+
-4.84E+
-5.64E+
-6.45E+
-7.25E+
-8.06E+



-853972	-1.10E-04	-0.026347	-8.86E+10	-868280	-1.10E-04	-0.026347	-8.70E+10
-931588	-1.20E-04	-0.028743	-9.66E+10	-946974	-1.20E-04	-0.028743	-9.49E+10
-1009400	-1.30E-04	-0.031138	-1.05E+11	-1026060	-1.30E-04	-0.031138	-1.03E+11
-1086820	-1.40E-04	-0.033533	-1.13E+11	-1104460	-1.40E-04	-0.033533	-1.11E+11
-1164240	-1.50E-04	-0.035928	-1.21E+11	-1182860	-1.50E-04	-0.035928	-1.19E+11
-1241660	-1.60E-04	-0.038323	-1.29E+11	-1262240	-1.60E-04	-0.038323	-1.27E+11
-1319080	-1.70E-04	-0.040719	-1.37E+11	-1340640	-1.70E-04	-0.040719	-1.34E+11
-1396500	-1.80E-04	-0.043114	-1.45E+11	-1419040	-1.80E-04	-0.043114	-1.42E+11
-1472940	-1.90E-04	-0.045509	-1.53E+11	-1497440	-1.90E-04	-0.045509	-1.50E+11
-1550360	-2.00E-04	-0.047904	-1.61E+11	-1575840	-2.00E-04	-0.047904	-1.58E+11
-1627780	-2.10E-04	-0.050299	-1.69E+11	-1655220	-2.10E-04	-0.050299	-1.66E+11
-1704220	-2.20E-04	-0.052695	-1.77E+11	-1733620	-2.20E-04	-0.052695	-1.74E+11
-1781640	-2.30E-04	-0.05509	-1.85E+11	-1812020	-2.30E-04	-0.05509	-1.82E+11
-1859060	-2.40E-04	-0.057485	-1.93E+11	-1890420	-2.40E-04	-0.057485	-1.89E+11
-1935500	-2.50E-04	-0.05988	-2.01E+11	-1968820	-2.50E-04	-0.05988	-1.97E+11
-2012920	-2.60E-04	-0.062275	-2.09E+11	-2047220	-2.60E-04	-0.062275	-2.05E+11
-2090340	-2.70E-04	-0.064671	-2.17E+11	-2124640	-2.70E-04	-0.064671	-2.13E+11
-2166780	-2.80E-04	-0.067066	-2.25E+11	-2203040	-2.80E-04	-0.067066	-2.21E+11
-2244200	-2.90E-04	-0.069461	-2.33E+11	-2281440	-2.90E-04	-0.069461	-2.29E+11
-2321620	-3.00E-04	-0.071856	-2.41E+11	-2359840	-3.00E-04	-0.071856	-2.37E+11
-2398060	-3.10E-04	-0.074251	-2.49E+11	-2438240	-3.10E-04	-0.074251	-2.44E+11
-2475480	-3.20E-04	-0.076647	-2.57E+11	-2516640	-3.20E-04	-0.076647	-2.52E+11
-2551920	-3.30E-04	-0.079042	-2.65E+11	-2595040	-3.30E-04	-0.079042	-2.60E+11
-2629340	-3.40E-04	-0.081437	-2.73E+11	-2672460	-3.40E-04	-0.081437	-2.68E+11
-2705780	-3.50E-04	-0.083832	-2.81E+11	-2750860	-3.50E-04	-0.083832	-2.76E+11
-2783200	-3.60E-04	-0.086228	-2.89E+11	-2829260	-3.60E-04	-0.086228	-2.84E+11
-2859640	-3.70E-04	-0.088623	-2.97E+11	-2907660	-3.70E-04	-0.088623	-2.92E+11
-2937060	-3.80E-04	-0.091018	-3.05E+11	-2985080	-3.80E-04	-0.091018	-2.99E+11
-3013500	-3.90E-04	-0.093413	-3.13E+11	-3063480	-3.90E-04	-0.093413	-3.07E+11
-3090920	-4.00E-04	-0.095808	-3.21E+11	-3141880	-4.00E-04	-0.095808	-3.15E+11
-3167360	-4.10E-04	-0.098204	-3.29E+11	-3219300	-4.10E-04	-0.098204	-3.23E+11
-3244780	-4.20E-04	-0.100599	-3.37E+11	-3297700	-4.20E-04	-0.100599	-3.31E+11
-3321220	-4.30E-04	-0.102994	-3.44E+11	-3375120	-4.30E-04	-0.102994	-3.39E+11
-3397660	-4.40E-04	-0.105389	-3.52E+11	-3453520	-4.40E-04	-0.105389	-3.46E+11
-3475080	-4.50E-04	-0.107784	-3.60E+11	-3530940	-4.50E-04	-0.107784	-3.54E+11
-3551520	-4.60E-04	-0.11018	-3.68E+11	-3609340	-4.60E-04	-0.11018	-3.62E+11

-3626980	-4.70E-04	-0.112575	-3.76E+11	-3686760	-4.70E-04	-0.112575	-3.70E+11
-3703420	-4.80E-04	-0.11497	-3.84E+11	-3765160	-4.80E-04	-0.11497	-3.77E+11
-3779860	-4.90E-04	-0.117365	-3.92E+11	-3842580	-4.90E-04	-0.117365	-3.85E+11
-3855320	-5.00E-04	-0.11976	-4.00E+11	-3920000	-5.00E-04	-0.11976	-3.93E+11
-3929800	-5.10E-04	-0.122156	-4.08E+11	-3997420	-5.10E-04	-0.122156	-4.01E+11
-4005260	-5.20E-04	-0.124551	-4.16E+11	-4074840	-5.20E-04	-0.124551	-4.08E+11
-4079740	-5.30E-04	-0.126946	-4.24E+11	-4151280	-5.30E-04	-0.126946	-4.16E+11
-4154220	-5.40E-04	-0.129341	-4.31E+11	-4227720	-5.40E-04	-0.129341	-4.23E+11
-4228700	-5.50E-04	-0.131737	-4.39E+11	-4304160	-5.50E-04	-0.131737	-4.31E+11
-4303180	-5.60E-04	-0.134132	-4.47E+11	-4379620	-5.60E-04	-0.134132	-4.38E+11
-4376680	-5.70E-04	-0.136527	-4.55E+11	-4455080	-5.70E-04	-0.136527	-4.46E+11
-4450180	-5.80E-04	-0.138922	-4.62E+11	-4530540	-5.80E-04	-0.138922	-4.53E+11
-4522700	-5.90E-04	-0.141317	-4.70E+11	-4606000	-5.90E-04	-0.141317	-4.61E+11
-4566800	-5.96E-04	-0.142802	-4.78E+11	-4680480	-6.00E-04	-0.143713	-4.63E+11
-4638340	-6.06E-04	-0.145198	-4.85E+11	-4754960	-6.10E-04	-0.146108	-4.70E+11
-4688320	-6.13E-04	-0.146874	-4.93E+11	-4828460	-6.20E-04	-0.148503	-4.74E+11
-4757900	-6.23E-04	-0.149269	-5.00E+11	-4901960	-6.30E-04	-0.150898	-4.81E+11
-4778480	-6.26E-04	-0.150012	-5.08E+11	-4974480	-6.40E-04	-0.153293	-4.83E+11
-4819640	-6.33E-04	-0.151497	-5.09E+11	-4986240	-6.42E-04	-0.153677	-4.87E+11
-4861780	-6.39E-04	-0.153102	-5.16E+11	-5057780	-6.52E-04	-0.156072	-4.91E+11
-4886280	-6.45E-04	-0.154443	-5.23E+11	-5129320	-6.62E-04	-0.158467	-4.93E+11
-4921560	-6.55E-04	-0.156838	-5.27E+11	-5166560	-6.67E-04	-0.159737	-4.96E+11
-4931360	-6.58E-04	-0.157509	-5.34E+11	-5236140	-6.77E-04	-0.162132	-4.99E+11
-4949000	-6.63E-04	-0.15885	-5.38E+11	-5275340	-6.83E-04	-0.163521	-5.02E+11
-4969580	-6.71E-04	-0.160647	-5.44E+11	-5327280	-6.91E-04	-0.165389	-5.02E+11
-4984280	-6.76E-04	-0.16194	-5.48E+11	-5369420	-6.97E-04	-0.166994	-5.03E+11
-5007800	-6.86E-04	-0.164335	-5.52E+11	-5406660	-7.05E-04	-0.16891	-5.05E+11
-5015640	-6.89E-04	-0.165126	-5.53E+11	-5423320	-7.12E-04	-0.170539	-5.06E+11
-5026420	-6.95E-04	-0.166419	-5.54E+11	-5427240	-7.18E-04	-0.171928	-5.06E+11
-5037200	-7.00E-04	-0.167593	-5.54E+11	-5426260	-7.26E-04	-0.173772	-5.07E+11
-5057780	-7.10E-04	-0.169988	-5.53E+11	-5423320	-7.31E-04	-0.17497	-5.09E+11
-5071500	-7.18E-04	-0.17188	-5.52E+11	-5410580	-7.41E-04	-0.177365	-5.09E+11
-5083260	-7.26E-04	-0.173916	-5.50E+11	-5391960	-7.51E-04	-0.17976	-5.10E+11
-5086200	-7.34E-04	-0.175856	-5.50E+11	-5390980	-7.51E-04	-0.179832	-5.11E+11
-5081300	-7.41E-04	-0.177389	-5.48E+11	-5371380	-7.61E-04	-0.182228	-5.11E+11
-5066600	-7.49E-04	-0.179497	-5.47E+11	-5358640	-7.67E-04	-0.183737	-5.11E+11
-5050920	-7.56E-04	-0.181006	-5.44E+11	-5331200	-7.77E-04	-0.186132	-5.10E+11
-5022500	-7.66E-04	-0.183401	-5.41E+11	-5299840	-7.87E-04	-0.188527	-5.08E+11
-5011720	-7.70E-04	-0.184431	-5.40E+11	-5295920	-7.88E-04	-0.188743	-5.06E+11
-4987220	-7.80E-04	-0.186731	-5.36E+11	-5248880	-7.98E-04	-0.191138	-5.02E+11
-4966640	-7.90E-04	-0.189126	-5.36E+11	-5247900	-7.98E-04	-0.191186	-5.02E+11
-4962720	-7.93E-04	-0.18982	-5.32E+11	-5212620	-8.04E-04	-0.192479	-5.00E+11
-4946060	-8.03E-04	-0.192216	-5.24E+11	-5133240	-8.14E-04	-0.194874	-4.99E+11
-4944100	-8.05E-04	-0.19279	-5.13E+11	-5027400	-8.24E-04	-0.197269	-4.98E+11
-4933320	-8.14E-04	-0.19485	-5.05E+11	-4944100	-8.31E-04	-0.198994	-4.96E+11

-4921560	-8.22E-04	-0.196958	-4.94E+11	-4837280	-8.41E-04	-0.201389	-4.96E+11
-4909800	-8.30E-04	-0.198778	-4.84E+11	-4745160	-8.51E-04	-0.203784	-4.95E+11
-4899020	-8.37E-04	-0.200479	-4.76E+11	-4667740	-8.61E-04	-0.20618	-4.95E+11
-4882360	-8.47E-04	-0.202874	-4.70E+11	-4606980	-8.71E-04	-0.208575	-4.94E+11
-4875500	-8.51E-04	-0.203904	-4.68E+11	-4589340	-8.74E-04	-0.209365	-4.93E+11
-4854920	-8.61E-04	-0.206299	-4.64E+11	-4543280	-8.84E-04	-0.21176	-4.92E+11
-4830420	-8.71E-04	-0.208695	-4.59E+11	-4501140	-8.94E-04	-0.214156	-4.91E+11
-4802980	-8.81E-04	-0.21109	-4.56E+11	-4465860	-9.04E-04	-0.216551	-4.89E+11
-4796120	-8.84E-04	-0.211713	-4.53E+11	-4434500	-9.14E-04	-0.218946	-4.89E+11
-4766720	-8.93E-04	-0.213988	-4.49E+11	-4404120	-9.24E-04	-0.221341	-4.87E+11
-4724580	-9.03E-04	-0.216383	-4.47E+11	-4377660	-9.34E-04	-0.223737	-4.85E+11
-4686360	-9.12E-04	-0.218491	-4.44E+11	-4352180	-9.44E-04	-0.226132	-4.82E+11
-4658920	-9.18E-04	-0.219976	-4.42E+11	-4328660	-9.54E-04	-0.228527	-4.81E+11
-4608940	-9.28E-04	-0.222371	-4.40E+11	-4307100	-9.64E-04	-0.230922	-4.78E+11
-4598160	-9.31E-04	-0.222898	-4.37E+11	-4285540	-9.74E-04	-0.233317	-4.78E+11
-4539360	-9.41E-04	-0.225293	-4.35E+11	-4263980	-9.84E-04	-0.235713	-4.73E+11
-4489380	-9.51E-04	-0.227689	-4.33E+11	-4245360	-9.94E-04	-0.238108	-4.70E+11
-4447240	-9.61E-04	-0.230084	-4.31E+11	-4225760	-1.00E-03	-0.240479	-4.67E+11
-4410980	-9.71E-04	-0.232479	-4.29E+11	-4207140	-1.01E-03	-0.242874	-4.65E+11
-4410980	-9.71E-04	-0.232503	-4.27E+11	-4188520	-1.02E-03	-0.245269	-4.61E+11
-4378640	-9.81E-04	-0.234898	-4.26E+11	-4171860	-1.03E-03	-0.247665	-4.55E+11
-4352180	-9.91E-04	-0.237293	-4.24E+11	-4154220	-1.04E-03	-0.25006	-4.50E+11
-4326700	-1.00E-03	-0.23976	-4.22E+11	-4137560	-1.05E-03	-0.252455	-4.46E+11
-4303180	-1.01E-03	-0.242156	-4.21E+11	-4120900	-1.06E-03	-0.25485	-4.43E+11
-4298280	-1.01E-03	-0.242635	-4.19E+11	-4105220	-1.07E-03	-0.257246	-4.42E+11
-4283580	-1.02E-03	-0.244311	-4.17E+11	-4088560	-1.08E-03	-0.259641	-4.39E+11
-4263000	-1.03E-03	-0.246707	-4.16E+11	-4072880	-1.09E-03	-0.262036	-4.36E+11
-4243400	-1.04E-03	-0.249102	-4.14E+11	-4057200	-1.10E-03	-0.264431	-4.34E+11
-4230660	-1.05E-03	-0.250778	-4.12E+11	-4041520	-1.11E-03	-0.266826	-4.32E+11
-4213020	-1.06E-03	-0.253174	-4.11E+11	-4025840	-1.12E-03	-0.269222	-4.30E+11
-4195380	-1.07E-03	-0.255569	-4.09E+11	-4010160	-1.13E-03	-0.271617	-4.30E+11
-4178720	-1.08E-03	-0.257964	-4.08E+11	-3994480	-1.14E-03	-0.274012	-4.28E+11
-4163040	-1.09E-03	-0.260359	-4.06E+11	-3978800	-1.15E-03	-0.276407	-4.26E+11
-4147360	-1.10E-03	-0.262754	-4.05E+11	-3964100	-1.16E-03	-0.278802	-4.24E+11
-4132660	-1.11E-03	-0.26515	-4.03E+11	-3948420	-1.17E-03	-0.281198	-4.24E+11
-4117960	-1.12E-03	-0.267545	-4.01E+11	-3931760	-1.18E-03	-0.283593	-4.22E+11
-4103260	-1.13E-03	-0.26994	-4.00E+11	-3916080	-1.19E-03	-0.285988	-4.20E+11
-4089540	-1.14E-03	-0.272335	-3.98E+11	-3900400	-1.20E-03	-0.288383	-4.19E+11
-4076800	-1.15E-03	-0.274731	-3.96E+11	-3883740	-1.21E-03	-0.290778	-4.17E+11
-4063080	-1.16E-03	-0.277126	-3.95E+11	-3867080	-1.22E-03	-0.293174	-4.16E+11
-4050340	-1.17E-03	-0.279521	-3.93E+11	-3849440	-1.23E-03	-0.295569	-4.14E+11
-4037600	-1.18E-03	-0.281916	-3.91E+11	-3833760	-1.24E-03	-0.297964	-4.13E+11
-4024860	-1.19E-03	-0.284311	-3.90E+11	-3818080	-1.25E-03	-0.300359	-4.11E+11
-4012120	-1.20E-03	-0.286707	-3.89E+11	-3809260	-1.26E-03	-0.301796	-4.10E+11
-3999380	-1.21E-03	-0.289102	-3.87E+11	-3794560	-1.27E-03	-0.304192	-4.09E+11

-3987620	-1.22E-03	-0.291497	-3.86E+11	-3781820	-1.28E-03	-0.306587	-4.07E+11
-3974880	-1.23E-03	-0.293892	-3.85E+11	-3769080	-1.29E-03	-0.308982	-4.06E+11
-3963120	-1.24E-03	-0.296287	-3.83E+11	-3757320	-1.30E-03	-0.311377	-4.05E+11
-3950380	-1.25E-03	-0.298683	-3.82E+11	-3745560	-1.31E-03	-0.313772	-4.04E+11
-3937640	-1.26E-03	-0.301078	-3.81E+11	-3733800	-1.32E-03	-0.316168	-4.02E+11
-3925880	-1.27E-03	-0.303473	-3.80E+11	-3724000	-1.33E-03	-0.318563	-4.01E+11
-3913140	-1.28E-03	-0.305868	-3.79E+11	-3713220	-1.34E-03	-0.320958	-4.00E+11
-3899420	-1.29E-03	-0.308263	-3.78E+11	-3703420	-1.35E-03	-0.323353	-3.99E+11
-3885700	-1.30E-03	-0.310659	-3.77E+11	-3693620	-1.36E-03	-0.325749	-3.97E+11
-3871980	-1.31E-03	-0.313054	-3.76E+11	-3683820	-1.37E-03	-0.328144	-3.96E+11
-3857280	-1.32E-03	-0.315449	-3.75E+11	-3674020	-1.38E-03	-0.330539	-3.95E+11
-3841600	-1.33E-03	-0.317844	-3.74E+11	-3665200	-1.39E-03	-0.332934	-3.94E+11
-3826900	-1.34E-03	-0.32024	-3.73E+11	-3656380	-1.40E-03	-0.335329	-3.92E+11
-3811220	-1.35E-03	-0.322635	-3.72E+11	-3647560	-1.41E-03	-0.337725	-3.91E+11
-3798480	-1.36E-03	-0.32503	-3.71E+11	-3639720	-1.42E-03	-0.34012	-3.89E+11
-3784760	-1.37E-03	-0.327425	-3.71E+11	-3630900	-1.43E-03	-0.342515	-3.88E+11
-3771040	-1.38E-03	-0.32982	-3.70E+11	-3623060	-1.44E-03	-0.34491	-3.87E+11
-3759280	-1.39E-03	-0.332216	-3.69E+11	-3614240	-1.45E-03	-0.347305	-3.85E+11
-3748500	-1.40E-03	-0.334611	-3.68E+11	-3607380	-1.46E-03	-0.349701	-3.83E+11
-3737720	-1.41E-03	-0.337006	-3.67E+11	-3599540	-1.47E-03	-0.352096	-3.82E+11
-3727920	-1.42E-03	-0.339401	-3.67E+11	-3591700	-1.48E-03	-0.354491	-3.81E+11
-3718120	-1.43E-03	-0.341796	-3.66E+11	-3584840	-1.49E-03	-0.356886	-3.79E+11
-3708320	-1.44E-03	-0.344192	-3.65E+11	-3577000	-1.50E-03	-0.359281	-3.78E+11
-3699500	-1.45E-03	-0.346587	-3.64E+11	-3570140	-1.51E-03	-0.361677	-3.77E+11
-3690680	-1.46E-03	-0.348982	-3.64E+11	-3563280	-1.52E-03	-0.364072	-3.76E+11
-3681860	-1.47E-03	-0.351377	-3.63E+11	-3556420	-1.53E-03	-0.366467	-3.75E+11
-3674020	-1.48E-03	-0.353772	-3.62E+11	-3549560	-1.54E-03	-0.368862	-3.74E+11
-3665200	-1.49E-03	-0.356168	-3.62E+11	-3542700	-1.55E-03	-0.371257	-3.73E+11
-3657360	-1.50E-03	-0.358563	-3.61E+11	-3536820	-1.56E-03	-0.373653	-3.72E+11
-3653440	-1.50E-03	-0.36	-3.60E+11	-3530940	-1.57E-03	-0.376048	-3.71E+11
-3645600	-1.51E-03	-0.362395	-3.60E+11	-3524080	-1.58E-03	-0.378443	-3.70E+11
-3637760	-1.52E-03	-0.36479	-3.59E+11	-3518200	-1.59E-03	-0.380838	-3.69E+11
-3629920	-1.53E-03	-0.367186	-3.58E+11	-3512320	-1.60E-03	-0.383234	-3.69E+11
-3623060	-1.54E-03	-0.369581	-3.58E+11	-3505460	-1.61E-03	-0.385629	-3.68E+11
-3615220	-1.55E-03	-0.371976	-3.57E+11	-3499580	-1.62E-03	-0.388024	-3.67E+11
-3608360	-1.56E-03	-0.374371	-3.57E+11	-3494680	-1.63E-03	-0.390419	-3.66E+11
-3601500	-1.57E-03	-0.376766	-3.56E+11	-3488800	-1.64E-03	-0.392814	-3.66E+11
-3594640	-1.58E-03	-0.379162	-3.55E+11	-3482920	-1.65E-03	-0.39521	-3.65E+11
-3587780	-1.59E-03	-0.381557	-3.55E+11	-3477040	-1.66E-03	-0.397605	-3.65E+11
-3581900	-1.60E-03	-0.383952	-3.54E+11	-3472140	-1.67E-03	-0.4	-3.64E+11
-3575040	-1.61E-03	-0.386347	-3.54E+11	-3466260	-1.68E-03	-0.402395	-3.63E+11
-3569160	-1.62E-03	-0.388743	-3.53E+11	-3461360	-1.69E-03	-0.40479	-3.62E+11
-3562300	-1.63E-03	-0.391138	-3.53E+11	-3455480	-1.70E-03	-0.407186	-3.62E+11
-3557400	-1.64E-03	-0.393293	-3.52E+11	-3450580	-1.71E-03	-0.409581	-3.61E+11
-3550540	-1.65E-03	-0.395689	-3.52E+11	-3445680	-1.72E-03	-0.411976	-3.60E+11

-3544660	-1.66E-03	-0.398084	-3.51E+11	-3440780	-1.73E-03	-0.414371	-3.60E+11
-3538780	-1.67E-03	-0.400479	-3.51E+11	-3435880	-1.74E-03	-0.416766	-3.59E+11
-3532900	-1.68E-03	-0.402874	-3.50E+11	-3430980	-1.75E-03	-0.419162	-3.58E+11
-3527020	-1.69E-03	-0.405269	-3.50E+11	-3426080	-1.76E-03	-0.421557	-3.58E+11
-3522120	-1.70E-03	-0.407665	-3.49E+11	-3421180	-1.77E-03	-0.423952	-3.57E+11
-3516240	-1.71E-03	-0.41006	-3.49E+11	-3416280	-1.78E-03	-0.426347	-3.56E+11
-3511340	-1.72E-03	-0.412455	-3.48E+11	-3411380	-1.79E-03	-0.428743	-3.56E+11
-3505460	-1.73E-03	-0.41485	-3.48E+11	-3406480	-1.80E-03	-0.431138	-3.55E+11
-3500560	-1.74E-03	-0.417246	-3.47E+11	-3402560	-1.81E-03	-0.433533	-3.55E+11
-3494680	-1.75E-03	-0.419641	-3.47E+11	-3397660	-1.82E-03	-0.435928	-3.54E+11
-3489780	-1.76E-03	-0.422036	-3.46E+11	-3392760	-1.83E-03	-0.438323	-3.54E+11
-3484880	-1.77E-03	-0.424431	-3.46E+11	-3388840	-1.84E-03	-0.440719	-3.53E+11
-3479000	-1.78E-03	-0.426826	-3.45E+11	-3383940	-1.85E-03	-0.443114	-3.52E+11
-3475080	-1.79E-03	-0.429222	-3.45E+11	-3380020	-1.86E-03	-0.445509	-3.52E+11
-3470180	-1.80E-03	-0.431617	-3.45E+11	-3376100	-1.87E-03	-0.447904	-3.51E+11
-3465280	-1.81E-03	-0.434012	-3.44E+11	-3371200	-1.88E-03	-0.450299	-3.51E+11
-3460380	-1.82E-03	-0.436407	-3.44E+11	-3367280	-1.89E-03	-0.452695	-3.50E+11
-3455480	-1.83E-03	-0.438802	-3.43E+11	-3363360	-1.90E-03	-0.45509	-3.50E+11
-3450580	-1.84E-03	-0.441198	-3.43E+11	-3358460	-1.91E-03	-0.457485	-3.49E+11
-3446660	-1.85E-03	-0.443593	-3.42E+11	-3354540	-1.92E-03	-0.45988	-3.49E+11
-3441760	-1.86E-03	-0.445988	-3.42E+11	-3350620	-1.93E-03	-0.462275	-3.49E+11
-3436860	-1.87E-03	-0.448383	-3.42E+11	-3346700	-1.94E-03	-0.464431	-3.48E+11
-3432940	-1.88E-03	-0.450778	-3.41E+11	-3342780	-1.95E-03	-0.466826	-3.48E+11
-3428040	-1.89E-03	-0.453174	-3.41E+11	-3338860	-1.96E-03	-0.469222	-3.47E+11
-3425100	-1.90E-03	-0.45485	-3.40E+11	-3334940	-1.97E-03	-0.471617	-3.47E+11
-3421180	-1.91E-03	-0.457246	-3.40E+11	-3331020	-1.98E-03	-0.474012	-3.46E+11
-3416280	-1.92E-03	-0.459641	-3.40E+11	-3327100	-1.99E-03	-0.476407	-3.46E+11
-3412360	-1.93E-03	-0.462036	-3.39E+11	-3323180	-2.00E-03	-0.478802	-3.46E+11
-3408440	-1.94E-03	-0.464431	-3.39E+11	-3319260	-2.01E-03	-0.481198	-3.45E+11
-3404520	-1.95E-03	-0.466826	-3.38E+11	-3315340	-2.02E-03	-0.483593	-3.45E+11
-3400600	-1.96E-03	-0.469222	-3.38E+11	-3311420	-2.03E-03	-0.485988	-3.44E+11
-3395700	-1.97E-03	-0.471617	-3.38E+11	-3307500	-2.04E-03	-0.488383	-3.44E+11
-3391780	-1.98E-03	-0.474012	-3.37E+11	-3304560	-2.05E-03	-0.490778	-3.43E+11
-3387860	-1.99E-03	-0.476407	-3.37E+11	-3300640	-2.06E-03	-0.493174	-3.43E+11
-3383940	-2.00E-03	-0.478802	-3.36E+11	-3296720	-2.07E-03	-0.495569	-3.43E+11
-3380020	-2.01E-03	-0.481198	-3.36E+11	-3292800	-2.08E-03	-0.497964	-3.42E+11
-3377080	-2.02E-03	-0.483593	-3.36E+11	-3289860	-2.09E-03	-0.500359	-3.42E+11
-3373160	-2.03E-03	-0.485988	-3.35E+11	-3285940	-2.10E-03	-0.502754	-3.41E+11
-3369240	-2.04E-03	-0.488383	-3.35E+11	-3282020	-2.11E-03	-0.50515	-3.41E+11
-3365320	-2.05E-03	-0.490778	-3.35E+11	-3279080	-2.12E-03	-0.507545	-3.40E+11
-3361400	-2.06E-03	-0.493174	-3.34E+11	-3275160	-2.13E-03	-0.50994	-3.40E+11
-3358460	-2.07E-03	-0.495569	-3.34E+11	-3272220	-2.14E-03	-0.512335	-3.40E+11
-3354540	-2.08E-03	-0.497964	-3.34E+11	-3268300	-2.15E-03	-0.514731	-3.39E+11
-3350620	-2.09E-03	-0.500359	-3.33E+11	-3265360	-2.16E-03	-0.517126	-3.39E+11
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-3343760 -2.11E-03 -0.50515	-3.33E+11 -3258500 -2.18E-03 -0.521916	-3.38E+11
-3339840 -2.12E-03 -0.507545	-3.32E+11 -3255560 -2.19E-03 -0.524311	-3.38E+11
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-3332980 -2.14E-03 -0.512335	-3.32E+11 -3248700 -2.21E-03 -0.529102	-3.37E+11
-3330040 -2.15E-03 -0.514731	-3.31E+11 -3247720 -2.21E-03 -0.529581	-3.37E+11
-3326120 -2.16E-03 -0.517126	-3.31E+11 -3244780 -2.22E-03 -0.531976	-3.36E+11
-3323180 -2.17E-03 -0.519521	-3.31E+11 -3241840 -2.23E-03 -0.534371	-3.36E+11
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-3316320 -2.19E-03 -0.524311	-3.30E+11 -3234980 -2.25E-03 -0.539162	-3.35E+11
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-3306520 -2.22E-03 -0.531497	-3.29E+11 -3226160 -2.28E-03 -0.546347	-3.34E+11
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-3296720 -2.25E-03 -0.538683	-3.28E+11 -3217340 -2.31E-03 -0.553533	-3.33E+11
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-3285940 -2.28E-03 -0.546826	-3.27E+11 -3204600 -2.35E-03 -0.563114	-3.32E+11
-3283000 -2.29E-03 -0.549222	-3.27E+11 -3201660 -2.36E-03 -0.565509	-3.32E+11
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-3252620 -2.39E-03 -0.573174	-3.24E+11 -3174220 -2.46E-03 -0.589461	-3.29E+11
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-3201660	-2.57E-03	-0.61485	-3.19E+11	-3127180	-2.64E-03	-0.632575	-3.23E+11
-3198720	-2.58E-03	-0.617246	-3.19E+11	-3125220	-2.65E-03	-0.63497	-3.23E+11
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-3173240	-2.67E-03	-0.638802	-3.17E+11	-3103660	-2.74E-03	-0.656527	-3.20E+11
-3171280	-2.68E-03	-0.641198	-3.17E+11	-3101700	-2.75E-03	-0.658922	-3.20E+11
-3168340	-2.69E-03	-0.643593	-3.16E+11	-3099740	-2.76E-03	-0.661317	-3.20E+11
-3165400	-2.70E-03	-0.645988	-3.16E+11	-3096800	-2.77E-03	-0.663713	-3.19E+11
-3163440	-2.71E-03	-0.648383	-3.16E+11	-3094840	-2.78E-03	-0.666108	-3.19E+11
-3160500	-2.72E-03	-0.650778	-3.16E+11	-3092880	-2.79E-03	-0.668503	-3.19E+11
-3157560	-2.73E-03	-0.653174	-3.15E+11	-3089940	-2.80E-03	-0.670898	-3.19E+11

lk Carrier (B1) Idchk = 2

70% damage

4.175 9.80E-06 1000

Rotation Curvature

7761.6	1.00E-06	0.00024
15513.4	2.00E-06	0.000479
23275	3.00E-06	0.000719
31026.8	4.00E-06	0.000958
38788.4	5.00E-06	0.001198
46540.2	6.00E-06	0.001437
54301.8	7.00E-06	0.001677
62053.6	8.00E-06	0.001916
69815.2	9.00E-06	0.002156
77567	1.00E-05	0.002395
155134	2.00E-05	0.00479
232652	3.00E-05	0.007186
310268	4.00E-05	0.009581
387786	5.00E-05	0.011976
465402	6.00E-05	0.014371
542920	7.00E-05	0.016766
620536	8.00E-05	0.019162
698054	9.00E-05	0.021557
775670	1.00E-04	0.023952
853188	1.10E-04	0.026347
930804	1.20E-04	0.028743
1008420	1.30E-04	0.031138
1085840	1.40E-04	0.033533
1163260	1.50E-04	0.035928
1240680	1.60E-04	0.038323
1318100	1.70E-04	0.040719
1396500	1.80E-04	0.043114
1473920	1.90E-04	0.045509
1551340	2.00E-04	0.047904
1628760	2.10E-04	0.050299
1706180	2.20E-04	0.052695
1783600	2.30E-04	0.05509
1861020	2.40E-04	0.057485
1938440	2.50E-04	0.05988
2015860	2.60E-04	0.062275
2093280	2.70E-04	0.064671
2170700	2.80E-04	0.067066
2248120	2.90E-04	0.069461
2326520	3.00E-04	0.071856
2403940	3.10E-04	0.074251

2481360	3.20E-04	0.076647
2558780	3.30E-04	0.079042
2636200	3.40E-04	0.081437
2713620	3.50E-04	0.083832
2791040	3.60E-04	0.086228
2868460	3.70E-04	0.088623
2945880	3.80E-04	0.091018
3023300	3.90E-04	0.093413
3100720	4.00E-04	0.095808
3178140	4.10E-04	0.098204
3255560	4.20E-04	0.100599
3332980	4.30E-04	0.102994
3410400	4.40E-04	0.105389
3487820	4.50E-04	0.107784
3565240	4.60E-04	0.11018
3642660	4.70E-04	0.112575
3720080	4.80E-04	0.11497
3797500	4.90E-04	0.117365
3874920	5.00E-04	0.11976
3952340	5.10E-04	0.122156
4029760	5.20E-04	0.124551
4107180	5.30E-04	0.126946
4184600	5.40E-04	0.129341
4262020	5.50E-04	0.131737
4339440	5.60E-04	0.134132
4416860	5.70E-04	0.136527
4493300	5.80E-04	0.138922
4570720	5.90E-04	0.141317
4647160	6.00E-04	0.143713
4724580	6.10E-04	0.146108
4801020	6.20E-04	0.148503
4877460	6.30E-04	0.150898
4953900	6.40E-04	0.153293
5009760	6.47E-04	0.155066
5068560	6.55E-04	0.15691
5119520	6.63E-04	0.158683
5177340	6.73E-04	0.161078
5212620	6.79E-04	0.162587
5268480	6.89E-04	0.164934
5305720	6.95E-04	0.166563
5338060	7.01E-04	0.167952
5369420	7.07E-04	0.169365
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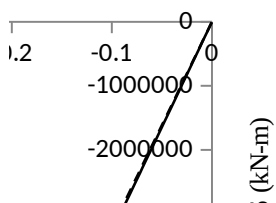
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5793760	8.12E-04	0.194419
5817280	8.22E-04	0.19679
5839820	8.32E-04	0.199186
5845700	8.34E-04	0.199737
5863340	8.44E-04	0.202132
5871180	8.48E-04	0.203138
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5894700	8.63E-04	0.206611
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5915280	8.79E-04	0.210515
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5950560	9.16E-04	0.219281
5952520	9.17E-04	0.219689
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5960360	9.30E-04	0.222635
5964280	9.37E-04	0.224335
5968200	9.47E-04	0.226731
5969180	9.49E-04	0.227329
5971140	9.59E-04	0.229725
5971140	9.60E-04	0.229964
5972120	9.70E-04	0.232359
5972120	9.72E-04	0.232719
5973100	9.82E-04	0.235114
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5971140	1.01E-03	0.241437
5970160	1.01E-03	0.242635
5968200	1.02E-03	0.24503
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5966240	1.04E-03	0.248144

5965260	1.04E-03	0.249341
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5957420	1.06E-03	0.254132
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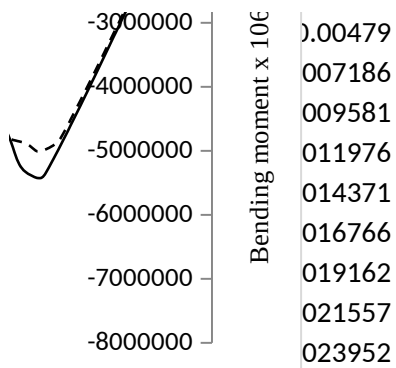
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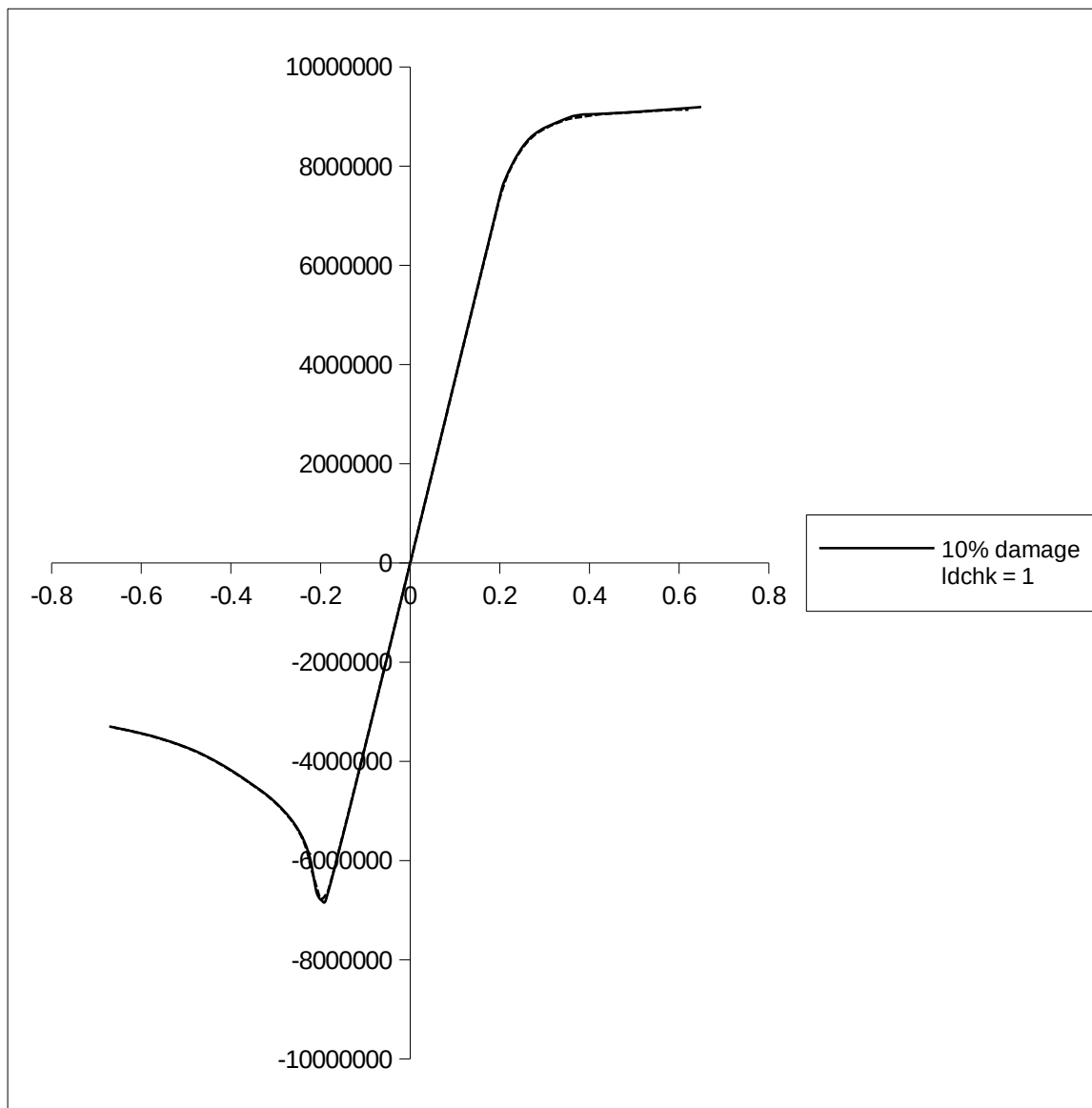
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-3150700 -2.57E-03 -0.61485
-3147760 -2.58E-03 -0.617246
-3144820 -2.59E-03 -0.619641
-3141880 -2.60E-03 -0.622036
-3138940 -2.61E-03 -0.624431
-3137960 -2.61E-03 -0.625868
-3135020 -2.62E-03 -0.628263
-3132080 -2.63E-03 -0.630659
-3130120 -2.64E-03 -0.633054
-3127180 -2.65E-03 -0.635449
-3124240 -2.66E-03 -0.637844
-3121300 -2.67E-03 -0.64024

Bulk Carrier (B4) Idchk = 1				Bulk Carrier (B4) Idchk = 2			
10% damage				10% damage			
frame spa	4.175	9.80E-06	1000	frame spa	4.175	9.80E-06	1000
Moment	Rotation Curvature			Moment	Rotation Curvature		
9.07E+08	8885.66	1.00E-06	0.00024	9.05E+08	8864.1	1.00E-06	0.00024
1.81E+09	17747.8	2.00E-06	0.000479	1.81E+09	17708.6	2.00E-06	0.000479
2.72E+09	26616.8	3.00E-06	0.000719	2.71E+09	26548.2	3.00E-06	0.000719



2.17E+11	2127580	2.40E-04	0.057485	2.17E+11	2121700	2.40E-04	0.057485
2.26E+11	2215780	2.50E-04	0.05988	2.26E+11	2209900	2.50E-04	0.05988
2.35E+11	2304960	2.60E-04	0.062275	2.35E+11	2299080	2.60E-04	0.062275
2.44E+11	2393160	2.70E-04	0.064671	2.44E+11	2387280	2.70E-04	0.064671
2.53E+11	2481360	2.80E-04	0.067066	2.53E+11	2475480	2.80E-04	0.067066
2.62E+11	2570540	2.90E-04	0.069461	2.62E+11	2563680	2.90E-04	0.069461
2.71E+11	2658740	3.00E-04	0.071856	2.71E+11	2651880	3.00E-04	0.071856
2.80E+11	2746940	3.10E-04	0.074251	2.80E+11	2740080	3.10E-04	0.074251

2.89E+11	2836120	3.20E-04	0.076647
2.98E+11	2924320	3.30E-04	0.079042
3.07E+11	3012520	3.40E-04	0.081437
3.17E+11	3101700	3.50E-04	0.083832
3.26E+11	3189900	3.60E-04	0.086228
3.35E+11	3278100	3.70E-04	0.088623
3.44E+11	3367280	3.80E-04	0.091018
3.53E+11	3455480	3.90E-04	0.093413
3.62E+11	3543680	4.00E-04	0.095808
3.71E+11	3632860	4.10E-04	0.098204
3.80E+11	3721060	4.20E-04	0.100599
3.89E+11	3809260	4.30E-04	0.102994
3.98E+11	3898440	4.40E-04	0.105389
4.07E+11	3986640	4.50E-04	0.107784
4.16E+11	4074840	4.60E-04	0.11018
4.25E+11	4163040	4.70E-04	0.112575
4.34E+11	4252220	4.80E-04	0.11497
4.43E+11	4340420	4.90E-04	0.117365
4.52E+11	4428620	5.00E-04	0.11976
4.61E+11	4517800	5.10E-04	0.122156
4.70E+11	4606000	5.20E-04	0.124551
4.79E+11	4694200	5.30E-04	0.126946
4.88E+11	4782400	5.40E-04	0.129341
4.97E+11	4871580	5.50E-04	0.131737
5.06E+11	4959780	5.60E-04	0.134132
5.15E+11	5047980	5.70E-04	0.136527
5.24E+11	5136180	5.80E-04	0.138922
5.33E+11	5225360	5.90E-04	0.141317
5.42E+11	5313560	6.00E-04	0.143713
5.51E+11	5401760	6.10E-04	0.146108
5.60E+11	5489960	6.20E-04	0.148503
5.69E+11	5578160	6.30E-04	0.150898
5.78E+11	5667340	6.40E-04	0.153293
5.87E+11	5755540	6.50E-04	0.155689
5.96E+11	5843740	6.60E-04	0.158084
6.05E+11	5931940	6.70E-04	0.160479
6.14E+11	6020140	6.80E-04	0.162874
6.23E+11	6109320	6.90E-04	0.165269
6.32E+11	6197520	7.00E-04	0.167665
6.41E+11	6285720	7.10E-04	0.17006
6.50E+11	6373920	7.20E-04	0.172455
6.59E+11	6462120	7.30E-04	0.17485
6.68E+11	6550320	7.40E-04	0.177246
6.78E+11	6639500	7.50E-04	0.179641
6.87E+11	6727700	7.60E-04	0.182036

2.89E+11	2828280	3.20E-04	0.076647
2.98E+11	2916480	3.30E-04	0.079042
3.07E+11	3005660	3.40E-04	0.081437
3.16E+11	3093860	3.50E-04	0.083832
3.25E+11	3182060	3.60E-04	0.086228
3.34E+11	3270260	3.70E-04	0.088623
3.43E+11	3358460	3.80E-04	0.091018
3.52E+11	3446660	3.90E-04	0.093413
3.61E+11	3534860	4.00E-04	0.095808
3.70E+11	3623060	4.10E-04	0.098204
3.79E+11	3711260	4.20E-04	0.100599
3.88E+11	3799460	4.30E-04	0.102994
3.97E+11	3887660	4.40E-04	0.105389
4.06E+11	3975860	4.50E-04	0.107784
4.15E+11	4065040	4.60E-04	0.11018
4.24E+11	4153240	4.70E-04	0.112575
4.33E+11	4241440	4.80E-04	0.11497
4.42E+11	4329640	4.90E-04	0.117365
4.51E+11	4417840	5.00E-04	0.11976
4.60E+11	4506040	5.10E-04	0.122156
4.69E+11	4594240	5.20E-04	0.124551
4.78E+11	4682440	5.30E-04	0.126946
4.87E+11	4770640	5.40E-04	0.129341
4.96E+11	4858840	5.50E-04	0.131737
5.05E+11	4947040	5.60E-04	0.134132
5.14E+11	5035240	5.70E-04	0.136527
5.23E+11	5123440	5.80E-04	0.138922
5.32E+11	5211640	5.90E-04	0.141317
5.41E+11	5299840	6.00E-04	0.143713
5.50E+11	5388040	6.10E-04	0.146108
5.59E+11	5476240	6.20E-04	0.148503
5.68E+11	5564440	6.30E-04	0.150898
5.77E+11	5652640	6.40E-04	0.153293
5.86E+11	5740840	6.50E-04	0.155689
5.95E+11	5829040	6.60E-04	0.158084
6.04E+11	5917240	6.70E-04	0.160479
6.13E+11	6005440	6.80E-04	0.162874
6.22E+11	6093640	6.90E-04	0.165269
6.31E+11	6181840	7.00E-04	0.167665
6.40E+11	6269060	7.10E-04	0.17006
6.49E+11	6357260	7.20E-04	0.172455
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6.67E+11	6533660	7.40E-04	0.177246
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6.96E+11	6815900	7.70E-04	0.184431
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7.69E+11	7539140	8.52E-04	0.204168
7.76E+11	7607740	8.62E-04	0.206419
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7.87E+11	7707700	8.80E-04	0.210754
7.90E+11	7739060	8.86E-04	0.212216
7.95E+11	7789040	8.96E-04	0.214611
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8.00E+11	7841960	9.07E-04	0.217126
8.05E+11	7889000	9.17E-04	0.219521
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8.10E+11	7937020	9.27E-04	0.221988
8.14E+11	7974260	9.35E-04	0.223976
8.18E+11	8016400	9.45E-04	0.226371
8.22E+11	8058540	9.55E-04	0.228766
8.27E+11	8099700	9.65E-04	0.231114
8.31E+11	8138900	9.75E-04	0.233509
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8.35E+11	8179080	9.85E-04	0.235976
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8.49E+11	8321180	1.03E-03	0.245749
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8.57E+11	8393700	1.05E-03	0.251018
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6.94E+11	6798260	7.70E-04	0.184431
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7.69E+11	7540120	8.61E-04	0.20618
7.76E+11	7606760	8.71E-04	0.208575
7.79E+11	7634200	8.75E-04	0.209557
7.85E+11	7695940	8.85E-04	0.211952
7.86E+11	7704760	8.86E-04	0.212311
7.92E+11	7762580	8.96E-04	0.214707
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7.98E+11	7824320	9.08E-04	0.217389
8.03E+11	7872340	9.18E-04	0.219784
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8.09E+11	7931140	9.30E-04	0.222778
8.14E+11	7974260	9.40E-04	0.225174
8.18E+11	8017380	9.50E-04	0.227569
8.23E+11	8060500	9.60E-04	0.229964
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8.38E+11	8216320	1.00E-03	0.23976
8.42E+11	8250620	1.01E-03	0.242156
8.45E+11	8284920	1.02E-03	0.244551
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8.49E+11	8318240	1.03E-03	0.246946
8.52E+11	8347640	1.04E-03	0.249341
8.55E+11	8378020	1.05E-03	0.251737
8.56E+11	8383900	1.05E-03	0.252216
8.58E+11	8412320	1.06E-03	0.254611
8.60E+11	8427020	1.07E-03	0.255808
8.63E+11	8452500	1.08E-03	0.258204
8.64E+11	8471120	1.09E-03	0.25988
8.67E+11	8494640	1.10E-03	0.262275
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8.70E+11	8524040	1.11E-03	0.265389

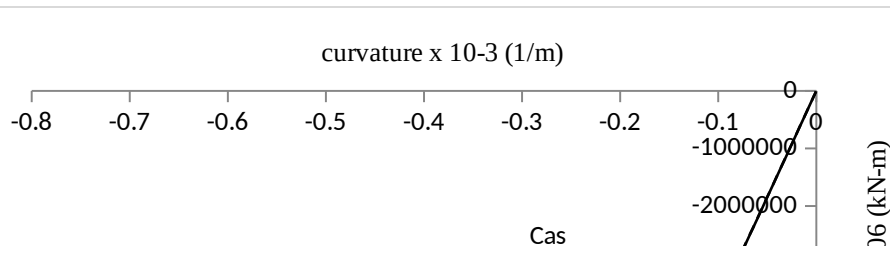
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8.99E+11	8805300	1.29E-03	0.307784
9.00E+11	8815100	1.30E-03	0.31018
9.01E+11	8824900	1.31E-03	0.312575
9.01E+11	8833720	1.32E-03	0.31497
9.02E+11	8843520	1.33E-03	0.317365
9.03E+11	8852340	1.34E-03	0.31976
9.04E+11	8862140	1.35E-03	0.322156
9.05E+11	8870960	1.36E-03	0.324551
9.06E+11	8879780	1.37E-03	0.326946
9.07E+11	8889580	1.38E-03	0.329341
9.08E+11	8898400	1.39E-03	0.331737
9.09E+11	8907220	1.40E-03	0.334132
9.10E+11	8917020	1.41E-03	0.336527
9.11E+11	8925840	1.42E-03	0.338922
9.12E+11	8934660	1.43E-03	0.341317
9.13E+11	8943480	1.44E-03	0.343713
9.14E+11	8952300	1.45E-03	0.346108
9.14E+11	8961120	1.46E-03	0.348503
9.15E+11	8969940	1.47E-03	0.350898
9.16E+11	8974840	1.47E-03	0.352335
9.17E+11	8982680	1.48E-03	0.354731
9.17E+11	8990520	1.49E-03	0.357126
9.18E+11	8998360	1.50E-03	0.359521
9.19E+11	9006200	1.51E-03	0.361916
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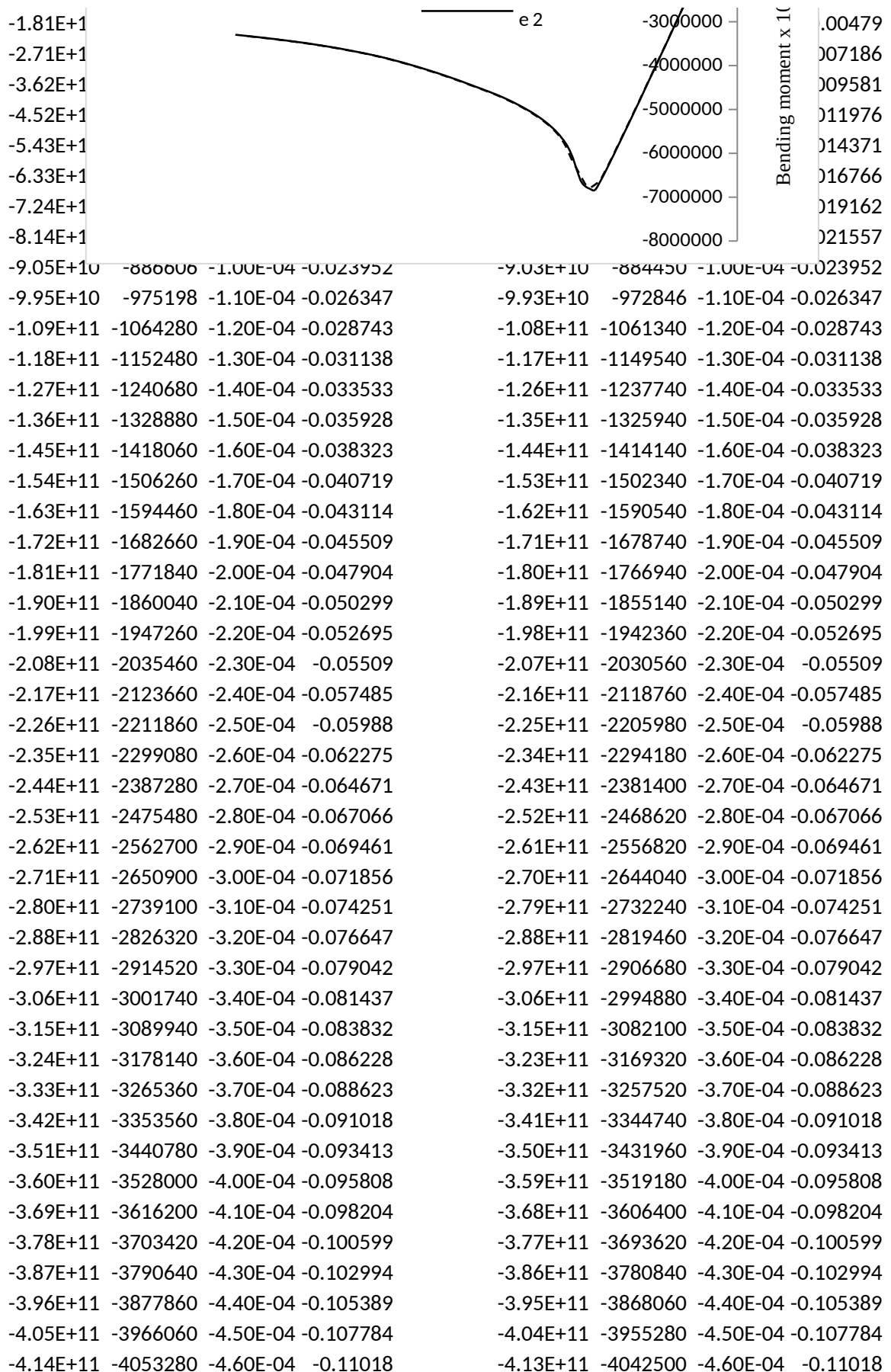
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8.83E+11	8653400	1.18E-03	0.281437
8.85E+11	8668100	1.19E-03	0.283832
8.86E+11	8680840	1.19E-03	0.285988
8.87E+11	8694560	1.20E-03	0.288383
8.89E+11	8707300	1.21E-03	0.290778
8.90E+11	8720040	1.22E-03	0.293174
8.91E+11	8728860	1.23E-03	0.294611
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8.94E+11	8761200	1.26E-03	0.301796
8.95E+11	8771980	1.27E-03	0.304192
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8.97E+11	8794520	1.29E-03	0.308982
8.98E+11	8801380	1.30E-03	0.310419
8.99E+11	8812160	1.31E-03	0.312814
9.00E+11	8820980	1.31E-03	0.314731
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9.02E+11	8840580	1.34E-03	0.31976
9.03E+11	8849400	1.35E-03	0.322156
9.04E+11	8858220	1.36E-03	0.324551
9.05E+11	8867040	1.37E-03	0.326946
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9.07E+11	8884680	1.39E-03	0.332455
9.07E+11	8889580	1.39E-03	0.333653
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9.10E+11	8913100	1.42E-03	0.340838
9.10E+11	8919960	1.43E-03	0.343234
9.11E+11	8927800	1.44E-03	0.345629
9.11E+11	8930740	1.45E-03	0.346587
9.12E+11	8937600	1.46E-03	0.348982
9.13E+11	8945440	1.47E-03	0.351377
9.13E+11	8946420	1.47E-03	0.351856
9.14E+11	8953280	1.48E-03	0.354251
9.14E+11	8956220	1.48E-03	0.355449

9.20E+11	9018940	1.54E-03	0.368383	9.14E+11	8960140	1.49E-03	0.357844
9.21E+11	9022860	1.55E-03	0.370778	9.15E+11	8964060	1.50E-03	0.36024
9.21E+11	9023840	1.55E-03	0.371497	9.15E+11	8964060	1.50E-03	0.36024
9.21E+11	9027760	1.56E-03	0.373892	9.15E+11	8967000	1.51E-03	0.362635
9.22E+11	9030700	1.57E-03	0.376287	9.15E+11	8970920	1.52E-03	0.36503
9.22E+11	9033640	1.58E-03	0.378683	9.16E+11	8972880	1.53E-03	0.366707
9.22E+11	9036580	1.59E-03	0.381078	9.16E+11	8976800	1.54E-03	0.369102
9.23E+11	9040500	1.60E-03	0.383473	9.16E+11	8979740	1.55E-03	0.371497
9.23E+11	9043440	1.61E-03	0.385868	9.17E+11	8982680	1.56E-03	0.373892
9.23E+11	9044420	1.61E-03	0.386347	9.17E+11	8983660	1.56E-03	0.374371
9.23E+11	9044420	1.62E-03	0.388743	9.17E+11	8986600	1.57E-03	0.376766
9.23E+11	9044420	1.63E-03	0.391138	9.17E+11	8989540	1.58E-03	0.379162
9.23E+11	9045400	1.64E-03	0.392096	9.18E+11	8993460	1.59E-03	0.381557
9.23E+11	9045400	1.65E-03	0.394491	9.18E+11	8996400	1.60E-03	0.383952
9.23E+11	9046380	1.66E-03	0.396886	9.18E+11	8999340	1.61E-03	0.386347
9.23E+11	9046380	1.67E-03	0.399281	9.19E+11	9002280	1.62E-03	0.388743
9.23E+11	9047360	1.68E-03	0.401677	9.19E+11	9006200	1.63E-03	0.391138
9.23E+11	9048340	1.69E-03	0.404072	9.19E+11	9006200	1.63E-03	0.391138
9.23E+11	9048340	1.69E-03	0.404311	9.19E+11	9009140	1.64E-03	0.393533
9.23E+11	9049320	1.70E-03	0.406707	9.20E+11	9012080	1.65E-03	0.395928
9.23E+11	9049320	1.71E-03	0.409102	9.20E+11	9015020	1.66E-03	0.398323
9.24E+11	9050300	1.72E-03	0.411497	9.20E+11	9017960	1.67E-03	0.400719
9.24E+11	9051280	1.73E-03	0.413892	9.20E+11	9019920	1.68E-03	0.401916
9.24E+11	9052260	1.74E-03	0.416048	9.21E+11	9022860	1.69E-03	0.404311
9.24E+11	9053240	1.75E-03	0.418443	9.21E+11	9025800	1.70E-03	0.406707
9.24E+11	9053240	1.76E-03	0.420838	9.21E+11	9027760	1.71E-03	0.408862
9.24E+11	9054220	1.77E-03	0.423234	9.22E+11	9030700	1.72E-03	0.411257
9.24E+11	9055200	1.78E-03	0.425629	9.22E+11	9033640	1.73E-03	0.413653
9.24E+11	9057160	1.79E-03	0.428024	9.22E+11	9036580	1.74E-03	0.415808
9.24E+11	9058140	1.80E-03	0.430419	9.22E+11	9039520	1.75E-03	0.418204
9.24E+11	9059120	1.80E-03	0.432096	9.23E+11	9042460	1.76E-03	0.420599
9.25E+11	9060100	1.81E-03	0.434491	9.23E+11	9045400	1.77E-03	0.422994
9.25E+11	9061080	1.82E-03	0.436886	9.23E+11	9046380	1.77E-03	0.423473
9.25E+11	9062060	1.83E-03	0.439281	9.23E+11	9048340	1.78E-03	0.425868
9.25E+11	9063040	1.84E-03	0.441677	9.24E+11	9051280	1.79E-03	0.428263
9.25E+11	9065000	1.85E-03	0.444072	9.24E+11	9052260	1.79E-03	0.429222
9.25E+11	9065980	1.86E-03	0.446467	9.24E+11	9053240	1.80E-03	0.431617
9.25E+11	9066960	1.87E-03	0.448383	9.24E+11	9054220	1.81E-03	0.434012
9.25E+11	9067940	1.88E-03	0.450778	9.24E+11	9055200	1.82E-03	0.436407
9.25E+11	9068920	1.89E-03	0.453174	9.24E+11	9056180	1.83E-03	0.437844
9.26E+11	9069900	1.90E-03	0.455569	9.24E+11	9057160	1.84E-03	0.44024
9.26E+11	9070880	1.91E-03	0.457964	9.24E+11	9058140	1.85E-03	0.442635
9.26E+11	9072840	1.92E-03	0.460359	9.24E+11	9059120	1.86E-03	0.44503
9.26E+11	9073820	1.93E-03	0.462754	9.25E+11	9060100	1.87E-03	0.447425
9.26E+11	9074800	1.94E-03	0.46515	9.25E+11	9061080	1.88E-03	0.44982

9.26E+11	9075780	1.95E-03	0.467545	9.25E+11	9062060	1.89E-03	0.452216
9.26E+11	9076760	1.96E-03	0.46994	9.25E+11	9063040	1.90E-03	0.454611
9.26E+11	9078720	1.97E-03	0.472335	9.25E+11	9065000	1.91E-03	0.457006
9.27E+11	9079700	1.98E-03	0.474731	9.25E+11	9065980	1.92E-03	0.459162
9.27E+11	9080680	1.99E-03	0.477126	9.25E+11	9066960	1.93E-03	0.461557
9.27E+11	9081660	2.00E-03	0.479521	9.25E+11	9067940	1.94E-03	0.463952
9.27E+11	9082640	2.01E-03	0.480479	9.25E+11	9068920	1.95E-03	0.466347
9.27E+11	9083620	2.02E-03	0.482874	9.26E+11	9070880	1.96E-03	0.468743
9.27E+11	9085580	2.03E-03	0.485269	9.26E+11	9071860	1.96E-03	0.470419
9.27E+11	9086560	2.04E-03	0.487665	9.26E+11	9072840	1.97E-03	0.472814
9.27E+11	9087540	2.05E-03	0.49006	9.26E+11	9073820	1.98E-03	0.47521
9.28E+11	9089500	2.06E-03	0.492455	9.26E+11	9075780	1.99E-03	0.477605
9.28E+11	9090480	2.07E-03	0.49485	9.26E+11	9076760	2.00E-03	0.48
9.28E+11	9092440	2.08E-03	0.497246	9.26E+11	9078720	2.01E-03	0.482395
9.28E+11	9093420	2.09E-03	0.499641	9.26E+11	9078720	2.02E-03	0.482874
9.28E+11	9095380	2.10E-03	0.502036	9.27E+11	9079700	2.03E-03	0.485269
9.28E+11	9096360	2.11E-03	0.504431	9.27E+11	9081660	2.04E-03	0.487665
9.28E+11	9098320	2.12E-03	0.506826	9.27E+11	9082640	2.05E-03	0.49006
9.29E+11	9099300	2.13E-03	0.509222	9.27E+11	9082640	2.05E-03	0.490539
9.29E+11	9100280	2.14E-03	0.511617	9.27E+11	9084600	2.06E-03	0.492934
9.29E+11	9102240	2.15E-03	0.514012	9.27E+11	9085580	2.07E-03	0.495329
9.29E+11	9103220	2.16E-03	0.516407	9.27E+11	9086560	2.08E-03	0.497485
9.29E+11	9105180	2.17E-03	0.518563	9.27E+11	9088520	2.09E-03	0.49988
9.29E+11	9106160	2.18E-03	0.520958	9.28E+11	9089500	2.10E-03	0.502275
9.29E+11	9108120	2.19E-03	0.523353	9.28E+11	9091460	2.11E-03	0.504671
9.30E+11	9109100	2.20E-03	0.525749	9.28E+11	9092440	2.12E-03	0.507066
9.30E+11	9111060	2.21E-03	0.528144	9.28E+11	9093420	2.13E-03	0.509461
9.30E+11	9113020	2.22E-03	0.530539	9.28E+11	9095380	2.14E-03	0.511856
9.30E+11	9114000	2.23E-03	0.532934	9.28E+11	9096360	2.15E-03	0.514251
9.30E+11	9115960	2.24E-03	0.535329	9.28E+11	9098320	2.16E-03	0.516647
9.30E+11	9116940	2.25E-03	0.537725	9.29E+11	9099300	2.17E-03	0.519042
9.31E+11	9118900	2.26E-03	0.54012	9.29E+11	9100280	2.18E-03	0.520958
9.31E+11	9120860	2.27E-03	0.542515	9.29E+11	9102240	2.19E-03	0.523353
9.31E+11	9121840	2.28E-03	0.54491	9.29E+11	9103220	2.20E-03	0.525749
9.31E+11	9123800	2.29E-03	0.547305	9.29E+11	9105180	2.21E-03	0.528144
9.31E+11	9124780	2.30E-03	0.549701	9.29E+11	9106160	2.22E-03	0.530539
9.31E+11	9126740	2.31E-03	0.552096	9.29E+11	9108120	2.23E-03	0.532934
9.32E+11	9128700	2.32E-03	0.554491	9.30E+11	9109100	2.24E-03	0.535329
9.32E+11	9129680	2.33E-03	0.556886	9.30E+11	9111060	2.25E-03	0.537725
9.32E+11	9131640	2.34E-03	0.559281	9.30E+11	9112040	2.26E-03	0.54012
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9.32E+11	9134580	2.36E-03	0.564072	9.30E+11	9114980	2.28E-03	0.54491
9.32E+11	9136540	2.37E-03	0.566467	9.30E+11	9116940	2.29E-03	0.547305
9.32E+11	9137520	2.38E-03	0.568862	9.30E+11	9117920	2.29E-03	0.548263
9.33E+11	9138500	2.38E-03	0.570299	9.31E+11	9118900	2.30E-03	0.550659

9.33E+11	9140460	2.39E-03	0.572695	9.31E+11	9119880	2.31E-03	0.553054
9.33E+11	9142420	2.40E-03	0.57509	9.31E+11	9121840	2.32E-03	0.555449
9.33E+11	9143400	2.41E-03	0.577485	9.31E+11	9122820	2.33E-03	0.557844
9.33E+11	9145360	2.42E-03	0.57988	9.31E+11	9123800	2.34E-03	0.56024
9.33E+11	9147320	2.43E-03	0.582275	9.31E+11	9125760	2.35E-03	0.562635
9.34E+11	9148300	2.44E-03	0.584671	9.31E+11	9125760	2.35E-03	0.563832
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9.34E+11	9155160	2.48E-03	0.594012	9.32E+11	9130660	2.39E-03	0.573413
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9.35E+11	9166920	2.55E-03	0.610778	9.32E+11	9137520	2.46E-03	0.589222
9.36E+11	9167900	2.56E-03	0.613174	9.32E+11	9137520	2.46E-03	0.589461
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9.38E+11	9188480	2.68E-03	0.642635	9.33E+11	9138500	2.57E-03	0.616048
9.38E+11	9189460	2.69E-03	0.64503	9.32E+11	9137520	2.58E-03	0.618443
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-2.72E+09	-26616.8	-3.00E-06	-0.000719	-2.71E+09	-26548.2	-3.00E-06	-0.000719
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-5.43E+C							001437
-6.34E+C							001677
-7.24E+C							001916
-8.14E+C							002156
-9.05E+C							002395





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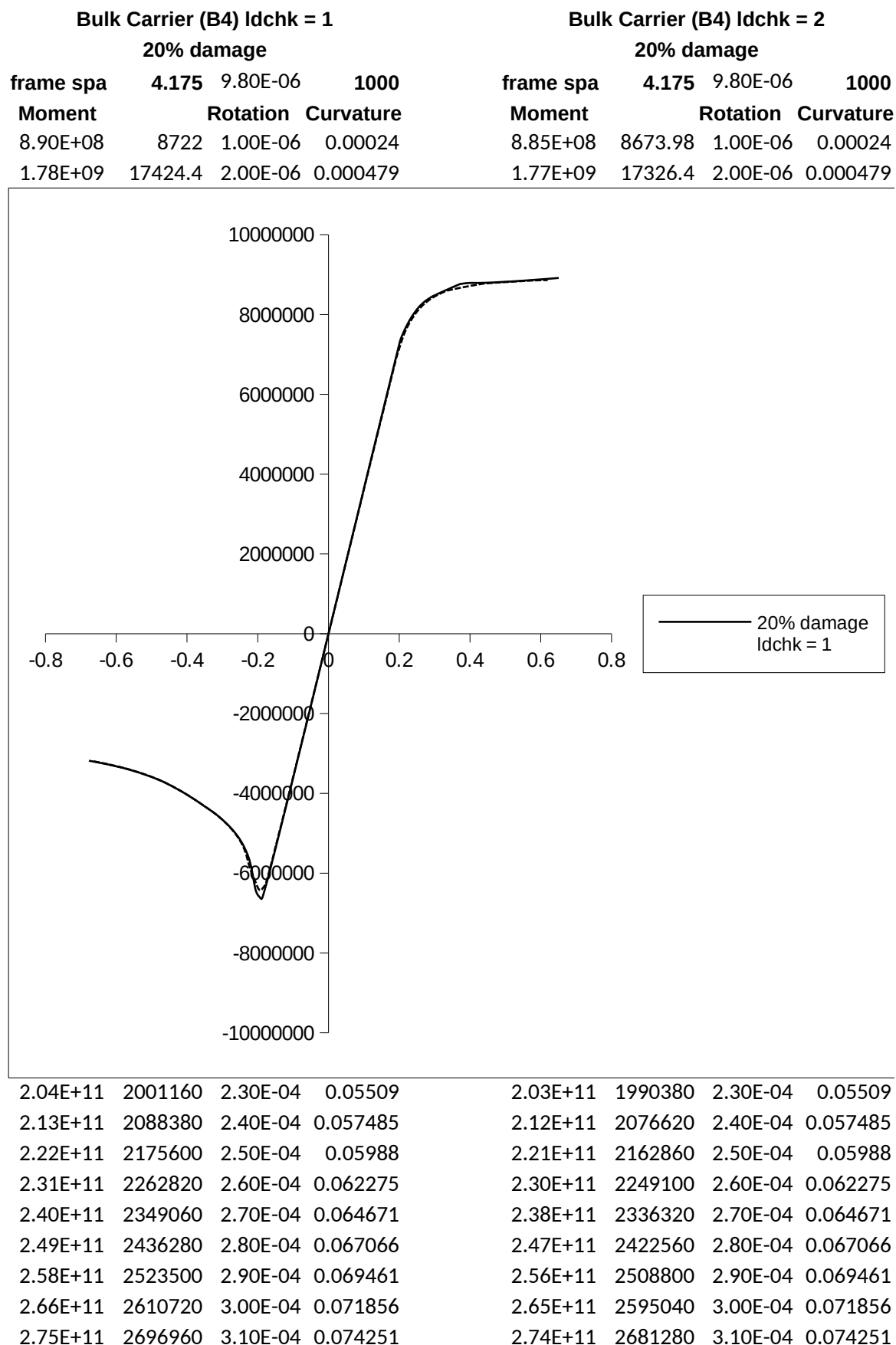
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3.02E+11	2957640	3.40E-04	0.081437	3.00E+11	2940980	3.40E-04	0.081437
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3.20E+11	3132080	3.60E-04	0.086228	3.18E+11	3113460	3.60E-04	0.086228
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3.46E+11	3392760	3.90E-04	0.093413	3.44E+11	3373160	3.90E-04	0.093413
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3.64E+11	3566220	4.10E-04	0.098204	3.62E+11	3545640	4.10E-04	0.098204
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3.91E+11	3826900	4.40E-04	0.105389	3.88E+11	3805340	4.40E-04	0.105389
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4.44E+11	4348260	5.00E-04	0.11976	4.41E+11	4322780	5.00E-04	0.11976
4.53E+11	4435480	5.10E-04	0.122156	4.50E+11	4409020	5.10E-04	0.122156
4.61E+11	4521720	5.20E-04	0.124551	4.59E+11	4495260	5.20E-04	0.124551
4.70E+11	4608940	5.30E-04	0.126946	4.68E+11	4581500	5.30E-04	0.126946
4.79E+11	4696160	5.40E-04	0.129341	4.76E+11	4668720	5.40E-04	0.129341
4.88E+11	4782400	5.50E-04	0.131737	4.85E+11	4754960	5.50E-04	0.131737
4.97E+11	4869620	5.60E-04	0.134132	4.94E+11	4841200	5.60E-04	0.134132
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5.86E+11	5737900	6.60E-04	0.158084	5.82E+11	5703600	6.60E-04	0.158084
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6.21E+11	6084820	7.00E-04	0.167665	6.17E+11	6049540	7.00E-04	0.167665
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6.65E+11	6518960	7.50E-04	0.179641	6.61E+11	6480740	7.50E-04	0.179641
6.74E+11	6606180	7.60E-04	0.182036	6.70E+11	6566980	7.60E-04	0.182036

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6.92E+11	6779640	7.80E-04	0.186826	6.88E+11	6739460	7.80E-04	0.186826
7.01E+11	6865880	7.90E-04	0.189222	6.97E+11	6825700	7.90E-04	0.189222
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7.39E+11	7242200	8.33E-04	0.199593	7.23E+11	7082460	8.25E-04	0.197557
7.47E+11	7320600	8.43E-04	0.201892	7.30E+11	7150080	8.35E-04	0.199952
7.54E+11	7385280	8.52E-04	0.204096	7.37E+11	7217700	8.45E-04	0.202347
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7.63E+11	7480340	8.70E-04	0.208383	7.43E+11	7284340	8.55E-04	0.204743
7.66E+11	7507780	8.76E-04	0.209749	7.45E+11	7303940	8.58E-04	0.205485
7.71E+11	7555800	8.86E-04	0.212144	7.52E+11	7368620	8.68E-04	0.20788
7.76E+11	7602840	8.96E-04	0.214491	7.52E+11	7371560	8.68E-04	0.208
7.80E+11	7646940	9.06E-04	0.216886	7.58E+11	7432320	8.78E-04	0.210395
7.85E+11	7690060	9.15E-04	0.219234	7.59E+11	7442120	8.80E-04	0.210778
7.88E+11	7724360	9.23E-04	0.221174	7.65E+11	7497980	8.90E-04	0.21315
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7.96E+11	7802760	9.43E-04	0.225964	7.73E+11	7576380	9.05E-04	0.216766
8.00E+11	7838040	9.52E-04	0.228096	7.78E+11	7623420	9.15E-04	0.219162
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8.07E+11	7908600	9.72E-04	0.232814	7.83E+11	7676340	9.27E-04	0.222036
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8.14E+11	7975240	9.92E-04	0.237605	7.93E+11	7772380	9.52E-04	0.227904
8.17E+11	8006600	1.00E-03	0.24	7.97E+11	7809620	9.62E-04	0.230299
8.20E+11	8037960	1.01E-03	0.242395	7.98E+11	7817460	9.64E-04	0.230802
8.21E+11	8042860	1.01E-03	0.242874	8.01E+11	7852740	9.74E-04	0.233198
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8.48E+11	8306480	1.13E-03	0.269461	8.32E+11	8150660	1.08E-03	0.257485
8.49E+11	8324120	1.14E-03	0.271856	8.34E+11	8173200	1.09E-03	0.25988
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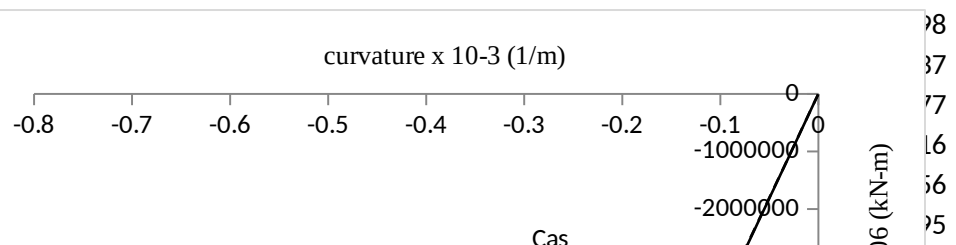
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8.67E+11	8491700	1.26E-03	0.302515	8.57E+11	8395660	1.21E-03	0.289581
8.68E+11	8501500	1.27E-03	0.30491	8.58E+11	8409380	1.22E-03	0.291976
8.69E+11	8511300	1.28E-03	0.307305	8.59E+11	8422120	1.23E-03	0.294371
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8.71E+11	8531880	1.30E-03	0.312096	8.61E+11	8440740	1.24E-03	0.297725
8.72E+11	8540700	1.31E-03	0.314491	8.62E+11	8445640	1.25E-03	0.298683
8.72E+11	8545600	1.32E-03	0.315449	8.63E+11	8457400	1.26E-03	0.301078
8.73E+11	8554420	1.33E-03	0.317844	8.64E+11	8468180	1.27E-03	0.303473
8.74E+11	8564220	1.34E-03	0.32024	8.65E+11	8479940	1.28E-03	0.305868
8.75E+11	8574020	1.35E-03	0.322635	8.66E+11	8486800	1.28E-03	0.307545
8.76E+11	8583820	1.36E-03	0.32503	8.67E+11	8497580	1.29E-03	0.30994
8.77E+11	8592640	1.37E-03	0.327425	8.68E+11	8508360	1.30E-03	0.312335
8.78E+11	8602440	1.38E-03	0.32982	8.69E+11	8519140	1.31E-03	0.314731
8.79E+11	8612240	1.39E-03	0.332216	8.70E+11	8529920	1.32E-03	0.317126
8.80E+11	8621060	1.40E-03	0.334611	8.72E+11	8540700	1.33E-03	0.319521
8.81E+11	8630860	1.41E-03	0.337006	8.72E+11	8546580	1.34E-03	0.320958
8.82E+11	8640660	1.42E-03	0.339401	8.73E+11	8556380	1.35E-03	0.323353
8.83E+11	8649480	1.43E-03	0.341796	8.74E+11	8565200	1.36E-03	0.325749
8.84E+11	8659280	1.44E-03	0.344192	8.74E+11	8566180	1.36E-03	0.325988
8.85E+11	8668100	1.45E-03	0.346587	8.75E+11	8575000	1.37E-03	0.328383
8.86E+11	8677900	1.46E-03	0.348982	8.76E+11	8582840	1.38E-03	0.330778
8.86E+11	8686720	1.47E-03	0.351377	8.77E+11	8591660	1.39E-03	0.333174
8.87E+11	8696520	1.48E-03	0.353772	8.77E+11	8598520	1.40E-03	0.33509
8.88E+11	8705340	1.49E-03	0.356168	8.78E+11	8603420	1.41E-03	0.337485
8.89E+11	8714160	1.50E-03	0.358563	8.78E+11	8608320	1.42E-03	0.33988
8.90E+11	8722980	1.51E-03	0.360958	8.79E+11	8611260	1.43E-03	0.341317
8.91E+11	8732780	1.52E-03	0.363353	8.79E+11	8616160	1.44E-03	0.343713
8.92E+11	8741600	1.53E-03	0.365749	8.80E+11	8621060	1.45E-03	0.346108
8.93E+11	8750420	1.54E-03	0.368144	8.80E+11	8625960	1.46E-03	0.348503
8.94E+11	8759240	1.55E-03	0.370539	8.80E+11	8625960	1.46E-03	0.348743
8.94E+11	8764140	1.55E-03	0.371737	8.81E+11	8630860	1.47E-03	0.351138
8.95E+11	8767080	1.56E-03	0.374132	8.81E+11	8635760	1.48E-03	0.353533

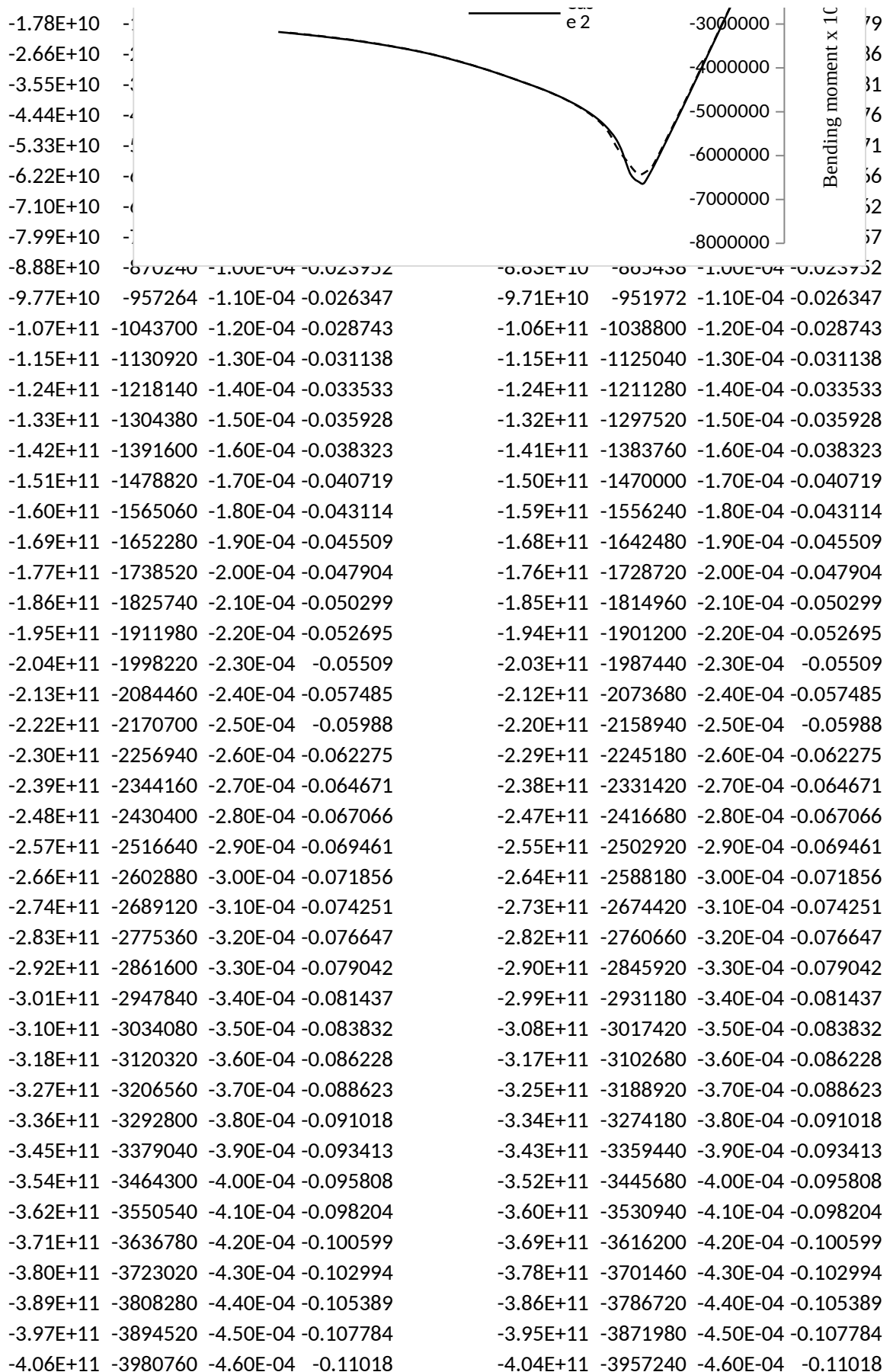
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8.95E+11	8773940	1.58E-03	0.378922	8.82E+11	8640660	1.49E-03	0.356168
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8.96E+11	8781780	1.61E-03	0.385868	8.83E+11	8653400	1.52E-03	0.363353
8.96E+11	8784720	1.62E-03	0.388263	8.83E+11	8657320	1.53E-03	0.365749
8.97E+11	8786680	1.63E-03	0.390659	8.84E+11	8662220	1.54E-03	0.368144
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8.97E+11	8792560	1.68E-03	0.401437	8.86E+11	8681820	1.58E-03	0.379401
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8.97E+11	8792560	1.80E-03	0.431377	8.91E+11	8732780	1.71E-03	0.410539
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8.99E+11	8812160	2.01E-03	0.482395
8.99E+11	8813140	2.02E-03	0.48479
8.99E+11	8814120	2.03E-03	0.487186
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8.97E+11	8791580	1.93E-03	0.462275
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9.07E+11	8892520	2.58E-03	0.617485	9.04E+11	8856260	2.45E-03	0.587784
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9.08E+11	8899380	2.61E-03	0.626108	9.04E+11	8858220	2.49E-03	0.595449
9.08E+11	8900360	2.62E-03	0.628503	9.04E+11	8859200	2.50E-03	0.597844
9.08E+11	8902320	2.63E-03	0.630898	9.04E+11	8860180	2.51E-03	0.60024
9.09E+11	8904280	2.64E-03	0.633293	9.04E+11	8860180	2.52E-03	0.602635
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9.09E+11	8909180	2.67E-03	0.640479	9.04E+11	8862140	2.54E-03	0.607665
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-5.33E+09							
-6.22E+09	-6						
-7.11E+09	-6						
-7.99E+09	-7						
-8.88E+09	-8						





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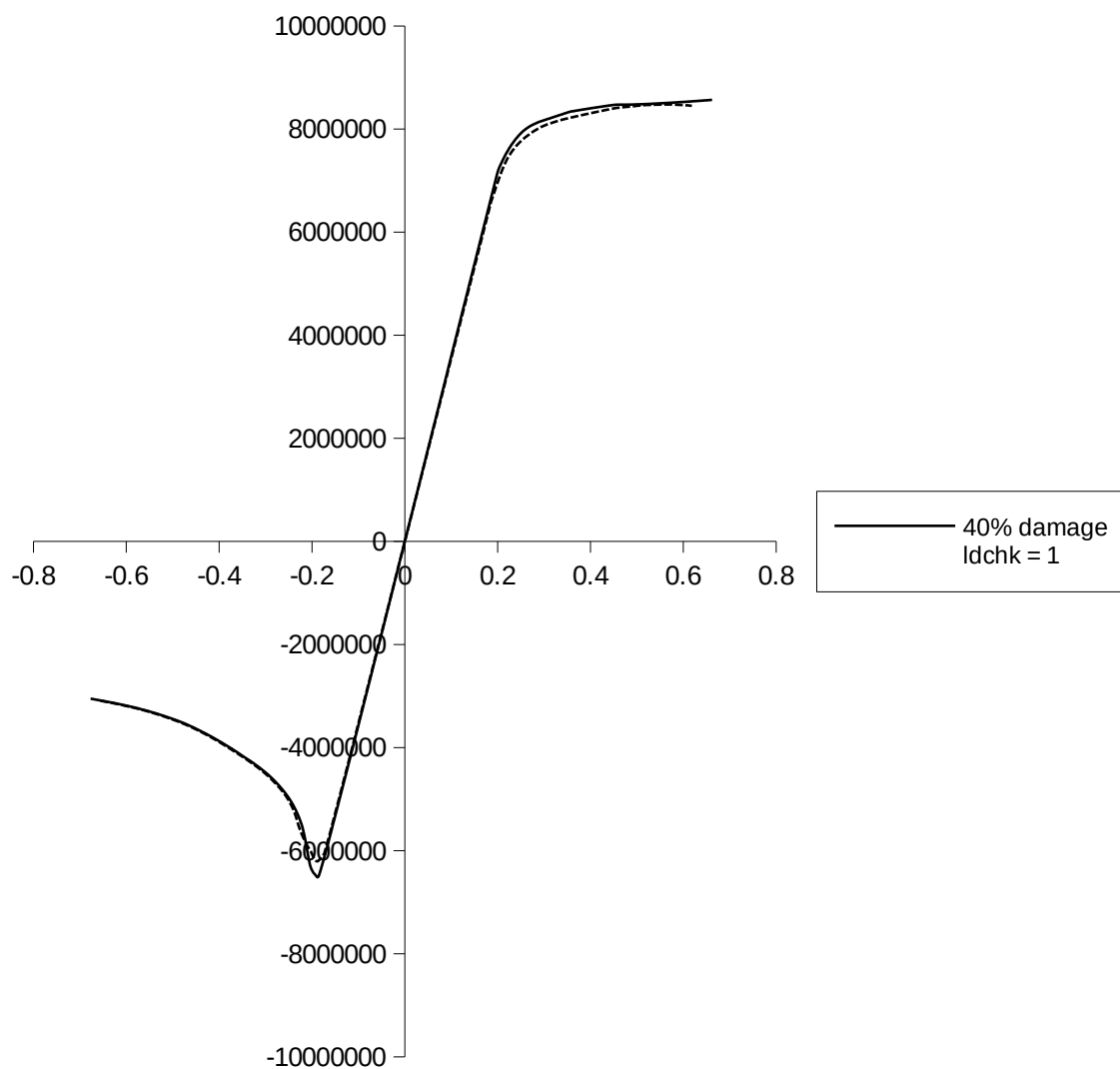
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-3.79E+11	-3713220	-1.95E-03	-0.466587	-3.84E+11	-3759280	-1.90E-03	-0.45509
-3.78E+11	-3702440	-1.96E-03	-0.468982	-3.83E+11	-3748500	-1.91E-03	-0.457485
-3.77E+11	-3692640	-1.97E-03	-0.471377	-3.82E+11	-3738700	-1.92E-03	-0.45988
-3.76E+11	-3682840	-1.98E-03	-0.473772	-3.80E+11	-3727920	-1.93E-03	-0.462275
-3.75E+11	-3674020	-1.99E-03	-0.476168	-3.79E+11	-3717140	-1.94E-03	-0.464671
-3.74E+11	-3665200	-2.00E-03	-0.478563	-3.78E+11	-3707340	-1.95E-03	-0.467066
-3.73E+11	-3656380	-2.01E-03	-0.480958	-3.78E+11	-3702440	-1.96E-03	-0.468503
-3.72E+11	-3647560	-2.02E-03	-0.483353	-3.77E+11	-3692640	-1.97E-03	-0.470898
-3.71E+11	-3638740	-2.03E-03	-0.485749	-3.76E+11	-3682840	-1.98E-03	-0.473293
-3.71E+11	-3630900	-2.04E-03	-0.488144	-3.75E+11	-3674020	-1.99E-03	-0.475689
-3.70E+11	-3622080	-2.05E-03	-0.490539	-3.74E+11	-3664220	-2.00E-03	-0.478084
-3.69E+11	-3614240	-2.06E-03	-0.492934	-3.73E+11	-3655400	-2.01E-03	-0.480479
-3.68E+11	-3605420	-2.07E-03	-0.495329	-3.72E+11	-3646580	-2.02E-03	-0.482874
-3.67E+11	-3597580	-2.08E-03	-0.497725	-3.71E+11	-3636780	-2.03E-03	-0.485269
-3.66E+11	-3588760	-2.09E-03	-0.50012	-3.70E+11	-3627960	-2.04E-03	-0.487665
-3.65E+11	-3580920	-2.10E-03	-0.502515	-3.69E+11	-3620120	-2.05E-03	-0.49006
-3.65E+11	-3573080	-2.11E-03	-0.50491	-3.69E+11	-3611300	-2.06E-03	-0.492455
-3.64E+11	-3565240	-2.12E-03	-0.507305	-3.68E+11	-3603460	-2.07E-03	-0.49485
-3.63E+11	-3558380	-2.13E-03	-0.509701	-3.67E+11	-3594640	-2.08E-03	-0.497246
-3.62E+11	-3550540	-2.14E-03	-0.512096	-3.66E+11	-3586800	-2.09E-03	-0.499641
-3.62E+11	-3543680	-2.15E-03	-0.514491	-3.65E+11	-3578960	-2.10E-03	-0.502036
-3.61E+11	-3535840	-2.16E-03	-0.516886	-3.64E+11	-3571120	-2.11E-03	-0.504431
-3.60E+11	-3528000	-2.17E-03	-0.519281	-3.64E+11	-3563280	-2.12E-03	-0.506826
-3.59E+11	-3521140	-2.18E-03	-0.521677	-3.63E+11	-3555440	-2.13E-03	-0.509222
-3.59E+11	-3513300	-2.19E-03	-0.524072	-3.62E+11	-3547600	-2.14E-03	-0.511617

-3.58E+11	-3506440	-2.20E-03	-0.526467	-3.61E+11	-3539760	-2.15E-03	-0.514012
-3.57E+11	-3499580	-2.21E-03	-0.528862	-3.61E+11	-3532900	-2.16E-03	-0.516407
-3.56E+11	-3491740	-2.22E-03	-0.531257	-3.60E+11	-3525060	-2.17E-03	-0.518802
-3.56E+11	-3484880	-2.23E-03	-0.533653	-3.59E+11	-3517220	-2.18E-03	-0.521198
-3.55E+11	-3478020	-2.24E-03	-0.536048	-3.58E+11	-3510360	-2.19E-03	-0.523593
-3.54E+11	-3471160	-2.25E-03	-0.538443	-3.57E+11	-3502520	-2.20E-03	-0.525988
-3.54E+11	-3465280	-2.26E-03	-0.540838	-3.57E+11	-3495660	-2.21E-03	-0.528383
-3.53E+11	-3458420	-2.27E-03	-0.543234	-3.56E+11	-3488800	-2.22E-03	-0.530778
-3.52E+11	-3452540	-2.28E-03	-0.545629	-3.55E+11	-3481940	-2.23E-03	-0.533174
-3.52E+11	-3445680	-2.29E-03	-0.548024	-3.55E+11	-3475080	-2.24E-03	-0.535569
-3.51E+11	-3439800	-2.30E-03	-0.550419	-3.54E+11	-3468220	-2.25E-03	-0.537964
-3.50E+11	-3432940	-2.31E-03	-0.552814	-3.53E+11	-3461360	-2.26E-03	-0.540359
-3.50E+11	-3427060	-2.32E-03	-0.55521	-3.53E+11	-3454500	-2.27E-03	-0.542754
-3.49E+11	-3420200	-2.33E-03	-0.557605	-3.52E+11	-3447640	-2.28E-03	-0.54515
-3.48E+11	-3414320	-2.34E-03	-0.56	-3.51E+11	-3440780	-2.29E-03	-0.547545
-3.48E+11	-3408440	-2.35E-03	-0.562395	-3.51E+11	-3434900	-2.30E-03	-0.54994
-3.47E+11	-3401580	-2.36E-03	-0.56479	-3.50E+11	-3428040	-2.31E-03	-0.552335
-3.47E+11	-3395700	-2.37E-03	-0.567186	-3.49E+11	-3422160	-2.32E-03	-0.554731
-3.46E+11	-3389820	-2.38E-03	-0.569581	-3.49E+11	-3415300	-2.33E-03	-0.557126
-3.45E+11	-3383940	-2.39E-03	-0.571976	-3.48E+11	-3409420	-2.34E-03	-0.559521
-3.45E+11	-3378060	-2.40E-03	-0.574371	-3.47E+11	-3403540	-2.35E-03	-0.561916
-3.44E+11	-3372180	-2.41E-03	-0.576766	-3.47E+11	-3396680	-2.36E-03	-0.564311
-3.44E+11	-3366300	-2.42E-03	-0.579162	-3.46E+11	-3390800	-2.37E-03	-0.566707
-3.43E+11	-3361400	-2.43E-03	-0.581557	-3.45E+11	-3384920	-2.38E-03	-0.569102
-3.43E+11	-3356500	-2.44E-03	-0.583952	-3.45E+11	-3379040	-2.39E-03	-0.571497
-3.42E+11	-3350620	-2.45E-03	-0.586347	-3.44E+11	-3373160	-2.40E-03	-0.573892
-3.41E+11	-3345720	-2.46E-03	-0.588743	-3.44E+11	-3368260	-2.41E-03	-0.576287
-3.41E+11	-3340820	-2.47E-03	-0.591138	-3.43E+11	-3362380	-2.42E-03	-0.578683
-3.40E+11	-3335920	-2.48E-03	-0.593533	-3.43E+11	-3356500	-2.43E-03	-0.581078
-3.40E+11	-3331020	-2.49E-03	-0.595928	-3.42E+11	-3351600	-2.44E-03	-0.583473
-3.39E+11	-3326120	-2.50E-03	-0.598323	-3.41E+11	-3345720	-2.45E-03	-0.585868
-3.39E+11	-3321220	-2.51E-03	-0.600719	-3.41E+11	-3340820	-2.46E-03	-0.588263
-3.38E+11	-3316320	-2.52E-03	-0.603114	-3.40E+11	-3335920	-2.47E-03	-0.590659
-3.38E+11	-3311420	-2.53E-03	-0.605509	-3.40E+11	-3330040	-2.48E-03	-0.593054
-3.37E+11	-3306520	-2.54E-03	-0.607904	-3.39E+11	-3325140	-2.49E-03	-0.595449
-3.37E+11	-3301620	-2.55E-03	-0.610299	-3.39E+11	-3320240	-2.50E-03	-0.597844
-3.36E+11	-3296720	-2.56E-03	-0.612695	-3.38E+11	-3315340	-2.51E-03	-0.60024
-3.36E+11	-3291820	-2.57E-03	-0.61509	-3.38E+11	-3310440	-2.52E-03	-0.602635
-3.35E+11	-3286920	-2.58E-03	-0.617485	-3.37E+11	-3305540	-2.53E-03	-0.60503
-3.35E+11	-3282020	-2.59E-03	-0.61988	-3.37E+11	-3300640	-2.54E-03	-0.607425
-3.34E+11	-3277120	-2.60E-03	-0.622275	-3.36E+11	-3295740	-2.55E-03	-0.60982
-3.34E+11	-3272220	-2.61E-03	-0.624671	-3.36E+11	-3290840	-2.56E-03	-0.612216
-3.34E+11	-3268300	-2.62E-03	-0.627066	-3.35E+11	-3285940	-2.57E-03	-0.614611
-3.33E+11	-3263400	-2.63E-03	-0.629461	-3.35E+11	-3281040	-2.58E-03	-0.617006
-3.33E+11	-3259480	-2.64E-03	-0.631856	-3.34E+11	-3276140	-2.59E-03	-0.619401

-3.32E+11 -3255560 -2.65E-03 -0.634251
-3.32E+11 -3250660 -2.66E-03 -0.636647
-3.31E+11 -3246740 -2.67E-03 -0.639042
-3.31E+11 -3242820 -2.68E-03 -0.641437
-3.30E+11 -3237920 -2.69E-03 -0.643832
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-3.28E+11 -3217340 -2.74E-03 -0.655808
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-3.28E+11 -3209500 -2.76E-03 -0.660599
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-3.27E+11 -3200680 -2.78E-03 -0.665389
-3.26E+11 -3196760 -2.79E-03 -0.667784
-3.26E+11 -3192840 -2.80E-03 -0.67018
-3.25E+11 -3188920 -2.81E-03 -0.672575
-3.25E+11 -3185000 -2.82E-03 -0.67497
-3.25E+11 -3181080 -2.83E-03 -0.677365

-3.34E+11 -3272220 -2.60E-03 -0.621796
-3.33E+11 -3267320 -2.61E-03 -0.624192
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-3.33E+11 -3258500 -2.63E-03 -0.628982
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-3.26E+11 -3198720 -2.77E-03 -0.662515
-3.26E+11 -3194800 -2.78E-03 -0.66491

Bulk Carrier (B4) Idchk = 1				Bulk Carrier (B4) Idchk = 2			
40% damage				40% damage			
frame spa	4.175	9.80E-06	1000	frame spa	4.175	9.80E-06	1000
Moment	Rotation Curvature			Moment	Rotation Curvature		
8.79E+08	8616.16	1.00E-06	0.00024	8.70E+08	8522.08	1.00E-06	0.00024
1.76E+09	17208.8	2.00E-06	0.000479	1.74E+09	17022.6	2.00E-06	0.000479



2.02E+11	1977640	2.30E-04	0.05509	2.00E+11	1955100	2.30E-04	0.05509
2.11E+11	2062900	2.40E-04	0.057485	2.08E+11	2040360	2.40E-04	0.057485
2.19E+11	2149140	2.50E-04	0.05988	2.17E+11	2125620	2.50E-04	0.05988
2.28E+11	2235380	2.60E-04	0.062275	2.26E+11	2209900	2.60E-04	0.062275
2.37E+11	2320640	2.70E-04	0.064671	2.34E+11	2295160	2.70E-04	0.064671
2.46E+11	2406880	2.80E-04	0.067066	2.43E+11	2380420	2.80E-04	0.067066
2.54E+11	2493120	2.90E-04	0.069461	2.52E+11	2464700	2.90E-04	0.069461
2.63E+11	2578380	3.00E-04	0.071856	2.60E+11	2549960	3.00E-04	0.071856
2.72E+11	2664620	3.10E-04	0.074251	2.69E+11	2635220	3.10E-04	0.074251

2.81E+11	2750860	3.20E-04	0.076647	2.78E+11	2719500	3.20E-04	0.076647
2.89E+11	2836120	3.30E-04	0.079042	2.86E+11	2804760	3.30E-04	0.079042
2.98E+11	2922360	3.40E-04	0.081437	2.95E+11	2890020	3.40E-04	0.081437
3.07E+11	3008600	3.50E-04	0.083832	3.04E+11	2974300	3.50E-04	0.083832
3.16E+11	3093860	3.60E-04	0.086228	3.12E+11	3059560	3.60E-04	0.086228
3.25E+11	3180100	3.70E-04	0.088623	3.21E+11	3143840	3.70E-04	0.088623
3.33E+11	3266340	3.80E-04	0.091018	3.30E+11	3229100	3.80E-04	0.091018
3.42E+11	3351600	3.90E-04	0.093413	3.38E+11	3314360	3.90E-04	0.093413
3.51E+11	3437840	4.00E-04	0.095808	3.47E+11	3398640	4.00E-04	0.095808
3.60E+11	3523100	4.10E-04	0.098204	3.56E+11	3483900	4.10E-04	0.098204
3.68E+11	3609340	4.20E-04	0.100599	3.64E+11	3568180	4.20E-04	0.100599
3.77E+11	3695580	4.30E-04	0.102994	3.73E+11	3653440	4.30E-04	0.102994
3.86E+11	3780840	4.40E-04	0.105389	3.82E+11	3738700	4.40E-04	0.105389
3.95E+11	3867080	4.50E-04	0.107784	3.90E+11	3822980	4.50E-04	0.107784
4.03E+11	3953320	4.60E-04	0.11018	3.99E+11	3908240	4.60E-04	0.11018
4.12E+11	4038580	4.70E-04	0.112575	4.07E+11	3992520	4.70E-04	0.112575
4.21E+11	4124820	4.80E-04	0.11497	4.16E+11	4077780	4.80E-04	0.11497
4.30E+11	4210080	4.90E-04	0.117365	4.25E+11	4162060	4.90E-04	0.117365
4.38E+11	4296320	5.00E-04	0.11976	4.33E+11	4247320	5.00E-04	0.11976
4.47E+11	4382560	5.10E-04	0.122156	4.42E+11	4332580	5.10E-04	0.122156
4.56E+11	4467820	5.20E-04	0.124551	4.51E+11	4416860	5.20E-04	0.124551
4.65E+11	4554060	5.30E-04	0.126946	4.59E+11	4502120	5.30E-04	0.126946
4.73E+11	4639320	5.40E-04	0.129341	4.68E+11	4586400	5.40E-04	0.129341
4.82E+11	4725560	5.50E-04	0.131737	4.77E+11	4671660	5.50E-04	0.131737
4.91E+11	4810820	5.60E-04	0.134132	4.85E+11	4755940	5.60E-04	0.134132
5.00E+11	4897060	5.70E-04	0.136527	4.94E+11	4841200	5.70E-04	0.136527
5.09E+11	4983300	5.80E-04	0.138922	5.03E+11	4925480	5.80E-04	0.138922
5.17E+11	5068560	5.90E-04	0.141317	5.11E+11	5010740	5.90E-04	0.141317
5.26E+11	5154800	6.00E-04	0.143713	5.20E+11	5095020	6.00E-04	0.143713
5.35E+11	5240060	6.10E-04	0.146108	5.29E+11	5180280	6.10E-04	0.146108
5.44E+11	5326300	6.20E-04	0.148503	5.37E+11	5264560	6.20E-04	0.148503
5.52E+11	5411560	6.30E-04	0.150898	5.46E+11	5349820	6.30E-04	0.150898
5.61E+11	5497800	6.40E-04	0.153293	5.55E+11	5434100	6.40E-04	0.153293
5.70E+11	5584040	6.50E-04	0.155689	5.63E+11	5519360	6.50E-04	0.155689
5.79E+11	5669300	6.60E-04	0.158084	5.72E+11	5604620	6.60E-04	0.158084
5.87E+11	5755540	6.70E-04	0.160479	5.81E+11	5688900	6.70E-04	0.160479
5.96E+11	5840800	6.80E-04	0.162874	5.89E+11	5774160	6.80E-04	0.162874
6.05E+11	5927040	6.90E-04	0.165269	5.98E+11	5858440	6.90E-04	0.165269
6.14E+11	6012300	7.00E-04	0.167665	6.07E+11	5943700	7.00E-04	0.167665
6.22E+11	6098540	7.10E-04	0.17006	6.15E+11	6027980	7.10E-04	0.17006
6.31E+11	6183800	7.20E-04	0.172455	6.24E+11	6113240	7.20E-04	0.172455
6.40E+11	6270040	7.30E-04	0.17485	6.32E+11	6197520	7.30E-04	0.17485
6.49E+11	6355300	7.40E-04	0.177246	6.41E+11	6282780	7.40E-04	0.177246
6.57E+11	6441540	7.50E-04	0.179641	6.50E+11	6367060	7.50E-04	0.179641
6.66E+11	6526800	7.60E-04	0.182036	6.58E+11	6452320	7.60E-04	0.182036

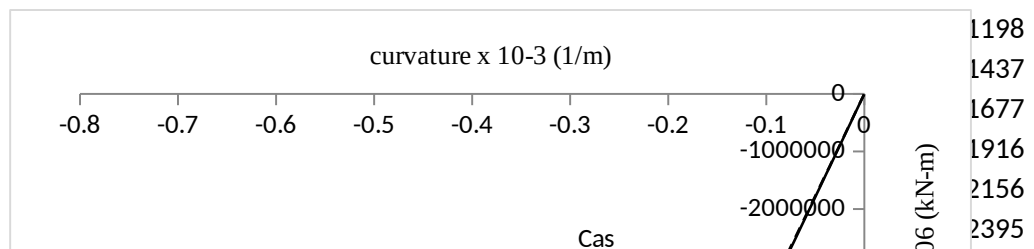
6.75E+11	6613040	7.70E-04	0.184431	6.65E+11	6517000	7.68E-04	0.18388
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6.92E+11	6784540	7.90E-04	0.189222	6.79E+11	6651260	7.86E-04	0.18824
7.01E+11	6869800	8.00E-04	0.191617	6.85E+11	6715940	7.96E-04	0.190635
7.10E+11	6956040	8.10E-04	0.194012	6.86E+11	6717900	7.96E-04	0.190683
7.19E+11	7041300	8.20E-04	0.196407	6.92E+11	6781600	8.06E-04	0.193078
7.22E+11	7071680	8.24E-04	0.197246	6.96E+11	6820800	8.12E-04	0.194539
7.29E+11	7147140	8.33E-04	0.199473	7.03E+11	6884500	8.22E-04	0.196934
7.36E+11	7208880	8.42E-04	0.201629	7.07E+11	6930560	8.30E-04	0.198707
7.40E+11	7252000	8.50E-04	0.203473	7.14E+11	6992300	8.40E-04	0.201102
7.45E+11	7299040	8.60E-04	0.205868	7.20E+11	7054040	8.50E-04	0.203497
7.47E+11	7323540	8.65E-04	0.207114	7.20E+11	7056980	8.50E-04	0.203617
7.52E+11	7368620	8.75E-04	0.209509	7.26E+11	7115780	8.60E-04	0.206012
7.56E+11	7410760	8.84E-04	0.211713	7.31E+11	7160860	8.68E-04	0.207832
7.61E+11	7452900	8.94E-04	0.214108	7.36E+11	7209860	8.77E-04	0.209988
7.64E+11	7491120	9.03E-04	0.216311	7.40E+11	7255920	8.86E-04	0.212096
7.68E+11	7522480	9.11E-04	0.218156	7.45E+11	7301000	8.95E-04	0.214251
7.71E+11	7558740	9.21E-04	0.220551	7.49E+11	7338240	9.03E-04	0.216168
7.75E+11	7595980	9.31E-04	0.222946	7.53E+11	7383320	9.13E-04	0.218563
7.78E+11	7625380	9.39E-04	0.224862	7.54E+11	7386260	9.13E-04	0.218683
7.82E+11	7658700	9.49E-04	0.227257	7.58E+11	7425460	9.22E-04	0.220934
7.85E+11	7688100	9.58E-04	0.229389	7.61E+11	7457800	9.31E-04	0.222874
7.88E+11	7719460	9.67E-04	0.231713	7.65E+11	7492100	9.41E-04	0.225269
7.91E+11	7747880	9.77E-04	0.234108	7.65E+11	7496020	9.42E-04	0.225509
7.94E+11	7776300	9.87E-04	0.236503	7.68E+11	7528360	9.52E-04	0.227904
7.97E+11	7805700	9.97E-04	0.238898	7.71E+11	7550900	9.59E-04	0.229605
7.97E+11	7805700	9.98E-04	0.23897	7.74E+11	7580300	9.69E-04	0.232
7.99E+11	7832160	1.01E-03	0.241437	7.76E+11	7608720	9.79E-04	0.234395
8.02E+11	7855680	1.02E-03	0.243593	7.77E+11	7618520	9.82E-04	0.235257
8.04E+11	7880180	1.03E-03	0.245988	7.80E+11	7645960	9.92E-04	0.237653
8.05E+11	7888020	1.03E-03	0.246707	7.83E+11	7672420	1.00E-03	0.24
8.07E+11	7909580	1.04E-03	0.249102	7.83E+11	7676340	1.00E-03	0.240479
8.09E+11	7931140	1.05E-03	0.251497	7.86E+11	7699860	1.01E-03	0.242874
8.12E+11	7952700	1.06E-03	0.253892	7.86E+11	7700840	1.01E-03	0.242874
8.12E+11	7958580	1.06E-03	0.254611	7.88E+11	7722400	1.02E-03	0.245269
8.14E+11	7975240	1.07E-03	0.257006	7.90E+11	7743960	1.03E-03	0.247665
8.16E+11	7991900	1.08E-03	0.259401	7.91E+11	7748860	1.04E-03	0.248144
8.17E+11	8008560	1.09E-03	0.261796	7.93E+11	7768460	1.05E-03	0.250539
8.18E+11	8011500	1.09E-03	0.262036	7.94E+11	7783160	1.05E-03	0.252216
8.19E+11	8025220	1.10E-03	0.264431	7.96E+11	7801780	1.06E-03	0.254611
8.20E+11	8038940	1.11E-03	0.266826	7.98E+11	7821380	1.07E-03	0.257006
8.22E+11	8052660	1.12E-03	0.269222	7.99E+11	7832160	1.08E-03	0.258443
8.22E+11	8054620	1.13E-03	0.269701	8.01E+11	7848820	1.09E-03	0.260838
8.23E+11	8066380	1.14E-03	0.272096	8.03E+11	7864500	1.10E-03	0.263234
8.24E+11	8078140	1.15E-03	0.274251	8.04E+11	7881160	1.11E-03	0.265629

8.25E+11	8087940	1.16E-03	0.276647	8.06E+11	7896840	1.12E-03	0.268024
8.26E+11	8097740	1.17E-03	0.279042	8.07E+11	7912520	1.13E-03	0.270419
8.27E+11	8107540	1.18E-03	0.281437	8.08E+11	7919380	1.13E-03	0.271377
8.28E+11	8118320	1.19E-03	0.283832	8.10E+11	7934080	1.14E-03	0.273772
8.29E+11	8120280	1.19E-03	0.284311	8.11E+11	7948780	1.15E-03	0.276168
8.30E+11	8130080	1.20E-03	0.286707	8.12E+11	7954660	1.16E-03	0.277126
8.30E+11	8136940	1.21E-03	0.288623	8.13E+11	7968380	1.17E-03	0.279521
8.31E+11	8144780	1.22E-03	0.291018	8.14E+11	7981120	1.18E-03	0.281916
8.32E+11	8151640	1.23E-03	0.293413	8.15E+11	7985040	1.18E-03	0.282635
8.33E+11	8158500	1.24E-03	0.295808	8.16E+11	7996800	1.19E-03	0.28503
8.33E+11	8166340	1.25E-03	0.298204	8.17E+11	8008560	1.20E-03	0.287425
8.34E+11	8173200	1.26E-03	0.300599	8.19E+11	8021300	1.21E-03	0.28982
8.35E+11	8180060	1.27E-03	0.302994	8.20E+11	8033060	1.22E-03	0.292216
8.36E+11	8187900	1.28E-03	0.305389	8.21E+11	8040900	1.23E-03	0.293653
8.36E+11	8194760	1.29E-03	0.307784	8.22E+11	8050700	1.24E-03	0.296048
8.37E+11	8201620	1.30E-03	0.31018	8.22E+11	8051680	1.24E-03	0.296527
8.38E+11	8208480	1.31E-03	0.312575	8.23E+11	8061480	1.25E-03	0.298922
8.38E+11	8216320	1.32E-03	0.31497	8.24E+11	8070300	1.26E-03	0.301317
8.39E+11	8223180	1.33E-03	0.317365	8.24E+11	8079120	1.27E-03	0.303713
8.40E+11	8230040	1.34E-03	0.31976	8.24E+11	8079120	1.27E-03	0.303713
8.41E+11	8237880	1.35E-03	0.322156	8.25E+11	8087940	1.28E-03	0.306108
8.41E+11	8244740	1.36E-03	0.324551	8.26E+11	8091860	1.28E-03	0.307066
8.42E+11	8251600	1.37E-03	0.326946	8.27E+11	8099700	1.29E-03	0.309461
8.43E+11	8258460	1.38E-03	0.329341	8.27E+11	8106560	1.30E-03	0.311856
8.44E+11	8266300	1.39E-03	0.331737	8.28E+11	8113420	1.31E-03	0.314251
8.44E+11	8273160	1.40E-03	0.334132	8.28E+11	8115380	1.32E-03	0.31497
8.45E+11	8280020	1.41E-03	0.336527	8.29E+11	8122240	1.33E-03	0.317365
8.46E+11	8286880	1.42E-03	0.338922	8.30E+11	8129100	1.34E-03	0.31976
8.46E+11	8293740	1.43E-03	0.341317	8.30E+11	8135960	1.35E-03	0.322156
8.47E+11	8301580	1.44E-03	0.343713	8.31E+11	8139880	1.35E-03	0.323353
8.48E+11	8308440	1.45E-03	0.346108	8.31E+11	8146740	1.36E-03	0.325749
8.49E+11	8315300	1.46E-03	0.348503	8.32E+11	8153600	1.37E-03	0.328144
8.49E+11	8322160	1.47E-03	0.350898	8.33E+11	8159480	1.38E-03	0.330539
8.50E+11	8329020	1.48E-03	0.353293	8.33E+11	8166340	1.39E-03	0.332934
8.51E+11	8335880	1.49E-03	0.355689	8.34E+11	8168300	1.39E-03	0.333653
8.51E+11	8337840	1.49E-03	0.356647	8.34E+11	8174180	1.40E-03	0.336048
8.51E+11	8341760	1.50E-03	0.359042	8.35E+11	8180060	1.41E-03	0.338443
8.52E+11	8345680	1.51E-03	0.361437	8.35E+11	8183000	1.42E-03	0.339401
8.52E+11	8348620	1.52E-03	0.363832	8.36E+11	8187900	1.43E-03	0.341796
8.52E+11	8352540	1.53E-03	0.366228	8.36E+11	8192800	1.44E-03	0.344192
8.53E+11	8356460	1.54E-03	0.368623	8.37E+11	8198680	1.45E-03	0.346587
8.53E+11	8359400	1.55E-03	0.371018	8.37E+11	8203580	1.46E-03	0.348982
8.53E+11	8363320	1.56E-03	0.373413	8.37E+11	8203580	1.46E-03	0.349222
8.54E+11	8367240	1.57E-03	0.375808	8.38E+11	8209460	1.47E-03	0.351617
8.54E+11	8370180	1.58E-03	0.378204	8.38E+11	8214360	1.48E-03	0.354012

8.55E+11	8374100	1.59E-03	0.380599	8.39E+11	8219260	1.49E-03	0.356407
8.55E+11	8377040	1.60E-03	0.382994	8.39E+11	8224160	1.50E-03	0.358802
8.55E+11	8380960	1.61E-03	0.385389	8.40E+11	8229060	1.51E-03	0.361198
8.56E+11	8384880	1.62E-03	0.387784	8.40E+11	8233960	1.52E-03	0.363593
8.56E+11	8387820	1.63E-03	0.39018	8.41E+11	8238860	1.53E-03	0.365988
8.56E+11	8391740	1.64E-03	0.392575	8.41E+11	8240820	1.53E-03	0.366467
8.57E+11	8394680	1.65E-03	0.39497	8.41E+11	8245720	1.54E-03	0.368862
8.57E+11	8398600	1.66E-03	0.397365	8.42E+11	8249640	1.55E-03	0.371257
8.57E+11	8401540	1.67E-03	0.39976	8.42E+11	8254540	1.56E-03	0.373653
8.58E+11	8405460	1.68E-03	0.402156	8.43E+11	8259440	1.57E-03	0.376048
8.58E+11	8408400	1.69E-03	0.404551	8.43E+11	8264340	1.58E-03	0.378443
8.58E+11	8411340	1.70E-03	0.406946	8.44E+11	8269240	1.59E-03	0.380838
8.59E+11	8415260	1.71E-03	0.409341	8.44E+11	8272180	1.60E-03	0.382275
8.59E+11	8418200	1.72E-03	0.411737	8.45E+11	8277080	1.61E-03	0.384671
8.59E+11	8422120	1.73E-03	0.414132	8.45E+11	8281980	1.62E-03	0.387066
8.60E+11	8425060	1.74E-03	0.416527	8.46E+11	8286880	1.63E-03	0.389461
8.60E+11	8428000	1.75E-03	0.418922	8.46E+11	8291780	1.64E-03	0.391856
8.60E+11	8431920	1.76E-03	0.421317	8.46E+11	8293740	1.64E-03	0.393293
8.61E+11	8434860	1.77E-03	0.423713	8.47E+11	8298640	1.65E-03	0.395689
8.61E+11	8437800	1.78E-03	0.426108	8.47E+11	8303540	1.66E-03	0.398084
8.61E+11	8441720	1.79E-03	0.428503	8.48E+11	8308440	1.67E-03	0.400479
8.62E+11	8444660	1.80E-03	0.430898	8.48E+11	8308440	1.67E-03	0.400719
8.62E+11	8446620	1.81E-03	0.432335	8.48E+11	8313340	1.68E-03	0.403114
8.62E+11	8449560	1.82E-03	0.434731	8.49E+11	8318240	1.69E-03	0.405509
8.63E+11	8452500	1.83E-03	0.437126	8.49E+11	8322160	1.70E-03	0.407904
8.63E+11	8456420	1.84E-03	0.439521	8.50E+11	8327060	1.71E-03	0.410299
8.63E+11	8459360	1.85E-03	0.441916	8.50E+11	8328040	1.72E-03	0.411018
8.63E+11	8460340	1.85E-03	0.442635	8.50E+11	8332940	1.73E-03	0.413413
8.64E+11	8462300	1.86E-03	0.44503	8.51E+11	8337840	1.74E-03	0.415808
8.64E+11	8465240	1.87E-03	0.447425	8.51E+11	8341760	1.75E-03	0.418204
8.64E+11	8468180	1.88E-03	0.44982	8.52E+11	8346660	1.76E-03	0.420599
8.64E+11	8469160	1.88E-03	0.451257	8.52E+11	8350580	1.77E-03	0.422994
8.64E+11	8471120	1.89E-03	0.453653	8.53E+11	8355480	1.78E-03	0.425389
8.65E+11	8472100	1.90E-03	0.456048	8.53E+11	8359400	1.79E-03	0.427784
8.65E+11	8473080	1.91E-03	0.458443	8.53E+11	8361360	1.79E-03	0.428503
8.65E+11	8474060	1.92E-03	0.460838	8.54E+11	8366260	1.80E-03	0.430898
8.65E+11	8474060	1.93E-03	0.463234	8.54E+11	8370180	1.81E-03	0.433293
8.65E+11	8474060	1.94E-03	0.465629	8.55E+11	8375080	1.82E-03	0.435689
8.65E+11	8474060	1.95E-03	0.468024	8.55E+11	8376060	1.82E-03	0.436168
8.65E+11	8474060	1.96E-03	0.470419	8.55E+11	8379980	1.83E-03	0.438563
8.65E+11	8474060	1.97E-03	0.472814	8.56E+11	8383900	1.84E-03	0.440958
8.65E+11	8474060	1.98E-03	0.47521	8.56E+11	8387820	1.85E-03	0.443114
8.65E+11	8474060	1.99E-03	0.477605	8.56E+11	8391740	1.86E-03	0.445509
8.65E+11	8474060	2.00E-03	0.48	8.57E+11	8395660	1.87E-03	0.447904
8.65E+11	8474060	2.01E-03	0.481916	8.57E+11	8400560	1.88E-03	0.450299

8.65E+11	8475040	2.02E-03	0.484311	8.58E+11	8404480	1.89E-03	0.452695
8.65E+11	8475040	2.03E-03	0.486707	8.58E+11	8408400	1.90E-03	0.45509
8.65E+11	8475040	2.04E-03	0.489102	8.58E+11	8409380	1.90E-03	0.455329
8.65E+11	8476020	2.05E-03	0.491497	8.58E+11	8411340	1.91E-03	0.457725
8.65E+11	8476020	2.06E-03	0.492216	8.59E+11	8413300	1.92E-03	0.46012
8.65E+11	8477000	2.07E-03	0.494611	8.59E+11	8416240	1.93E-03	0.462515
8.65E+11	8477980	2.08E-03	0.497006	8.59E+11	8418200	1.94E-03	0.46491
8.65E+11	8477980	2.08E-03	0.497964	8.59E+11	8420160	1.95E-03	0.467305
8.65E+11	8478960	2.09E-03	0.500359	8.59E+11	8422120	1.96E-03	0.469461
8.65E+11	8478960	2.10E-03	0.502754	8.60E+11	8425060	1.97E-03	0.471856
8.65E+11	8479940	2.11E-03	0.50515	8.60E+11	8427020	1.98E-03	0.474251
8.65E+11	8480920	2.12E-03	0.507545	8.60E+11	8428980	1.99E-03	0.476647
8.66E+11	8481900	2.13E-03	0.50994	8.60E+11	8431920	2.00E-03	0.479042
8.66E+11	8481900	2.14E-03	0.512096	8.61E+11	8433880	2.01E-03	0.481437
8.66E+11	8482880	2.15E-03	0.514491	8.61E+11	8435840	2.02E-03	0.483832
8.66E+11	8483860	2.16E-03	0.516886	8.61E+11	8436820	2.03E-03	0.48503
8.66E+11	8484840	2.17E-03	0.519281	8.61E+11	8438780	2.04E-03	0.487425
8.66E+11	8485820	2.18E-03	0.521677	8.61E+11	8441720	2.05E-03	0.48982
8.66E+11	8486800	2.19E-03	0.524072	8.62E+11	8443680	2.06E-03	0.492216
8.66E+11	8487780	2.20E-03	0.526467	8.62E+11	8445640	2.07E-03	0.494611
8.66E+11	8488760	2.21E-03	0.528862	8.62E+11	8447600	2.08E-03	0.497006
8.66E+11	8489740	2.22E-03	0.531257	8.62E+11	8450540	2.09E-03	0.499401
8.66E+11	8490720	2.22E-03	0.531976	8.62E+11	8451520	2.09E-03	0.500599
8.67E+11	8491700	2.23E-03	0.534371	8.63E+11	8453480	2.10E-03	0.502994
8.67E+11	8492680	2.24E-03	0.536766	8.63E+11	8455440	2.11E-03	0.505389
8.67E+11	8493660	2.25E-03	0.539162	8.63E+11	8457400	2.12E-03	0.507784
8.67E+11	8494640	2.26E-03	0.541557	8.63E+11	8458380	2.13E-03	0.509222
8.67E+11	8496600	2.27E-03	0.543952	8.63E+11	8460340	2.14E-03	0.511617
8.67E+11	8497580	2.28E-03	0.546347	8.64E+11	8462300	2.15E-03	0.514012
8.67E+11	8498560	2.29E-03	0.548743	8.64E+11	8464260	2.16E-03	0.516407
8.67E+11	8499540	2.30E-03	0.551138	8.64E+11	8465240	2.16E-03	0.517605
8.67E+11	8500520	2.31E-03	0.553533	8.64E+11	8466220	2.17E-03	0.52
8.68E+11	8502480	2.32E-03	0.555928	8.64E+11	8467200	2.18E-03	0.522395
8.68E+11	8502480	2.33E-03	0.557365	8.64E+11	8467200	2.19E-03	0.52479
8.68E+11	8503460	2.34E-03	0.55976	8.64E+11	8468180	2.20E-03	0.527186
8.68E+11	8505420	2.35E-03	0.562156	8.64E+11	8468180	2.20E-03	0.527665
8.68E+11	8506400	2.36E-03	0.564551	8.64E+11	8469160	2.21E-03	0.53006
8.68E+11	8507380	2.37E-03	0.566946	8.64E+11	8470140	2.22E-03	0.532455
8.68E+11	8508360	2.38E-03	0.569341	8.64E+11	8471120	2.23E-03	0.53485
8.68E+11	8510320	2.39E-03	0.571737	8.64E+11	8471120	2.24E-03	0.537246
8.69E+11	8511300	2.40E-03	0.574132	8.65E+11	8472100	2.25E-03	0.539641
8.69E+11	8512280	2.41E-03	0.576527	8.65E+11	8473080	2.26E-03	0.542036
8.69E+11	8514240	2.42E-03	0.578922	8.65E+11	8473080	2.26E-03	0.542036
8.69E+11	8515220	2.43E-03	0.581317	8.65E+11	8473080	2.27E-03	0.544431
8.69E+11	8516200	2.44E-03	0.583713	8.65E+11	8474060	2.28E-03	0.546826

8.69E+11	8518160	2.45E-03	0.586108	8.65E+11	8474060	2.29E-03	0.549222
8.69E+11	8519140	2.46E-03	0.588503	8.65E+11	8475040	2.30E-03	0.551617
8.70E+11	8521100	2.47E-03	0.590898	8.65E+11	8475040	2.31E-03	0.554012
8.70E+11	8522080	2.47E-03	0.592335	8.65E+11	8475040	2.32E-03	0.556407
8.70E+11	8523060	2.48E-03	0.594731	8.65E+11	8476020	2.33E-03	0.558802
8.70E+11	8524040	2.49E-03	0.597126	8.65E+11	8476020	2.34E-03	0.56
8.70E+11	8526000	2.50E-03	0.599521	8.65E+11	8476020	2.35E-03	0.562395
8.70E+11	8526980	2.51E-03	0.601916	8.65E+11	8476020	2.36E-03	0.56479
8.70E+11	8527960	2.52E-03	0.602874	8.65E+11	8476020	2.37E-03	0.567186
8.70E+11	8528940	2.53E-03	0.605269	8.65E+11	8476020	2.38E-03	0.569581
8.71E+11	8530900	2.54E-03	0.607665	8.65E+11	8476020	2.38E-03	0.570778
8.71E+11	8531880	2.55E-03	0.61006	8.65E+11	8476020	2.39E-03	0.573174
8.71E+11	8533840	2.56E-03	0.612455	8.65E+11	8476020	2.40E-03	0.575329
8.71E+11	8534820	2.57E-03	0.61485	8.65E+11	8475040	2.41E-03	0.577725
8.71E+11	8536780	2.58E-03	0.617246	8.65E+11	8474060	2.42E-03	0.58012
8.71E+11	8538740	2.59E-03	0.619641	8.65E+11	8473080	2.43E-03	0.582515
8.71E+11	8539720	2.60E-03	0.622036	8.65E+11	8472100	2.44E-03	0.58491
8.72E+11	8541680	2.61E-03	0.624431	8.64E+11	8471120	2.45E-03	0.587305
8.72E+11	8542660	2.62E-03	0.626826	8.64E+11	8470140	2.46E-03	0.589701
8.72E+11	8544620	2.63E-03	0.629222	8.64E+11	8469160	2.47E-03	0.592096
8.72E+11	8545600	2.64E-03	0.631617	8.64E+11	8469160	2.47E-03	0.592096
8.72E+11	8547560	2.65E-03	0.634012	8.64E+11	8468180	2.48E-03	0.594491
8.72E+11	8549520	2.66E-03	0.636407	8.64E+11	8467200	2.49E-03	0.596886
8.73E+11	8550500	2.67E-03	0.638802	8.64E+11	8466220	2.50E-03	0.598323
8.73E+11	8551480	2.67E-03	0.640479	8.64E+11	8465240	2.51E-03	0.600719
8.73E+11	8553440	2.68E-03	0.642874	8.64E+11	8463280	2.52E-03	0.603114
8.73E+11	8555400	2.69E-03	0.645269	8.64E+11	8462300	2.53E-03	0.605509
8.73E+11	8556380	2.70E-03	0.647665	8.63E+11	8461320	2.54E-03	0.607904
8.73E+11	8558340	2.71E-03	0.65006	8.63E+11	8460340	2.54E-03	0.608623
8.73E+11	8559320	2.72E-03	0.652455	8.63E+11	8458380	2.55E-03	0.611018
8.74E+11	8561280	2.73E-03	0.65485	8.63E+11	8457400	2.56E-03	0.612695
8.74E+11	8563240	2.74E-03	0.657246	8.63E+11	8454460	2.57E-03	0.61509
8.74E+11	8564220	2.75E-03	0.659641	8.62E+11	8451520	2.58E-03	0.617485
8.74E+11	8566180	2.76E-03	0.662036	8.62E+11	8450540	2.58E-03	0.618683
0.00E+00	0	0.00E+00		0.00E+00	0	0.00E+00	
-8.79E+08	-8616.16	-1.00E-06	-0.00024	-8.70E+08	-8522.08	-1.00E-06	-0.00024
-1.76E+09	-17208.8	-2.00E-06	-0.000479	-1.74E+09	-17022.6	-2.00E-06	-0.000479
-2.63E+09	-25803.4	-3.00E-06	-0.000719	-2.61E+09	-25529	-3.00E-06	-0.000719
-3.51E+09	-34398	-4.00E-06	-0.000958	-3.47E+09	-34025.6	-4.00E-06	-0.000958
-4.39E+09							1198
-5.26E+09							1437
-6.14E+09							1677
-7.02E+09							1916
-7.90E+09							2156
-8.77E+09							2395



-8.77E+10	-859558	-1.00E-04	-0.023952	-8.68E+10	-850150	-1.00E-04	-0.023952
-9.65E+10	-945406	-1.10E-04	-0.026347	-9.54E+10	-935018	-1.10E-04	-0.026347
-1.05E+11	-1030960	-1.20E-04	-0.028743	-1.04E+11	-1020180	-1.20E-04	-0.028743
-1.14E+11	-1117200	-1.30E-04	-0.031138	-1.13E+11	-1104460	-1.30E-04	-0.031138
-1.23E+11	-1202460	-1.40E-04	-0.033533	-1.21E+11	-1189720	-1.40E-04	-0.033533
-1.32E+11	-1288700	-1.50E-04	-0.035928	-1.30E+11	-1274980	-1.50E-04	-0.035928
-1.40E+11	-1373960	-1.60E-04	-0.038323	-1.39E+11	-1359260	-1.60E-04	-0.038323
-1.49E+11	-1460200	-1.70E-04	-0.040719	-1.47E+11	-1444520	-1.70E-04	-0.040719
-1.58E+11	-1545460	-1.80E-04	-0.043114	-1.56E+11	-1528800	-1.80E-04	-0.043114
-1.67E+11	-1631700	-1.90E-04	-0.045509	-1.65E+11	-1613080	-1.90E-04	-0.045509
-1.75E+11	-1716960	-2.00E-04	-0.047904	-1.73E+11	-1698340	-2.00E-04	-0.047904
-1.84E+11	-1802220	-2.10E-04	-0.050299	-1.82E+11	-1782620	-2.10E-04	-0.050299
-1.93E+11	-1888460	-2.20E-04	-0.052695	-1.91E+11	-1866900	-2.20E-04	-0.052695
-2.01E+11	-1973720	-2.30E-04	-0.05509	-1.99E+11	-1951180	-2.30E-04	-0.05509
-2.10E+11	-2058980	-2.40E-04	-0.057485	-2.08E+11	-2036440	-2.40E-04	-0.057485
-2.19E+11	-2144240	-2.50E-04	-0.05988	-2.16E+11	-2120720	-2.50E-04	-0.05988
-2.28E+11	-2229500	-2.60E-04	-0.062275	-2.25E+11	-2205000	-2.60E-04	-0.062275
-2.36E+11	-2314760	-2.70E-04	-0.064671	-2.34E+11	-2289280	-2.70E-04	-0.064671
-2.45E+11	-2400020	-2.80E-04	-0.067066	-2.42E+11	-2373560	-2.80E-04	-0.067066
-2.54E+11	-2485280	-2.90E-04	-0.069461	-2.51E+11	-2457840	-2.90E-04	-0.069461
-2.62E+11	-2570540	-3.00E-04	-0.071856	-2.59E+11	-2542120	-3.00E-04	-0.071856
-2.71E+11	-2655800	-3.10E-04	-0.074251	-2.68E+11	-2626400	-3.10E-04	-0.074251
-2.80E+11	-2741060	-3.20E-04	-0.076647	-2.77E+11	-2710680	-3.20E-04	-0.076647
-2.88E+11	-2825340	-3.30E-04	-0.079042	-2.85E+11	-2794960	-3.30E-04	-0.079042
-2.97E+11	-2910600	-3.40E-04	-0.081437	-2.94E+11	-2879240	-3.40E-04	-0.081437
-3.06E+11	-2995860	-3.50E-04	-0.083832	-3.02E+11	-2963520	-3.50E-04	-0.083832
-3.14E+11	-3081120	-3.60E-04	-0.086228	-3.11E+11	-3047800	-3.60E-04	-0.086228
-3.23E+11	-3166380	-3.70E-04	-0.088623	-3.20E+11	-3132080	-3.70E-04	-0.088623
-3.32E+11	-3251640	-3.80E-04	-0.091018	-3.28E+11	-3216360	-3.80E-04	-0.091018
-3.41E+11	-3336900	-3.90E-04	-0.093413	-3.37E+11	-3300640	-3.90E-04	-0.093413
-3.49E+11	-3421180	-4.00E-04	-0.095808	-3.45E+11	-3384920	-4.00E-04	-0.095808
-3.58E+11	-3506440	-4.10E-04	-0.098204	-3.54E+11	-3469200	-4.10E-04	-0.098204
-3.67E+11	-3591700	-4.20E-04	-0.100599	-3.63E+11	-3553480	-4.20E-04	-0.100599
-3.75E+11	-3676960	-4.30E-04	-0.102994	-3.71E+11	-3637760	-4.30E-04	-0.102994
-3.84E+11	-3761240	-4.40E-04	-0.105389	-3.80E+11	-3722040	-4.40E-04	-0.105389
-3.93E+11	-3846500	-4.50E-04	-0.107784	-3.88E+11	-3806320	-4.50E-04	-0.107784
-4.01E+11	-3931760	-4.60E-04	-0.11018	-3.97E+11	-3889620	-4.60E-04	-0.11018

-4.10E+11	-4016040	-4.70E-04	-0.112575	-4.06E+11	-3973900	-4.70E-04	-0.112575
-4.19E+11	-4101300	-4.80E-04	-0.11497	-4.14E+11	-4058180	-4.80E-04	-0.11497
-4.27E+11	-4186560	-4.90E-04	-0.117365	-4.23E+11	-4142460	-4.90E-04	-0.117365
-4.36E+11	-4270840	-5.00E-04	-0.11976	-4.31E+11	-4225760	-5.00E-04	-0.11976
-4.45E+11	-4356100	-5.10E-04	-0.122156	-4.40E+11	-4310040	-5.10E-04	-0.122156
-4.53E+11	-4440380	-5.20E-04	-0.124551	-4.48E+11	-4393340	-5.20E-04	-0.124551
-4.62E+11	-4524660	-5.30E-04	-0.126946	-4.57E+11	-4477620	-5.30E-04	-0.126946
-4.70E+11	-4608940	-5.40E-04	-0.129341	-4.65E+11	-4560920	-5.40E-04	-0.129341
-4.79E+11	-4693220	-5.50E-04	-0.131737	-4.74E+11	-4644220	-5.50E-04	-0.131737
-4.88E+11	-4777500	-5.60E-04	-0.134132	-4.82E+11	-4727520	-5.60E-04	-0.134132
-4.96E+11	-4860800	-5.70E-04	-0.136527	-4.91E+11	-4810820	-5.70E-04	-0.136527
-5.05E+11	-4945080	-5.80E-04	-0.138922	-4.99E+11	-4894120	-5.80E-04	-0.138922
-5.13E+11	-5028380	-5.90E-04	-0.141317	-5.08E+11	-4977420	-5.90E-04	-0.141317
-5.22E+11	-5111680	-6.00E-04	-0.143713	-5.16E+11	-5059740	-6.00E-04	-0.143713
-5.30E+11	-5194980	-6.10E-04	-0.146108	-5.25E+11	-5143040	-6.10E-04	-0.146108
-5.39E+11	-5278280	-6.20E-04	-0.148503	-5.33E+11	-5225360	-6.20E-04	-0.148503
-5.47E+11	-5361580	-6.30E-04	-0.150898	-5.42E+11	-5307680	-6.30E-04	-0.150898
-5.56E+11	-5443900	-6.40E-04	-0.153293	-5.50E+11	-5390000	-6.40E-04	-0.153293
-5.64E+11	-5527200	-6.50E-04	-0.155689	-5.58E+11	-5471340	-6.50E-04	-0.155689
-5.72E+11	-5609520	-6.60E-04	-0.158084	-5.67E+11	-5552680	-6.60E-04	-0.158084
-5.81E+11	-5690860	-6.70E-04	-0.160479	-5.75E+11	-5634020	-6.70E-04	-0.160479
-5.89E+11	-5773180	-6.80E-04	-0.162874	-5.83E+11	-5712420	-6.80E-04	-0.162874
-5.97E+11	-5854520	-6.90E-04	-0.165269	-5.91E+11	-5790820	-6.90E-04	-0.165269
-6.06E+11	-5935860	-7.00E-04	-0.167665	-5.99E+11	-5869220	-7.00E-04	-0.167665
-6.14E+11	-6015240	-7.10E-04	-0.17006	-6.07E+11	-5945660	-7.10E-04	-0.17006
-6.22E+11	-6094620	-7.20E-04	-0.172455	-6.11E+11	-5982900	-7.15E-04	-0.171234
-6.30E+11	-6172040	-7.30E-04	-0.17485	-6.18E+11	-6058360	-7.25E-04	-0.173629
-6.38E+11	-6247500	-7.40E-04	-0.177246	-6.19E+11	-6064240	-7.26E-04	-0.173844
-6.45E+11	-6321980	-7.50E-04	-0.179641	-6.21E+11	-6081880	-7.33E-04	-0.175641
-6.51E+11	-6374900	-7.57E-04	-0.181341	-6.23E+11	-6101480	-7.40E-04	-0.177269
-6.57E+11	-6436640	-7.66E-04	-0.183449	-6.24E+11	-6116180	-7.45E-04	-0.178491
-6.61E+11	-6479760	-7.73E-04	-0.185102	-6.27E+11	-6139700	-7.54E-04	-0.180623
-6.64E+11	-6508180	-7.80E-04	-0.186802	-6.29E+11	-6166160	-7.64E-04	-0.183018
-6.65E+11	-6516020	-7.86E-04	-0.188359	-6.30E+11	-6171060	-7.66E-04	-0.183497
-6.63E+11	-6500340	-7.94E-04	-0.190084	-6.32E+11	-6192620	-7.76E-04	-0.185892
-6.61E+11	-6472900	-8.04E-04	-0.192479	-6.32E+11	-6197520	-7.79E-04	-0.186515
-6.59E+11	-6461140	-8.08E-04	-0.193509	-6.33E+11	-6205360	-7.85E-04	-0.187904
-6.58E+11	-6446440	-8.14E-04	-0.194994	-6.33E+11	-6206340	-7.91E-04	-0.189389
-6.56E+11	-6423900	-8.23E-04	-0.197198	-6.33E+11	-6201440	-7.96E-04	-0.190754
-6.52E+11	-6384700	-8.33E-04	-0.199593	-6.32E+11	-6190660	-8.03E-04	-0.192287
-6.47E+11	-6342560	-8.43E-04	-0.201892	-6.30E+11	-6169100	-8.11E-04	-0.194156
-6.41E+11	-6276900	-8.53E-04	-0.204287	-6.27E+11	-6142640	-8.18E-04	-0.195952
-6.39E+11	-6262200	-8.55E-04	-0.204671	-6.24E+11	-6112260	-8.25E-04	-0.197629
-6.28E+11	-6157340	-8.65E-04	-0.207066	-6.19E+11	-6062280	-8.35E-04	-0.200024
-6.25E+11	-6121080	-8.68E-04	-0.207832	-6.18E+11	-6057380	-8.36E-04	-0.200287

-6.18E+11	-6052480	-8.74E-04	-0.209246	-6.14E+11	-6018180	-8.45E-04	-0.202467
-6.05E+11	-5931940	-8.84E-04	-0.211641	-6.11E+11	-5983880	-8.55E-04	-0.204719
-5.93E+11	-5810420	-8.94E-04	-0.214036	-6.07E+11	-5950560	-8.64E-04	-0.206994
-5.82E+11	-5703600	-9.04E-04	-0.216431	-6.05E+11	-5929980	-8.70E-04	-0.208383
-5.78E+11	-5665380	-9.08E-04	-0.217437	-6.02E+11	-5894700	-8.79E-04	-0.210611
-5.69E+11	-5572280	-9.18E-04	-0.219832	-5.97E+11	-5852560	-8.89E-04	-0.213006
-5.61E+11	-5497800	-9.28E-04	-0.222228	-5.94E+11	-5821200	-8.97E-04	-0.214731
-5.55E+11	-5435080	-9.38E-04	-0.224623	-5.91E+11	-5787880	-9.04E-04	-0.216527
-5.49E+11	-5376280	-9.48E-04	-0.227018	-5.88E+11	-5757500	-9.11E-04	-0.218251
-5.47E+11	-5359620	-9.51E-04	-0.227784	-5.83E+11	-5712420	-9.21E-04	-0.220575
-5.42E+11	-5307680	-9.61E-04	-0.23018	-5.78E+11	-5660480	-9.31E-04	-0.22297
-5.37E+11	-5258680	-9.71E-04	-0.232575	-5.76E+11	-5645780	-9.34E-04	-0.223617
-5.32E+11	-5211640	-9.81E-04	-0.23497	-5.70E+11	-5588940	-9.44E-04	-0.226012
-5.32E+11	-5211640	-9.81E-04	-0.235018	-5.64E+11	-5527200	-9.54E-04	-0.228407
-5.28E+11	-5169500	-9.91E-04	-0.237413	-5.62E+11	-5509560	-9.57E-04	-0.229126
-5.23E+11	-5128340	-1.00E-03	-0.23976	-5.58E+11	-5469380	-9.62E-04	-0.230395
-5.19E+11	-5089140	-1.01E-03	-0.242156	-5.51E+11	-5394900	-9.72E-04	-0.23279
-5.16E+11	-5053860	-1.02E-03	-0.244551	-5.44E+11	-5326300	-9.82E-04	-0.235186
-5.12E+11	-5019560	-1.03E-03	-0.246946	-5.37E+11	-5265540	-9.92E-04	-0.237581
-5.09E+11	-4986240	-1.04E-03	-0.249341	-5.35E+11	-5244960	-9.96E-04	-0.238515
-5.06E+11	-4953900	-1.05E-03	-0.251737	-5.30E+11	-5189100	-1.01E-03	-0.240958
-5.03E+11	-4924500	-1.06E-03	-0.254132	-5.25E+11	-5142060	-1.02E-03	-0.243353
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-4.97E+11	-4866680	-1.08E-03	-0.258922	-5.19E+11	-5086200	-1.03E-03	-0.246467
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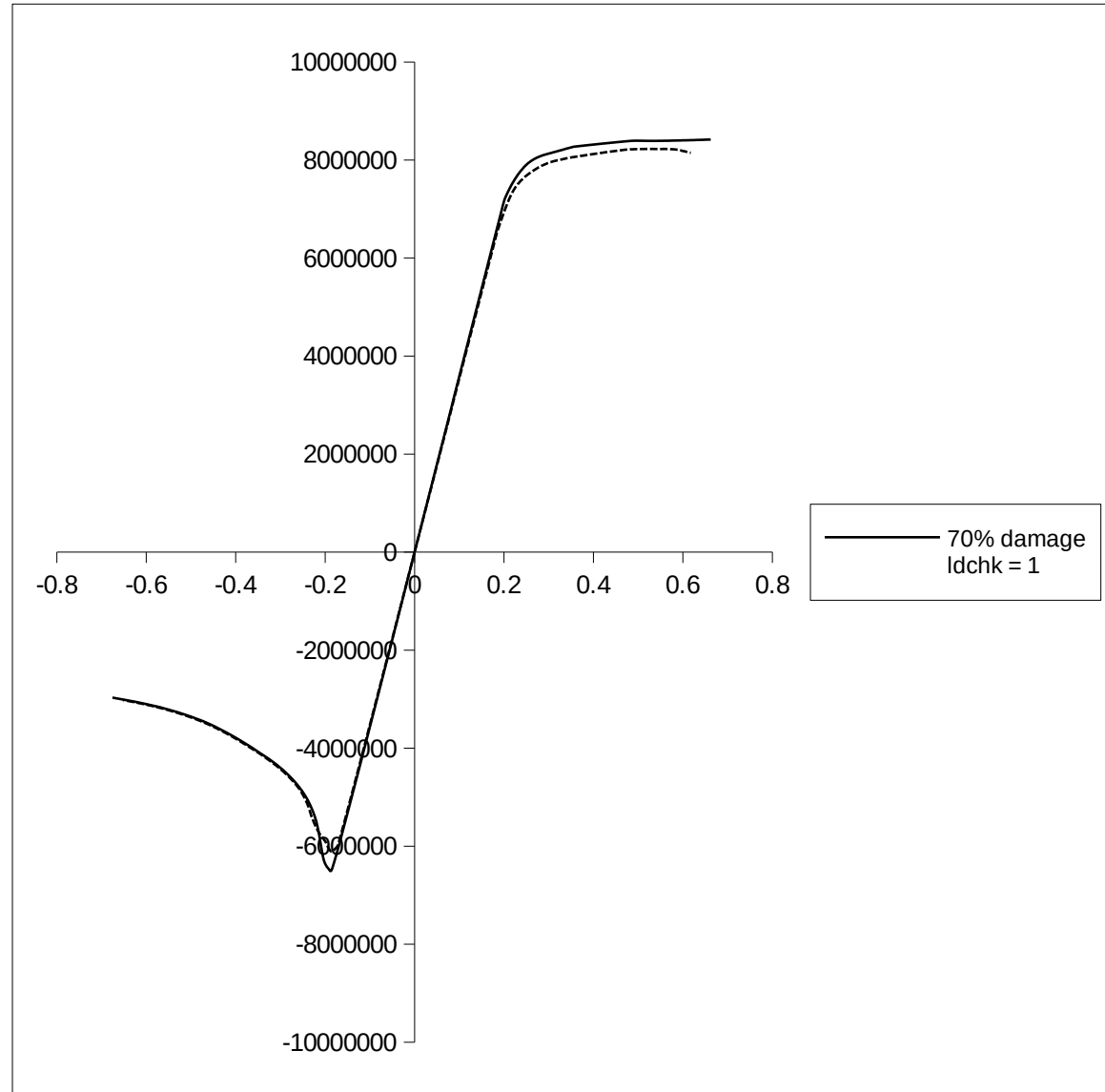
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-3.32E+11 -3250660 -2.39E-03 -0.573174
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-3.29E+11 -3228120 -2.43E-03 -0.582754
-3.29E+11 -3223220 -2.44E-03 -0.58515
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-3.22E+11 -3156580 -2.58E-03 -0.618683

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-3.15E+11 -3084060 -2.76E-03 -0.66012
-3.14E+11 -3079160 -2.77E-03 -0.662515

Bulk Carrier (B4) Idchk = 1				Bulk Carrier (B4) Idchk = 2			
70% damage				70% damage			
frame spa	4.175	9.80E-06	1000	frame spa	4.175	9.80E-06	1000
Moment	Rotation Curvature			Moment	Rotation Curvature		
8.79E+08	8610.28	1.00E-06	0.00024	8.69E+08	8511.3	1.00E-06	0.00024
1.76E+09	17199	2.00E-06	0.000479	1.74E+09	17003	2.00E-06	0.000479



2.02E+11	1975680	2.30E-04	0.05509	1.99E+11	1953140	2.30E-04	0.05509
2.10E+11	2061920	2.40E-04	0.057485	2.08E+11	2037420	2.40E-04	0.057485
2.19E+11	2148160	2.50E-04	0.05988	2.17E+11	2122680	2.50E-04	0.05988
2.28E+11	2233420	2.60E-04	0.062275	2.25E+11	2206960	2.60E-04	0.062275
2.37E+11	2319660	2.70E-04	0.064671	2.34E+11	2292220	2.70E-04	0.064671
2.46E+11	2405900	2.80E-04	0.067066	2.43E+11	2376500	2.80E-04	0.067066
2.54E+11	2491160	2.90E-04	0.069461	2.51E+11	2461760	2.90E-04	0.069461
2.63E+11	2577400	3.00E-04	0.071856	2.60E+11	2546040	3.00E-04	0.071856
2.72E+11	2662660	3.10E-04	0.074251	2.69E+11	2631300	3.10E-04	0.074251

2.81E+11	2748900	3.20E-04	0.076647	2.77E+11	2715580	3.20E-04	0.076647
2.89E+11	2834160	3.30E-04	0.079042	2.86E+11	2800840	3.30E-04	0.079042
2.98E+11	2920400	3.40E-04	0.081437	2.95E+11	2886100	3.40E-04	0.081437
3.07E+11	3006640	3.50E-04	0.083832	3.03E+11	2970380	3.50E-04	0.083832
3.16E+11	3091900	3.60E-04	0.086228	3.12E+11	3055640	3.60E-04	0.086228
3.24E+11	3178140	3.70E-04	0.088623	3.20E+11	3139920	3.70E-04	0.088623
3.33E+11	3263400	3.80E-04	0.091018	3.29E+11	3225180	3.80E-04	0.091018
3.42E+11	3349640	3.90E-04	0.093413	3.38E+11	3309460	3.90E-04	0.093413
3.51E+11	3435880	4.00E-04	0.095808	3.46E+11	3394720	4.00E-04	0.095808
3.59E+11	3521140	4.10E-04	0.098204	3.55E+11	3479000	4.10E-04	0.098204
3.68E+11	3607380	4.20E-04	0.100599	3.64E+11	3563280	4.20E-04	0.100599
3.77E+11	3692640	4.30E-04	0.102994	3.72E+11	3648540	4.30E-04	0.102994
3.86E+11	3778880	4.40E-04	0.105389	3.81E+11	3732820	4.40E-04	0.105389
3.94E+11	3864140	4.50E-04	0.107784	3.90E+11	3818080	4.50E-04	0.107784
4.03E+11	3950380	4.60E-04	0.11018	3.98E+11	3902360	4.60E-04	0.11018
4.12E+11	4035640	4.70E-04	0.112575	4.07E+11	3987620	4.70E-04	0.112575
4.21E+11	4121880	4.80E-04	0.11497	4.16E+11	4071900	4.80E-04	0.11497
4.29E+11	4207140	4.90E-04	0.117365	4.24E+11	4157160	4.90E-04	0.117365
4.38E+11	4293380	5.00E-04	0.11976	4.33E+11	4241440	5.00E-04	0.11976
4.47E+11	4379620	5.10E-04	0.122156	4.41E+11	4325720	5.10E-04	0.122156
4.56E+11	4464880	5.20E-04	0.124551	4.50E+11	4410980	5.20E-04	0.124551
4.64E+11	4551120	5.30E-04	0.126946	4.59E+11	4495260	5.30E-04	0.126946
4.73E+11	4636380	5.40E-04	0.129341	4.67E+11	4580520	5.40E-04	0.129341
4.82E+11	4722620	5.50E-04	0.131737	4.76E+11	4664800	5.50E-04	0.131737
4.91E+11	4807880	5.60E-04	0.134132	4.85E+11	4750060	5.60E-04	0.134132
4.99E+11	4894120	5.70E-04	0.136527	4.93E+11	4834340	5.70E-04	0.136527
5.08E+11	4979380	5.80E-04	0.138922	5.02E+11	4918620	5.80E-04	0.138922
5.17E+11	5065620	5.90E-04	0.141317	5.11E+11	5003880	5.90E-04	0.141317
5.26E+11	5150880	6.00E-04	0.143713	5.19E+11	5088160	6.00E-04	0.143713
5.34E+11	5237120	6.10E-04	0.146108	5.28E+11	5173420	6.10E-04	0.146108
5.43E+11	5322380	6.20E-04	0.148503	5.37E+11	5257700	6.20E-04	0.148503
5.52E+11	5408620	6.30E-04	0.150898	5.45E+11	5341980	6.30E-04	0.150898
5.61E+11	5493880	6.40E-04	0.153293	5.54E+11	5427240	6.40E-04	0.153293
5.69E+11	5580120	6.50E-04	0.155689	5.62E+11	5511520	6.50E-04	0.155689
5.78E+11	5665380	6.60E-04	0.158084	5.71E+11	5596780	6.60E-04	0.158084
5.87E+11	5751620	6.70E-04	0.160479	5.80E+11	5681060	6.70E-04	0.160479
5.96E+11	5836880	6.80E-04	0.162874	5.88E+11	5765340	6.80E-04	0.162874
6.04E+11	5923120	6.90E-04	0.165269	5.97E+11	5850600	6.90E-04	0.165269
6.13E+11	6008380	7.00E-04	0.167665	6.06E+11	5934880	7.00E-04	0.167665
6.22E+11	6094620	7.10E-04	0.17006	6.14E+11	6020140	7.10E-04	0.17006
6.31E+11	6179880	7.20E-04	0.172455	6.23E+11	6104420	7.20E-04	0.172455
6.39E+11	6266120	7.30E-04	0.17485	6.32E+11	6188700	7.30E-04	0.17485
6.48E+11	6351380	7.40E-04	0.177246	6.40E+11	6273960	7.40E-04	0.177246
6.57E+11	6437620	7.50E-04	0.179641	6.49E+11	6358240	7.50E-04	0.179641
6.66E+11	6522880	7.60E-04	0.182036	6.58E+11	6443500	7.60E-04	0.182036

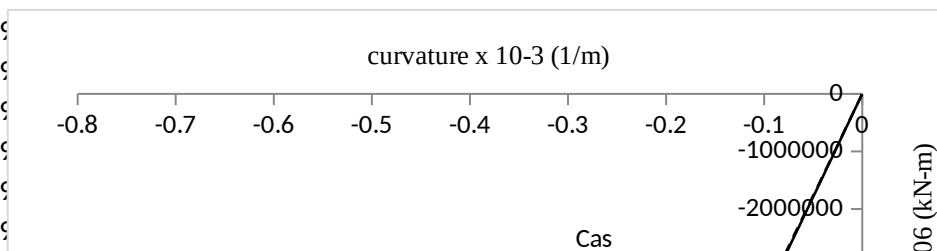
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7.01E+11	6865880	8.00E-04	0.191617	6.76E+11	6628720	7.86E-04	0.188216
7.09E+11	6951140	8.10E-04	0.194012	6.79E+11	6657140	7.90E-04	0.189269
7.18E+11	7037380	8.20E-04	0.196407	6.86E+11	6719860	8.00E-04	0.191665
7.21E+11	7069720	8.24E-04	0.197293	6.88E+11	6739460	8.03E-04	0.192407
7.29E+11	7144200	8.33E-04	0.199521	6.93E+11	6792380	8.12E-04	0.194419
7.35E+11	7206920	8.42E-04	0.201677	7.00E+11	6855100	8.22E-04	0.196814
7.40E+11	7248080	8.50E-04	0.203497	7.00E+11	6859020	8.22E-04	0.196958
7.44E+11	7295120	8.60E-04	0.205892	7.06E+11	6918800	8.32E-04	0.199353
7.47E+11	7319620	8.65E-04	0.207114	7.12E+11	6975640	8.42E-04	0.201605
7.52E+11	7364700	8.75E-04	0.209509	7.18E+11	7034440	8.52E-04	0.204
7.56E+11	7405860	8.84E-04	0.211713	7.21E+11	7064820	8.57E-04	0.205269
7.60E+11	7448000	8.94E-04	0.214108	7.27E+11	7119700	8.67E-04	0.207665
7.64E+11	7485240	9.03E-04	0.216263	7.27E+11	7122640	8.68E-04	0.207784
7.67E+11	7515620	9.11E-04	0.218108	7.32E+11	7173600	8.77E-04	0.21006
7.71E+11	7551880	9.21E-04	0.220503	7.37E+11	7220640	8.86E-04	0.212311
7.74E+11	7588140	9.31E-04	0.222898	7.42E+11	7266700	8.96E-04	0.214611
7.77E+11	7616560	9.38E-04	0.224743	7.46E+11	7309820	9.06E-04	0.216982
7.81E+11	7648900	9.48E-04	0.227138	7.50E+11	7351960	9.16E-04	0.219377
7.84E+11	7678300	9.57E-04	0.229222	7.50E+11	7351960	9.16E-04	0.219401
7.87E+11	7707700	9.67E-04	0.231521	7.54E+11	7391160	9.26E-04	0.221796
7.89E+11	7736120	9.77E-04	0.233916	7.54E+11	7392140	9.26E-04	0.221892
7.92E+11	7764540	9.87E-04	0.236311	7.58E+11	7427420	9.36E-04	0.224287
7.95E+11	7791980	9.97E-04	0.238707	7.58E+11	7428400	9.37E-04	0.224383
7.98E+11	7817460	1.01E-03	0.241198	7.61E+11	7453880	9.45E-04	0.226299
8.00E+11	7840000	1.02E-03	0.243114	7.64E+11	7482300	9.55E-04	0.228695
8.02E+11	7863520	1.03E-03	0.245509	7.66E+11	7507780	9.63E-04	0.230731
8.03E+11	7871360	1.03E-03	0.246228	7.69E+11	7532280	9.73E-04	0.233126
8.05E+11	7891940	1.04E-03	0.248623	7.71E+11	7557760	9.83E-04	0.235521
8.07E+11	7912520	1.05E-03	0.251018	7.73E+11	7578340	9.92E-04	0.237509
8.10E+11	7933100	1.06E-03	0.253413	7.76E+11	7599900	1.00E-03	0.24
8.10E+11	7938980	1.06E-03	0.254132	7.76E+11	7608720	1.01E-03	0.240719
8.12E+11	7954660	1.07E-03	0.256527	7.79E+11	7629300	1.02E-03	0.243114
8.13E+11	7970340	1.08E-03	0.258922	7.79E+11	7635180	1.02E-03	0.244072
8.15E+11	7986020	1.09E-03	0.261317	7.81E+11	7650860	1.03E-03	0.245749
8.15E+11	7987980	1.09E-03	0.261557	7.83E+11	7668500	1.04E-03	0.248144
8.16E+11	8000720	1.10E-03	0.263952	7.84E+11	7686140	1.05E-03	0.250539
8.18E+11	8013460	1.11E-03	0.266347	7.84E+11	7686140	1.05E-03	0.250539
8.19E+11	8027180	1.12E-03	0.268743	7.86E+11	7702800	1.06E-03	0.252934
8.19E+11	8028160	1.12E-03	0.268982	7.88E+11	7719460	1.07E-03	0.255329
8.20E+11	8038940	1.13E-03	0.271377	7.89E+11	7736120	1.08E-03	0.257725
8.21E+11	8048740	1.14E-03	0.273293	7.91E+11	7751800	1.09E-03	0.26012
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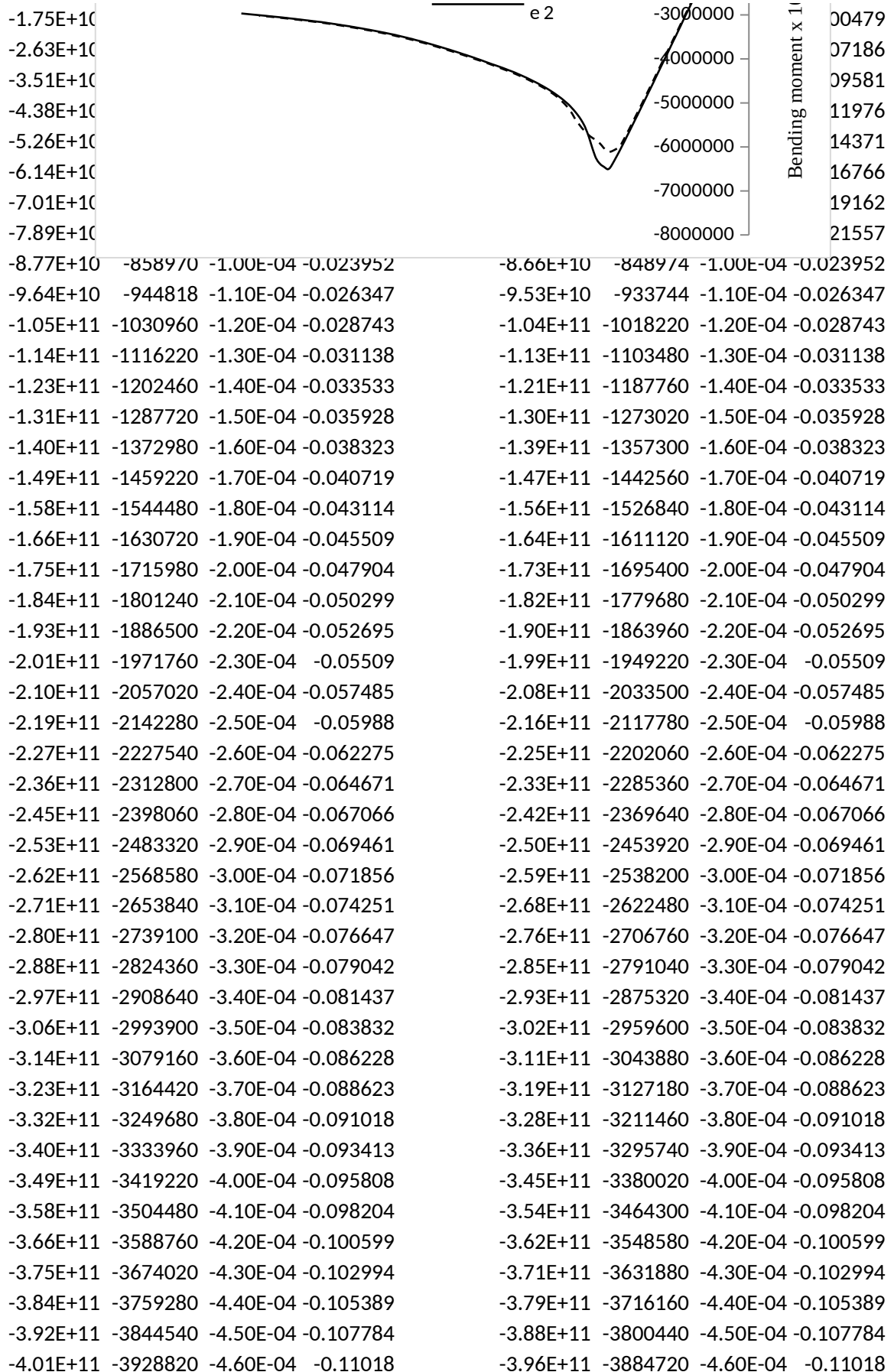
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8.25E+11	8085000	1.18E-03	0.282874	7.96E+11	7802760	1.12E-03	0.268743
8.25E+11	8085980	1.18E-03	0.283353	7.98E+11	7816480	1.13E-03	0.271138
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8.33E+11	8161440	1.30E-03	0.311617	8.08E+11	7919380	1.22E-03	0.293174
8.33E+11	8167320	1.31E-03	0.314012	8.09E+11	7929180	1.23E-03	0.295569
8.34E+11	8173200	1.32E-03	0.316407	8.10E+11	7934080	1.24E-03	0.296766
8.35E+11	8179080	1.33E-03	0.318802	8.11E+11	7942900	1.25E-03	0.299162
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8.36E+11	8191820	1.35E-03	0.323593	8.11E+11	7950740	1.26E-03	0.301557
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8.37E+11	8203580	1.37E-03	0.328383	8.13E+11	7963480	1.28E-03	0.306347
8.38E+11	8209460	1.38E-03	0.330778	8.13E+11	7970340	1.29E-03	0.308743
8.38E+11	8215340	1.39E-03	0.333174	8.14E+11	7975240	1.30E-03	0.310659
8.39E+11	8222200	1.40E-03	0.335569	8.14E+11	7981120	1.31E-03	0.313054
8.40E+11	8228080	1.41E-03	0.337964	8.15E+11	7986020	1.32E-03	0.315449
8.40E+11	8233960	1.42E-03	0.340359	8.15E+11	7990920	1.33E-03	0.317844
8.41E+11	8239840	1.43E-03	0.342754	8.16E+11	7993860	1.33E-03	0.319042
8.41E+11	8245720	1.44E-03	0.34515	8.16E+11	7997780	1.34E-03	0.321437
8.42E+11	8251600	1.45E-03	0.347545	8.17E+11	8002680	1.35E-03	0.323832
8.43E+11	8257480	1.46E-03	0.34994	8.17E+11	8007580	1.36E-03	0.326228
8.43E+11	8263360	1.47E-03	0.352335	8.18E+11	8012480	1.37E-03	0.328623
8.44E+11	8269240	1.48E-03	0.354731	8.18E+11	8017380	1.38E-03	0.331018
8.44E+11	8271200	1.48E-03	0.355449	8.18E+11	8017380	1.38E-03	0.331018
8.44E+11	8274140	1.49E-03	0.357844	8.19E+11	8022280	1.39E-03	0.333413
8.45E+11	8276100	1.50E-03	0.36024	8.19E+11	8027180	1.40E-03	0.335808
8.45E+11	8279040	1.51E-03	0.362635	8.20E+11	8032080	1.41E-03	0.338204
8.45E+11	8281000	1.52E-03	0.36503	8.20E+11	8036980	1.42E-03	0.340599
8.45E+11	8283940	1.53E-03	0.367425	8.21E+11	8040900	1.43E-03	0.342994
8.46E+11	8285900	1.54E-03	0.36982	8.21E+11	8041880	1.43E-03	0.343473
8.46E+11	8288840	1.55E-03	0.372216	8.21E+11	8045800	1.44E-03	0.345868
8.46E+11	8290800	1.56E-03	0.374611	8.22E+11	8050700	1.45E-03	0.348263
8.46E+11	8293740	1.57E-03	0.377006	8.22E+11	8050700	1.45E-03	0.348263
8.46E+11	8294720	1.58E-03	0.378443	8.22E+11	8053640	1.46E-03	0.350659

8.47E+11	8297660	1.59E-03	0.380838	8.22E+11	8057560	1.47E-03	0.353054
8.47E+11	8299620	1.60E-03	0.383234	8.23E+11	8060500	1.48E-03	0.355449
8.47E+11	8301580	1.61E-03	0.385629	8.23E+11	8064420	1.49E-03	0.357844
8.47E+11	8304520	1.62E-03	0.388024	8.23E+11	8065400	1.50E-03	0.358563
8.48E+11	8306480	1.63E-03	0.390419	8.23E+11	8068340	1.51E-03	0.360958
8.48E+11	8309420	1.64E-03	0.392814	8.24E+11	8072260	1.52E-03	0.363353
8.48E+11	8311380	1.65E-03	0.39521	8.24E+11	8075200	1.53E-03	0.365749
8.48E+11	8313340	1.66E-03	0.397605	8.24E+11	8077160	1.53E-03	0.367186
8.49E+11	8316280	1.67E-03	0.4	8.25E+11	8081080	1.54E-03	0.369581
8.49E+11	8318240	1.68E-03	0.402395	8.25E+11	8084020	1.55E-03	0.371976
8.49E+11	8320200	1.69E-03	0.40479	8.25E+11	8086960	1.56E-03	0.374371
8.49E+11	8323140	1.70E-03	0.407186	8.26E+11	8090880	1.57E-03	0.376766
8.50E+11	8325100	1.71E-03	0.409581	8.26E+11	8093820	1.58E-03	0.379162
8.50E+11	8328040	1.72E-03	0.411976	8.26E+11	8097740	1.59E-03	0.381557
8.50E+11	8330000	1.73E-03	0.414371	8.27E+11	8100680	1.60E-03	0.383952
8.50E+11	8331960	1.74E-03	0.416766	8.27E+11	8103620	1.61E-03	0.385868
8.51E+11	8334900	1.75E-03	0.419162	8.27E+11	8106560	1.62E-03	0.388263
8.51E+11	8336860	1.76E-03	0.421557	8.28E+11	8109500	1.63E-03	0.390659
8.51E+11	8338820	1.77E-03	0.423952	8.28E+11	8113420	1.64E-03	0.393054
8.51E+11	8340780	1.78E-03	0.426347	8.28E+11	8116360	1.65E-03	0.395449
8.51E+11	8343720	1.79E-03	0.428743	8.29E+11	8120280	1.66E-03	0.397844
8.52E+11	8345680	1.80E-03	0.431138	8.29E+11	8123220	1.67E-03	0.40024
8.52E+11	8347640	1.81E-03	0.433533	8.29E+11	8124200	1.67E-03	0.400958
8.52E+11	8349600	1.82E-03	0.435928	8.29E+11	8127140	1.68E-03	0.403353
8.52E+11	8352540	1.83E-03	0.438323	8.30E+11	8131060	1.69E-03	0.405749
8.53E+11	8354500	1.84E-03	0.440719	8.30E+11	8134000	1.70E-03	0.408144
8.53E+11	8356460	1.85E-03	0.443114	8.30E+11	8136940	1.71E-03	0.410539
8.53E+11	8358420	1.86E-03	0.445509	8.31E+11	8139880	1.72E-03	0.412934
8.53E+11	8360380	1.87E-03	0.447904	8.31E+11	8140860	1.72E-03	0.412934
8.53E+11	8363320	1.88E-03	0.450299	8.31E+11	8143800	1.73E-03	0.415329
8.54E+11	8365280	1.89E-03	0.452695	8.31E+11	8146740	1.74E-03	0.417725
8.54E+11	8367240	1.90E-03	0.45509	8.32E+11	8149680	1.75E-03	0.42012
8.54E+11	8369200	1.91E-03	0.457485	8.32E+11	8151640	1.76E-03	0.421557
8.54E+11	8371160	1.92E-03	0.45988	8.32E+11	8154580	1.77E-03	0.423952
8.54E+11	8373120	1.93E-03	0.462275	8.32E+11	8157520	1.78E-03	0.426347
8.55E+11	8375080	1.94E-03	0.463713	8.33E+11	8160460	1.79E-03	0.428743
8.55E+11	8377040	1.95E-03	0.466108	8.33E+11	8162420	1.80E-03	0.43018
8.55E+11	8379000	1.96E-03	0.468503	8.33E+11	8165360	1.81E-03	0.432575
8.55E+11	8380960	1.97E-03	0.470898	8.34E+11	8168300	1.82E-03	0.43497
8.55E+11	8382920	1.98E-03	0.473293	8.34E+11	8171240	1.83E-03	0.437365
8.56E+11	8384880	1.99E-03	0.475689	8.34E+11	8174180	1.84E-03	0.43976
8.56E+11	8385860	1.99E-03	0.476886	8.34E+11	8177120	1.85E-03	0.442156
8.56E+11	8387820	2.00E-03	0.479281	8.35E+11	8180060	1.86E-03	0.444551
8.56E+11	8389780	2.01E-03	0.481677	8.35E+11	8182020	1.86E-03	0.446467
8.56E+11	8390760	2.02E-03	0.484072	8.35E+11	8184960	1.87E-03	0.448862

8.56E+11	8392720	2.03E-03	0.486467	8.36E+11	8187900	1.88E-03	0.451257
8.56E+11	8392720	2.03E-03	0.486946	8.36E+11	8190840	1.89E-03	0.453653
8.57E+11	8393700	2.04E-03	0.489341	8.36E+11	8191820	1.90E-03	0.454371
8.57E+11	8393700	2.05E-03	0.491737	8.36E+11	8194760	1.91E-03	0.456766
8.57E+11	8394680	2.06E-03	0.494132	8.37E+11	8197700	1.92E-03	0.459162
8.57E+11	8394680	2.07E-03	0.496527	8.37E+11	8200640	1.93E-03	0.461557
8.57E+11	8394680	2.08E-03	0.498922	8.37E+11	8203580	1.94E-03	0.463952
8.57E+11	8394680	2.09E-03	0.501317	8.37E+11	8205540	1.94E-03	0.465629
8.57E+11	8393700	2.10E-03	0.503713	8.38E+11	8207500	1.95E-03	0.468024
8.57E+11	8393700	2.11E-03	0.506108	8.38E+11	8210440	1.96E-03	0.470419
8.57E+11	8393700	2.12E-03	0.508503	8.38E+11	8212400	1.97E-03	0.472814
8.56E+11	8392720	2.13E-03	0.510898	8.38E+11	8215340	1.98E-03	0.47521
8.56E+11	8392720	2.14E-03	0.513293	8.38E+11	8216320	1.99E-03	0.476407
8.56E+11	8392720	2.15E-03	0.515689	8.39E+11	8217300	2.00E-03	0.478802
8.56E+11	8391740	2.16E-03	0.518084	8.39E+11	8218280	2.01E-03	0.481198
8.56E+11	8391740	2.17E-03	0.520479	8.39E+11	8219260	2.02E-03	0.483593
8.56E+11	8391740	2.18E-03	0.522874	8.39E+11	8219260	2.03E-03	0.485988
8.56E+11	8390760	2.19E-03	0.525269	8.39E+11	8220240	2.04E-03	0.488144
8.56E+11	8391740	2.20E-03	0.527665	8.39E+11	8221220	2.05E-03	0.490539
8.56E+11	8391740	2.21E-03	0.53006	8.39E+11	8222200	2.06E-03	0.492934
8.56E+11	8391740	2.22E-03	0.530778	8.39E+11	8222200	2.07E-03	0.495329
8.56E+11	8391740	2.23E-03	0.533174	8.39E+11	8223180	2.08E-03	0.497725
8.56E+11	8391740	2.24E-03	0.535569	8.39E+11	8223180	2.08E-03	0.497964
8.56E+11	8391740	2.25E-03	0.537964	8.39E+11	8224160	2.09E-03	0.500359
8.56E+11	8391740	2.26E-03	0.540359	8.39E+11	8224160	2.10E-03	0.502754
8.56E+11	8391740	2.27E-03	0.542754	8.39E+11	8225140	2.11E-03	0.50515
8.56E+11	8392720	2.28E-03	0.54515	8.39E+11	8225140	2.11E-03	0.506347
8.56E+11	8392720	2.29E-03	0.547545	8.39E+11	8225140	2.12E-03	0.508743
8.56E+11	8392720	2.30E-03	0.54994	8.39E+11	8225140	2.13E-03	0.511138
8.56E+11	8392720	2.31E-03	0.552335	8.39E+11	8225140	2.14E-03	0.513533
8.56E+11	8392720	2.32E-03	0.554731	8.39E+11	8226120	2.15E-03	0.515928
8.56E+11	8392720	2.32E-03	0.556168	8.39E+11	8226120	2.16E-03	0.518323
8.57E+11	8393700	2.33E-03	0.558563	8.39E+11	8226120	2.17E-03	0.520719
8.57E+11	8393700	2.34E-03	0.560958	8.39E+11	8226120	2.18E-03	0.523114
8.57E+11	8393700	2.35E-03	0.563353	8.39E+11	8226120	2.19E-03	0.525509
8.57E+11	8394680	2.36E-03	0.565749	8.39E+11	8226120	2.20E-03	0.527904
8.57E+11	8394680	2.36E-03	0.565988	8.39E+11	8226120	2.21E-03	0.530299
8.57E+11	8394680	2.37E-03	0.568383	8.39E+11	8226120	2.22E-03	0.532695
8.57E+11	8395660	2.38E-03	0.570778	8.39E+11	8226120	2.23E-03	0.532934
8.57E+11	8395660	2.39E-03	0.573174	8.39E+11	8226120	2.24E-03	0.535329
8.57E+11	8396640	2.40E-03	0.575569	8.39E+11	8225140	2.25E-03	0.537725
8.57E+11	8396640	2.41E-03	0.577964	8.39E+11	8225140	2.26E-03	0.54012
8.57E+11	8397620	2.42E-03	0.579162	8.39E+11	8225140	2.27E-03	0.542515
8.57E+11	8397620	2.43E-03	0.581557	8.39E+11	8225140	2.28E-03	0.54491
8.57E+11	8398600	2.44E-03	0.583952	8.39E+11	8225140	2.29E-03	0.547305

8.57E+11	8398600	2.45E-03	0.586347	8.39E+11	8225140	2.30E-03	0.549701
8.57E+11	8399580	2.46E-03	0.588743	8.39E+11	8225140	2.31E-03	0.552096
8.57E+11	8399580	2.47E-03	0.591138	8.39E+11	8225140	2.32E-03	0.554491
8.57E+11	8400560	2.48E-03	0.593533	8.39E+11	8226120	2.32E-03	0.554491
8.57E+11	8400560	2.49E-03	0.595928	8.39E+11	8226120	2.33E-03	0.556886
8.57E+11	8401540	2.50E-03	0.598323	8.39E+11	8226120	2.34E-03	0.559281
8.57E+11	8402520	2.51E-03	0.600719	8.39E+11	8226120	2.35E-03	0.561677
8.57E+11	8402520	2.52E-03	0.603114	8.39E+11	8226120	2.35E-03	0.562874
8.58E+11	8403500	2.53E-03	0.605509	8.39E+11	8225140	2.36E-03	0.565269
8.58E+11	8403500	2.54E-03	0.607904	8.39E+11	8224160	2.37E-03	0.567665
8.58E+11	8404480	2.55E-03	0.610299	8.39E+11	8223180	2.38E-03	0.57006
8.58E+11	8404480	2.55E-03	0.610539	8.39E+11	8223180	2.38E-03	0.570539
8.58E+11	8404480	2.56E-03	0.612934	8.39E+11	8222200	2.39E-03	0.572934
8.58E+11	8405460	2.57E-03	0.615329	8.39E+11	8221220	2.40E-03	0.575329
8.58E+11	8406440	2.58E-03	0.617725	8.39E+11	8220240	2.41E-03	0.577725
8.58E+11	8406440	2.59E-03	0.62012	8.39E+11	8220240	2.41E-03	0.577725
8.58E+11	8407420	2.60E-03	0.622515	8.39E+11	8218280	2.42E-03	0.58012
8.58E+11	8407420	2.61E-03	0.62491	8.38E+11	8216320	2.43E-03	0.582515
8.58E+11	8408400	2.62E-03	0.627305	8.38E+11	8214360	2.44E-03	0.58491
8.58E+11	8409380	2.63E-03	0.629701	8.38E+11	8213380	2.45E-03	0.585868
8.58E+11	8410360	2.64E-03	0.632096	8.38E+11	8210440	2.46E-03	0.588263
8.58E+11	8410360	2.65E-03	0.634491	8.37E+11	8206520	2.47E-03	0.590659
8.58E+11	8411340	2.66E-03	0.636886	8.37E+11	8203580	2.47E-03	0.592575
8.58E+11	8412320	2.67E-03	0.639281	8.37E+11	8197700	2.48E-03	0.59497
8.58E+11	8412320	2.68E-03	0.641677	8.36E+11	8191820	2.49E-03	0.597365
8.59E+11	8413300	2.69E-03	0.644072	8.35E+11	8185940	2.50E-03	0.59976
8.59E+11	8414280	2.70E-03	0.646467	8.35E+11	8181040	2.51E-03	0.602156
8.59E+11	8415260	2.71E-03	0.648862	8.35E+11	8179080	2.52E-03	0.603832
8.59E+11	8416240	2.72E-03	0.651257	8.34E+11	8173200	2.53E-03	0.606228
8.59E+11	8416240	2.73E-03	0.653653	8.34E+11	8168300	2.54E-03	0.608144
8.59E+11	8417220	2.74E-03	0.655329	8.33E+11	8163400	2.55E-03	0.610539
8.59E+11	8417220	2.75E-03	0.657725	8.33E+11	8159480	2.56E-03	0.612934
8.59E+11	8417220	2.76E-03	0.66012	8.32E+11	8154580	2.57E-03	0.615329
8.59E+11	8417220	2.77E-03	0.662515	8.32E+11	8149680	2.58E-03	0.617725
0.00E+00	0	0.00E+00		0.00E+00	0	0.00E+00	
-8.79E+08	-8610.28	-1.00E-06	-0.00024	-8.69E+08	-8511.3	-1.00E-06	-0.00024
-1.76E+09	-17199	-2.00E-06	-0.000479	-1.74E+09	-17003	-2.00E-06	-0.000479
-2.63E+09	-25793.6	-3.00E-06	-0.000719	-2.60E+09	-25489.8	-3.00E-06	-0.000719
-3.51E+09	-34378.4	-4.00E-06	-0.000958	-3.47E+09	-33976.6	-4.00E-06	-0.000958
-4.38E+09							01198
-5.26E+09							01437
-6.14E+09							01677
-7.01E+09							01916
-7.89E+09							02156
-8.77E+09							02395





-4.10E+11	-4014080	-4.70E-04	-0.112575	-4.05E+11	-3968020	-4.70E-04	-0.112575
-4.18E+11	-4098360	-4.80E-04	-0.11497	-4.14E+11	-4052300	-4.80E-04	-0.11497
-4.27E+11	-4183620	-4.90E-04	-0.117365	-4.22E+11	-4135600	-4.90E-04	-0.117365
-4.36E+11	-4267900	-5.00E-04	-0.11976	-4.31E+11	-4219880	-5.00E-04	-0.11976
-4.44E+11	-4353160	-5.10E-04	-0.122156	-4.39E+11	-4303180	-5.10E-04	-0.122156
-4.53E+11	-4437440	-5.20E-04	-0.124551	-4.48E+11	-4387460	-5.20E-04	-0.124551
-4.61E+11	-4521720	-5.30E-04	-0.126946	-4.56E+11	-4470760	-5.30E-04	-0.126946
-4.70E+11	-4606000	-5.40E-04	-0.129341	-4.65E+11	-4554060	-5.40E-04	-0.129341
-4.79E+11	-4690280	-5.50E-04	-0.131737	-4.73E+11	-4637360	-5.50E-04	-0.131737
-4.87E+11	-4774560	-5.60E-04	-0.134132	-4.82E+11	-4720660	-5.60E-04	-0.134132
-4.96E+11	-4857860	-5.70E-04	-0.136527	-4.90E+11	-4803960	-5.70E-04	-0.136527
-5.04E+11	-4941160	-5.80E-04	-0.138922	-4.99E+11	-4886280	-5.80E-04	-0.138922
-5.13E+11	-5025440	-5.90E-04	-0.141317	-5.07E+11	-4969580	-5.90E-04	-0.141317
-5.21E+11	-5108740	-6.00E-04	-0.143713	-5.16E+11	-5051900	-6.00E-04	-0.143713
-5.30E+11	-5192040	-6.10E-04	-0.146108	-5.24E+11	-5134220	-6.10E-04	-0.146108
-5.38E+11	-5275340	-6.20E-04	-0.148503	-5.32E+11	-5216540	-6.20E-04	-0.148503
-5.47E+11	-5357660	-6.30E-04	-0.150898	-5.41E+11	-5298860	-6.30E-04	-0.150898
-5.55E+11	-5440960	-6.40E-04	-0.153293	-5.49E+11	-5381180	-6.40E-04	-0.153293
-5.64E+11	-5523280	-6.50E-04	-0.155689	-5.57E+11	-5462520	-6.50E-04	-0.155689
-5.72E+11	-5605600	-6.60E-04	-0.158084	-5.66E+11	-5543860	-6.60E-04	-0.158084
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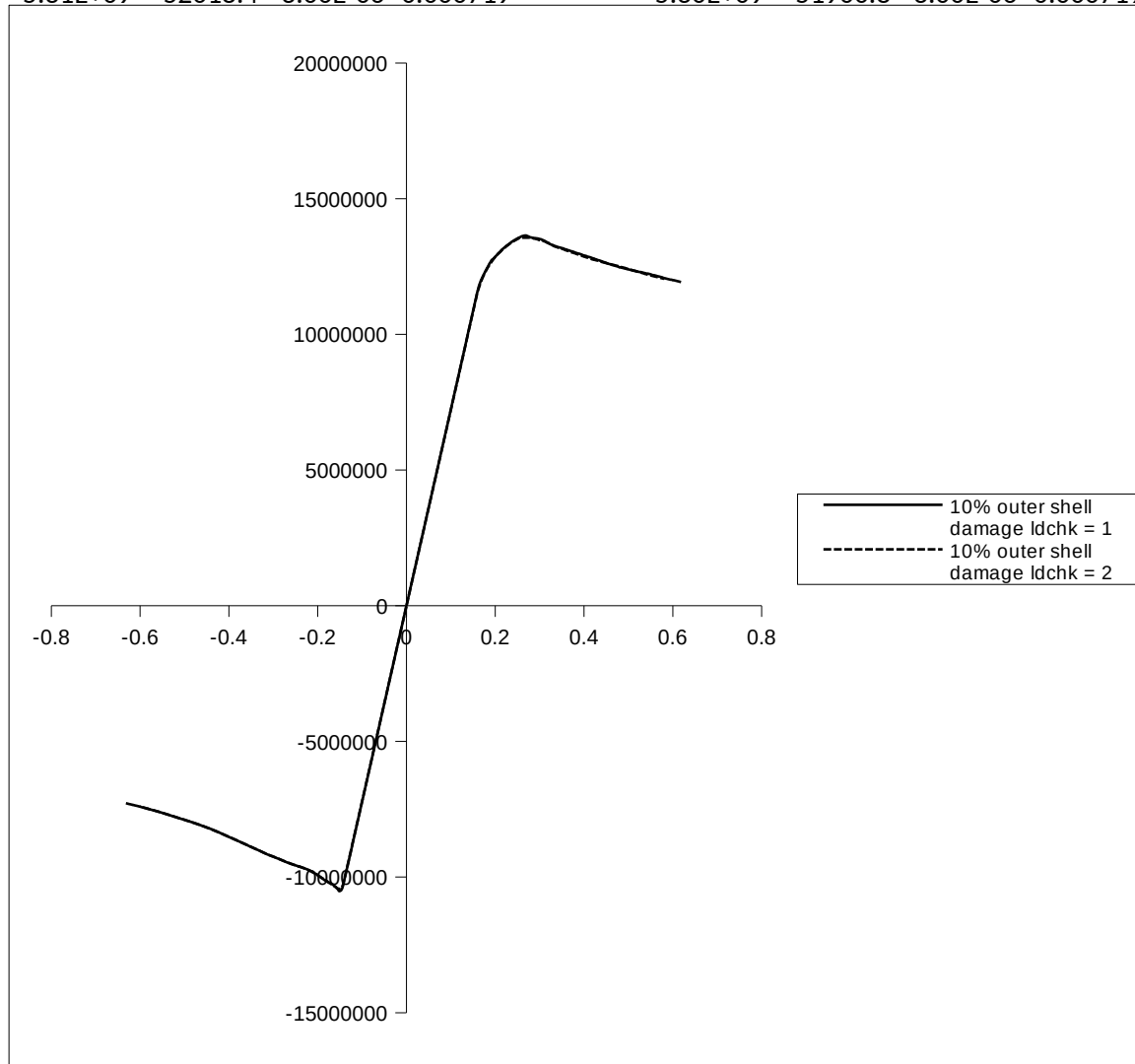
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-3.48E+11	-3407460	-2.03E-03	-0.48503	-3.57E+11	-3498600	-1.94E-03	-0.465389
-3.47E+11	-3399620	-2.04E-03	-0.487425	-3.56E+11	-3488800	-1.95E-03	-0.467784
-3.46E+11	-3391780	-2.05E-03	-0.48982	-3.55E+11	-3479980	-1.96E-03	-0.47018
-3.45E+11	-3382960	-2.06E-03	-0.492216	-3.54E+11	-3470180	-1.97E-03	-0.472575
-3.44E+11	-3375120	-2.07E-03	-0.494611	-3.53E+11	-3461360	-1.98E-03	-0.47497
-3.44E+11	-3367280	-2.08E-03	-0.497006	-3.52E+11	-3452540	-1.99E-03	-0.477365
-3.43E+11	-3359440	-2.09E-03	-0.499401	-3.51E+11	-3442740	-2.00E-03	-0.47976
-3.42E+11	-3351600	-2.10E-03	-0.501796	-3.50E+11	-3433920	-2.01E-03	-0.482156
-3.41E+11	-3344740	-2.11E-03	-0.504192	-3.50E+11	-3426080	-2.02E-03	-0.484551
-3.41E+11	-3336900	-2.12E-03	-0.506587	-3.49E+11	-3422160	-2.03E-03	-0.485749
-3.40E+11	-3330040	-2.13E-03	-0.508982	-3.48E+11	-3413340	-2.04E-03	-0.488144
-3.39E+11	-3322200	-2.14E-03	-0.511377	-3.47E+11	-3404520	-2.05E-03	-0.490539
-3.38E+11	-3315340	-2.15E-03	-0.513772	-3.47E+11	-3396680	-2.06E-03	-0.492934
-3.38E+11	-3307500	-2.16E-03	-0.516168	-3.46E+11	-3388840	-2.07E-03	-0.495329
-3.37E+11	-3300640	-2.17E-03	-0.518563	-3.45E+11	-3380020	-2.08E-03	-0.497725
-3.36E+11	-3293780	-2.18E-03	-0.520958	-3.44E+11	-3372180	-2.09E-03	-0.50012
-3.35E+11	-3286920	-2.19E-03	-0.523353	-3.43E+11	-3364340	-2.10E-03	-0.502515

-3.35E+11	-3279080	-2.20E-03	-0.525749	-3.43E+11	-3356500	-2.11E-03	-0.50491
-3.34E+11	-3272220	-2.21E-03	-0.528144	-3.42E+11	-3349640	-2.12E-03	-0.507305
-3.33E+11	-3265360	-2.22E-03	-0.530539	-3.41E+11	-3341800	-2.13E-03	-0.509701
-3.33E+11	-3258500	-2.23E-03	-0.532934	-3.40E+11	-3333960	-2.14E-03	-0.512096
-3.32E+11	-3252620	-2.24E-03	-0.535329	-3.39E+11	-3326120	-2.15E-03	-0.514491
-3.31E+11	-3245760	-2.25E-03	-0.537725	-3.39E+11	-3319260	-2.16E-03	-0.516886
-3.31E+11	-3239880	-2.26E-03	-0.54012	-3.38E+11	-3312400	-2.17E-03	-0.519281
-3.30E+11	-3234000	-2.27E-03	-0.542515	-3.37E+11	-3304560	-2.18E-03	-0.521677
-3.29E+11	-3227140	-2.28E-03	-0.54491	-3.37E+11	-3297700	-2.19E-03	-0.524072
-3.29E+11	-3221260	-2.29E-03	-0.547305	-3.36E+11	-3290840	-2.20E-03	-0.526467
-3.28E+11	-3214400	-2.30E-03	-0.549701	-3.35E+11	-3283980	-2.21E-03	-0.528862
-3.27E+11	-3208520	-2.31E-03	-0.552096	-3.34E+11	-3277120	-2.22E-03	-0.531257
-3.27E+11	-3202640	-2.32E-03	-0.554491	-3.34E+11	-3270260	-2.23E-03	-0.533653
-3.26E+11	-3196760	-2.33E-03	-0.556886	-3.33E+11	-3263400	-2.24E-03	-0.536048
-3.26E+11	-3190880	-2.34E-03	-0.559281	-3.32E+11	-3257520	-2.25E-03	-0.538443
-3.25E+11	-3185000	-2.35E-03	-0.561677	-3.32E+11	-3250660	-2.26E-03	-0.540838
-3.24E+11	-3178140	-2.36E-03	-0.564072	-3.31E+11	-3243800	-2.27E-03	-0.543234
-3.24E+11	-3172260	-2.37E-03	-0.566467	-3.30E+11	-3236940	-2.28E-03	-0.545629
-3.23E+11	-3166380	-2.38E-03	-0.568862	-3.30E+11	-3231060	-2.29E-03	-0.548024
-3.23E+11	-3161480	-2.39E-03	-0.571257	-3.29E+11	-3224200	-2.30E-03	-0.550419
-3.22E+11	-3155600	-2.40E-03	-0.573653	-3.28E+11	-3218320	-2.31E-03	-0.552814
-3.22E+11	-3150700	-2.41E-03	-0.576048	-3.28E+11	-3212440	-2.32E-03	-0.55521
-3.21E+11	-3145800	-2.42E-03	-0.578443	-3.27E+11	-3206560	-2.33E-03	-0.557605
-3.21E+11	-3140900	-2.43E-03	-0.580838	-3.27E+11	-3200680	-2.34E-03	-0.56
-3.20E+11	-3136000	-2.44E-03	-0.583234	-3.26E+11	-3194800	-2.35E-03	-0.562395
-3.20E+11	-3131100	-2.45E-03	-0.585629	-3.25E+11	-3188920	-2.36E-03	-0.56479
-3.19E+11	-3126200	-2.46E-03	-0.588024	-3.25E+11	-3183040	-2.37E-03	-0.567186
-3.19E+11	-3121300	-2.47E-03	-0.590419	-3.24E+11	-3178140	-2.38E-03	-0.569581
-3.18E+11	-3116400	-2.48E-03	-0.592814	-3.24E+11	-3172260	-2.39E-03	-0.571976
-3.18E+11	-3111500	-2.49E-03	-0.59521	-3.23E+11	-3166380	-2.40E-03	-0.574371
-3.17E+11	-3106600	-2.50E-03	-0.597605	-3.23E+11	-3161480	-2.41E-03	-0.576766
-3.17E+11	-3101700	-2.51E-03	-0.6	-3.22E+11	-3155600	-2.42E-03	-0.579162
-3.16E+11	-3096800	-2.52E-03	-0.602395	-3.22E+11	-3150700	-2.43E-03	-0.581557
-3.16E+11	-3091900	-2.53E-03	-0.60479	-3.21E+11	-3144820	-2.44E-03	-0.583952
-3.15E+11	-3087980	-2.54E-03	-0.607186	-3.20E+11	-3139920	-2.45E-03	-0.586347
-3.15E+11	-3083080	-2.55E-03	-0.609581	-3.20E+11	-3135020	-2.46E-03	-0.588743
-3.14E+11	-3078180	-2.56E-03	-0.611976	-3.19E+11	-3130120	-2.47E-03	-0.591138
-3.14E+11	-3073280	-2.57E-03	-0.614371	-3.19E+11	-3125220	-2.48E-03	-0.593533
-3.13E+11	-3068380	-2.58E-03	-0.616766	-3.18E+11	-3120320	-2.49E-03	-0.595928
-3.13E+11	-3064460	-2.59E-03	-0.619162	-3.18E+11	-3115420	-2.50E-03	-0.598323
-3.12E+11	-3059560	-2.60E-03	-0.621557	-3.17E+11	-3110520	-2.51E-03	-0.600719
-3.12E+11	-3055640	-2.61E-03	-0.623952	-3.17E+11	-3105620	-2.52E-03	-0.603114
-3.11E+11	-3050740	-2.62E-03	-0.626347	-3.16E+11	-3100720	-2.53E-03	-0.605509
-3.11E+11	-3046820	-2.63E-03	-0.628743	-3.16E+11	-3096800	-2.54E-03	-0.607904
-3.11E+11	-3042900	-2.64E-03	-0.631138	-3.16E+11	-3091900	-2.55E-03	-0.610299

-3.10E+11 -3038980 -2.65E-03 -0.633533
-3.10E+11 -3035060 -2.66E-03 -0.635928
-3.09E+11 -3031140 -2.67E-03 -0.638323
-3.09E+11 -3027220 -2.68E-03 -0.640719
-3.08E+11 -3022320 -2.69E-03 -0.643114
-3.08E+11 -3018400 -2.70E-03 -0.645509
-3.08E+11 -3014480 -2.71E-03 -0.647904
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-3.04E+11 -2979200 -2.80E-03 -0.669461
-3.04E+11 -2975280 -2.81E-03 -0.671856
-3.03E+11 -2971360 -2.82E-03 -0.674251
-3.03E+11 -2967440 -2.83E-03 -0.676647

-3.15E+11 -3087000 -2.56E-03 -0.612695
-3.15E+11 -3085040 -2.56E-03 -0.614132
-3.14E+11 -3080140 -2.57E-03 -0.616527
-3.14E+11 -3076220 -2.58E-03 -0.618922
-3.13E+11 -3071320 -2.59E-03 -0.621317
-3.13E+11 -3067400 -2.60E-03 -0.623713
-3.13E+11 -3062500 -2.61E-03 -0.626108
-3.12E+11 -3058580 -2.62E-03 -0.628503
-3.12E+11 -3053680 -2.63E-03 -0.630898
-3.11E+11 -3049760 -2.64E-03 -0.633293
-3.11E+11 -3048780 -2.65E-03 -0.634012
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-3.09E+11 -3028200 -2.70E-03 -0.645988
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-3.08E+11 -3019380 -2.72E-03 -0.650778
-3.08E+11 -3015460 -2.73E-03 -0.653174

Tanker (T4) Idchk = 1				Tanker (T4) Idchk = 2			
10% outer shell damage				10% outer shell damage			
frame spa	4.175	9.80E-06	1000	frame spa	4.175	9.80E-06	1000
Moment	Rotation		Curvature	Moment	Rotation		Curvature
1.77E+09	17336.2	1.00E-06	0.00024	1.77E+09	17306.8	1.00E-06	0.00024
3.54E+09	34682.2	2.00E-06	0.000479	3.53E+09	34603.8	2.00E-06	0.000479
5.31E+09	52018.4	3.00E-06	0.000719	5.30E+09	51900.8	3.00E-06	0.000719



3.89E+11	3814160	2.20E-04	0.052695	3.88E+11	3806320	2.20E-04	0.052695
4.07E+11	3987620	2.30E-04	0.05509	4.06E+11	3978800	2.30E-04	0.05509
4.25E+11	4161080	2.40E-04	0.057485	4.24E+11	4152260	2.40E-04	0.057485
4.42E+11	4334540	2.50E-04	0.05988	4.41E+11	4324740	2.50E-04	0.05988
4.60E+11	4508000	2.60E-04	0.062275	4.59E+11	4498200	2.60E-04	0.062275
4.78E+11	4680480	2.70E-04	0.064671	4.77E+11	4670680	2.70E-04	0.064671
4.95E+11	4853940	2.80E-04	0.067066	4.94E+11	4844140	2.80E-04	0.067066
5.13E+11	5027400	2.90E-04	0.069461	5.12E+11	5016620	2.90E-04	0.069461
5.31E+11	5200860	3.00E-04	0.071856	5.30E+11	5190080	3.00E-04	0.071856
5.48E+11	5374320	3.10E-04	0.074251	5.47E+11	5362560	3.10E-04	0.074251

5.66E+11	5547780	3.20E-04	0.076647
5.84E+11	5721240	3.30E-04	0.079042
6.02E+11	5894700	3.40E-04	0.081437
6.19E+11	6068160	3.50E-04	0.083832
6.37E+11	6241620	3.60E-04	0.086228
6.55E+11	6415080	3.70E-04	0.088623
6.72E+11	6587560	3.80E-04	0.091018
6.90E+11	6761020	3.90E-04	0.093413
7.08E+11	6934480	4.00E-04	0.095808
7.25E+11	7107940	4.10E-04	0.098204
7.43E+11	7281400	4.20E-04	0.100599
7.61E+11	7454860	4.30E-04	0.102994
7.78E+11	7628320	4.40E-04	0.105389
7.96E+11	7801780	4.50E-04	0.107784
8.14E+11	7975240	4.60E-04	0.11018
8.31E+11	8147720	4.70E-04	0.112575
8.49E+11	8321180	4.80E-04	0.11497
8.67E+11	8494640	4.90E-04	0.117365
8.85E+11	8668100	5.00E-04	0.11976
9.02E+11	8841560	5.10E-04	0.122156
9.20E+11	9015020	5.20E-04	0.124551
9.38E+11	9188480	5.30E-04	0.126946
9.55E+11	9361940	5.40E-04	0.129341
9.73E+11	9535400	5.50E-04	0.131737
9.91E+11	9707880	5.60E-04	0.134132
1.01E+12	9878400	5.70E-04	0.136527
1.03E+12	10054800	5.80E-04	0.138922
1.04E+12	10231200	5.90E-04	0.141317
1.06E+12	10397800	6.00E-04	0.143713
1.08E+12	10574200	6.10E-04	0.146108
1.10E+12	10750600	6.20E-04	0.148503
1.11E+12	10917200	6.30E-04	0.150898
1.13E+12	11093600	6.40E-04	0.153293
1.15E+12	11270000	6.50E-04	0.155689
1.17E+12	11446400	6.60E-04	0.158084
1.18E+12	11515000	6.64E-04	0.159066
1.19E+12	11632600	6.72E-04	0.16091
1.20E+12	11750200	6.80E-04	0.162778
1.21E+12	11848200	6.87E-04	0.164647
1.22E+12	11926600	6.95E-04	0.166467
1.22E+12	11995200	7.02E-04	0.168096
1.23E+12	12044200	7.08E-04	0.169557
1.24E+12	12103000	7.15E-04	0.171162
1.24E+12	12181400	7.25E-04	0.173557
1.25E+12	12259800	7.35E-04	0.175952

5.65E+11	5536020	3.20E-04	0.076647
5.83E+11	5708500	3.30E-04	0.079042
6.00E+11	5881960	3.40E-04	0.081437
6.18E+11	6054440	3.50E-04	0.083832
6.36E+11	6227900	3.60E-04	0.086228
6.53E+11	6400380	3.70E-04	0.088623
6.71E+11	6573840	3.80E-04	0.091018
6.88E+11	6746320	3.90E-04	0.093413
7.06E+11	6919780	4.00E-04	0.095808
7.24E+11	7093240	4.10E-04	0.098204
7.41E+11	7265720	4.20E-04	0.100599
7.59E+11	7439180	4.30E-04	0.102994
7.77E+11	7611660	4.40E-04	0.105389
7.94E+11	7785120	4.50E-04	0.107784
8.12E+11	7957600	4.60E-04	0.11018
8.30E+11	8131060	4.70E-04	0.112575
8.47E+11	8303540	4.80E-04	0.11497
8.65E+11	8477000	4.90E-04	0.117365
8.83E+11	8649480	5.00E-04	0.11976
9.00E+11	8822940	5.10E-04	0.122156
9.18E+11	8995420	5.20E-04	0.124551
9.36E+11	9168880	5.30E-04	0.126946
9.53E+11	9341360	5.40E-04	0.129341
9.71E+11	9514820	5.50E-04	0.131737
9.89E+11	9687300	5.60E-04	0.134132
1.01E+12	9858800	5.70E-04	0.136527
1.02E+12	10035200	5.80E-04	0.138922
1.04E+12	10201800	5.90E-04	0.141317
1.06E+12	10378200	6.00E-04	0.143713
1.08E+12	10554600	6.10E-04	0.146108
1.09E+12	10721200	6.20E-04	0.148503
1.11E+12	10897600	6.30E-04	0.150898
1.13E+12	11074000	6.40E-04	0.153293
1.15E+12	11240600	6.50E-04	0.155689
1.17E+12	11417000	6.60E-04	0.158084
1.17E+12	11475800	6.63E-04	0.158826
1.18E+12	11573800	6.70E-04	0.160383
1.19E+12	11652200	6.76E-04	0.161868
1.20E+12	11730600	6.83E-04	0.163497
1.21E+12	11838400	6.92E-04	0.165749
1.22E+12	11907000	6.99E-04	0.167305
1.22E+12	11975600	7.05E-04	0.168862
1.23E+12	12034400	7.11E-04	0.170299
1.24E+12	12103000	7.18E-04	0.171952
1.24E+12	12161800	7.24E-04	0.173509

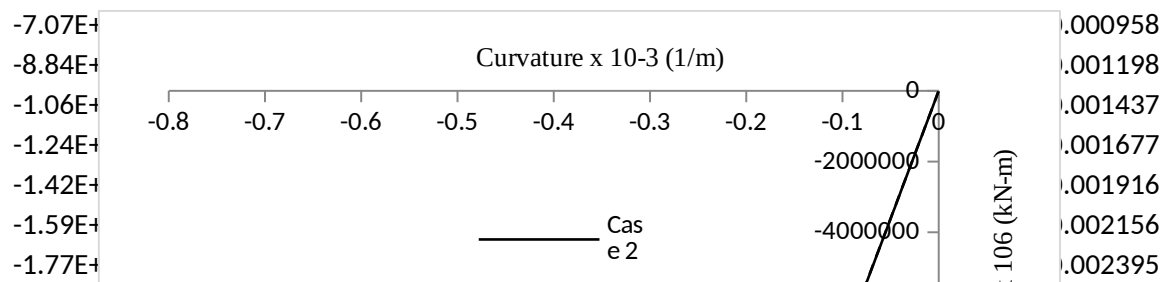
1.25E+12	12279400	7.36E-04	0.176359	1.25E+12	12220600	7.31E-04	0.175186
1.26E+12	12348000	7.46E-04	0.178754	1.25E+12	12269600	7.38E-04	0.176719
1.27E+12	12426400	7.56E-04	0.18115	1.26E+12	12338200	7.47E-04	0.178898
1.28E+12	12495000	7.66E-04	0.183545	1.27E+12	12406800	7.57E-04	0.181293
1.28E+12	12573400	7.76E-04	0.18594	1.27E+12	12416600	7.58E-04	0.181581
1.29E+12	12612600	7.82E-04	0.187281	1.27E+12	12485200	7.68E-04	0.183976
1.29E+12	12671400	7.92E-04	0.189677	1.27E+12	12485200	7.69E-04	0.184096
1.30E+12	12740000	8.02E-04	0.192024	1.28E+12	12544000	7.79E-04	0.186491
1.30E+12	12759600	8.10E-04	0.194012	1.28E+12	12563600	7.81E-04	0.187018
1.31E+12	12798800	8.20E-04	0.196407	1.29E+12	12612600	7.90E-04	0.189269
1.31E+12	12808600	8.23E-04	0.197054	1.29E+12	12671400	8.00E-04	0.191665
1.31E+12	12847800	8.33E-04	0.199449	1.29E+12	12671400	8.01E-04	0.191904
1.31E+12	12867400	8.36E-04	0.200311	1.30E+12	12730200	8.11E-04	0.194299
1.32E+12	12896800	8.44E-04	0.202156	1.30E+12	12749800	8.14E-04	0.195066
1.32E+12	12936000	8.54E-04	0.204551	1.31E+12	12798800	8.24E-04	0.197413
1.33E+12	12985000	8.64E-04	0.206946	1.31E+12	12847800	8.34E-04	0.199808
1.33E+12	13004600	8.71E-04	0.208599	1.31E+12	12857600	8.36E-04	0.200311
1.33E+12	13043800	8.81E-04	0.210994	1.32E+12	12887000	8.44E-04	0.202204
1.33E+12	13073200	8.87E-04	0.212359	1.32E+12	12936000	8.54E-04	0.204599
1.34E+12	13112400	8.97E-04	0.214754	1.32E+12	12936000	8.55E-04	0.204743
1.34E+12	13112400	8.97E-04	0.214874	1.32E+12	12975200	8.65E-04	0.207138
1.34E+12	13151600	9.07E-04	0.217269	1.33E+12	12985000	8.66E-04	0.207521
1.34E+12	13171200	9.13E-04	0.218635	1.33E+12	13024200	8.76E-04	0.209916
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1.35E+12	13210400	9.26E-04	0.22182	1.33E+12	13063400	8.88E-04	0.212695
1.35E+12	13249600	9.36E-04	0.224216	1.33E+12	13073200	8.91E-04	0.213317
1.35E+12	13249600	9.37E-04	0.224455	1.34E+12	13112400	8.99E-04	0.215425
1.36E+12	13279000	9.47E-04	0.22685	1.34E+12	13141800	9.09E-04	0.21782
1.36E+12	13279000	9.48E-04	0.226946	1.34E+12	13151600	9.13E-04	0.218563
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1.36E+12	13328000	9.64E-04	0.230874	1.35E+12	13190800	9.25E-04	0.221581
1.36E+12	13357400	9.74E-04	0.233269	1.35E+12	13230000	9.35E-04	0.223976
1.37E+12	13386800	9.84E-04	0.235665	1.35E+12	13259400	9.45E-04	0.226371
1.37E+12	13416200	9.93E-04	0.237749	1.36E+12	13279000	9.51E-04	0.227856
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1.38E+12	13475000	1.02E-03	0.243832	1.36E+12	13357400	9.80E-04	0.234754
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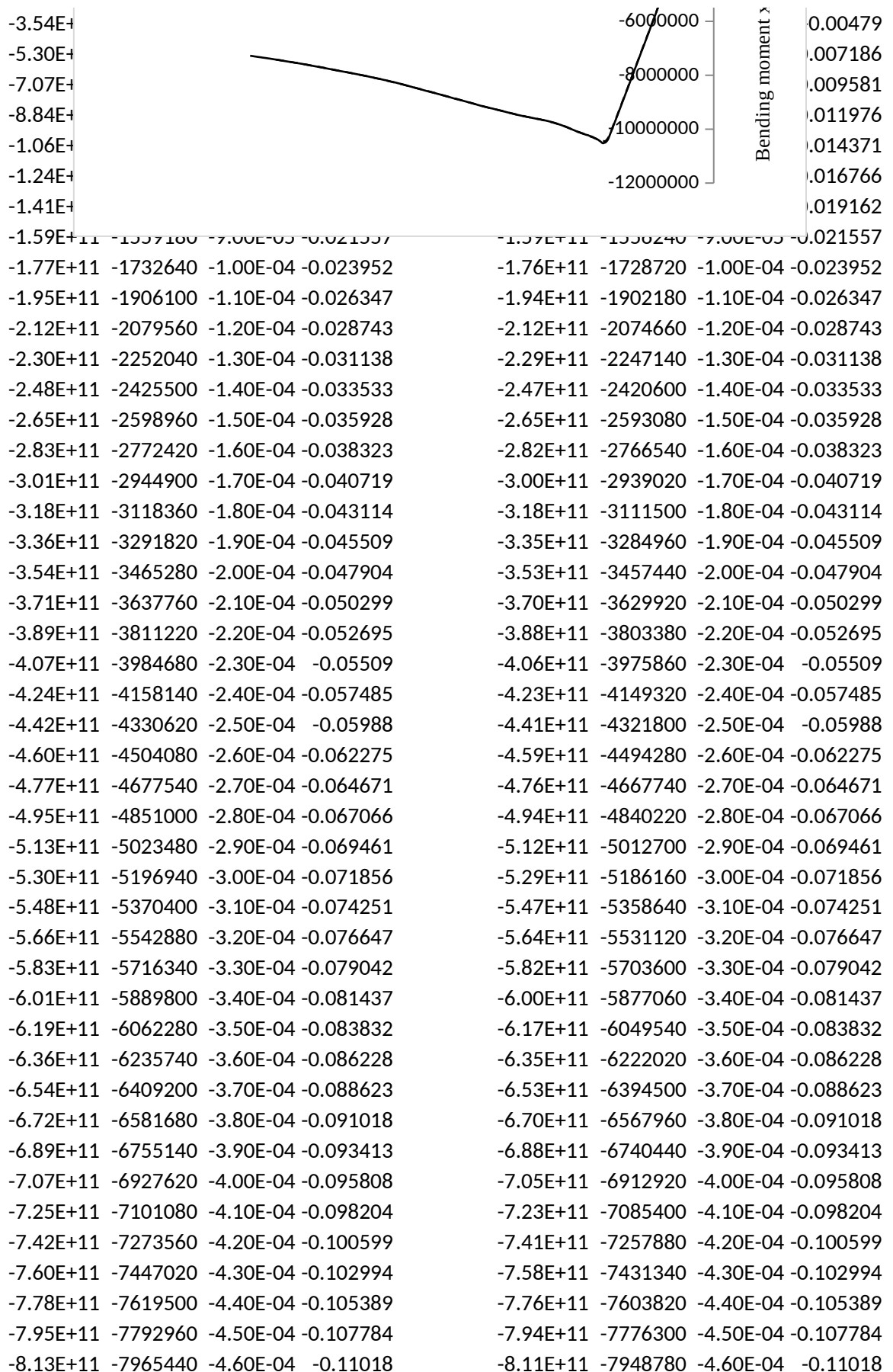
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1.39E+12	13631800	1.10E-03	0.263952	1.38E+12	13553400	1.06E-03	0.25485
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1.35E+12	13181000	1.46E-03	0.349461	1.36E+12	13328000	1.35E-03	0.322635
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1.34E+12	13161400	1.48E-03	0.353772	1.36E+12	13298600	1.36E-03	0.325749
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1.25E+12	12250000	2.25E-03	0.538683	1.26E+12	12387200	2.11E-03	0.50491
1.25E+12	12240200	2.26E-03	0.541078	1.26E+12	12377400	2.12E-03	0.507305
1.25E+12	12240200	2.27E-03	0.543473	1.26E+12	12367600	2.12E-03	0.507545

1.25E+12	12230400	2.28E-03	0.545868	1.26E+12	12357800	2.13E-03	0.50994
1.25E+12	12220600	2.29E-03	0.548263	1.26E+12	12357800	2.13E-03	0.511138
1.25E+12	12210800	2.30E-03	0.550659	1.26E+12	12338200	2.14E-03	0.513533
1.25E+12	12201000	2.30E-03	0.551138	1.26E+12	12328400	2.15E-03	0.515928
1.24E+12	12191200	2.31E-03	0.553533	1.26E+12	12318600	2.16E-03	0.518084
1.24E+12	12181400	2.32E-03	0.555928	1.26E+12	12308800	2.17E-03	0.520479
1.24E+12	12181400	2.33E-03	0.557365	1.26E+12	12299000	2.18E-03	0.522874
1.24E+12	12171600	2.34E-03	0.55976	1.25E+12	12289200	2.19E-03	0.524311
1.24E+12	12161800	2.35E-03	0.562156	1.25E+12	12279400	2.20E-03	0.526707
1.24E+12	12152000	2.35E-03	0.563832	1.25E+12	12269600	2.21E-03	0.529102
1.24E+12	12142200	2.36E-03	0.566228	1.25E+12	12259800	2.22E-03	0.531497
1.24E+12	12132400	2.37E-03	0.568623	1.25E+12	12250000	2.23E-03	0.533892
1.24E+12	12122600	2.38E-03	0.571018	1.25E+12	12250000	2.23E-03	0.534132
1.24E+12	12112800	2.39E-03	0.573413	1.25E+12	12240200	2.24E-03	0.536527
1.24E+12	12103000	2.40E-03	0.575808	1.25E+12	12230400	2.24E-03	0.536527
1.23E+12	12083400	2.41E-03	0.578204	1.25E+12	12220600	2.25E-03	0.538922
1.23E+12	12073600	2.42E-03	0.580599	1.25E+12	12210800	2.26E-03	0.541317
1.23E+12	12063800	2.43E-03	0.582994	1.25E+12	12201000	2.27E-03	0.542754
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-9.58E+11 -9392320 -1.16E-03 -0.278563
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-8.72E+11	-8546580	-1.66E-03	-0.396407	-8.87E+11	-8688680	-1.57E-03	-0.376287
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-8.68E+11	-8501500	-1.68E-03	-0.402635	-8.81E+11	-8634780	-1.60E-03	-0.383473
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-8.32E+11	-8148700	-1.89E-03	-0.453653	-8.47E+11	-8297660	-1.80E-03	-0.431138
-8.30E+11	-8134000	-1.90E-03	-0.456048	-8.45E+11	-8281000	-1.81E-03	-0.433533
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-8.24E+11	-8078140	-1.94E-03	-0.465629	-8.39E+11	-8217300	-1.85E-03	-0.443114
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-8.18E+11	-8012480	-1.99E-03	-0.477126	-8.32E+11	-8148700	-1.90E-03	-0.453892
-8.16E+11	-7998760	-2.00E-03	-0.479521	-8.30E+11	-8134000	-1.91E-03	-0.456287
-8.15E+11	-7986020	-2.01E-03	-0.481916	-8.29E+11	-8121260	-1.91E-03	-0.458443
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-8.10E+11 -7934080 -2.05E-03 -0.491497
-8.08E+11 -7921340 -2.06E-03 -0.493892
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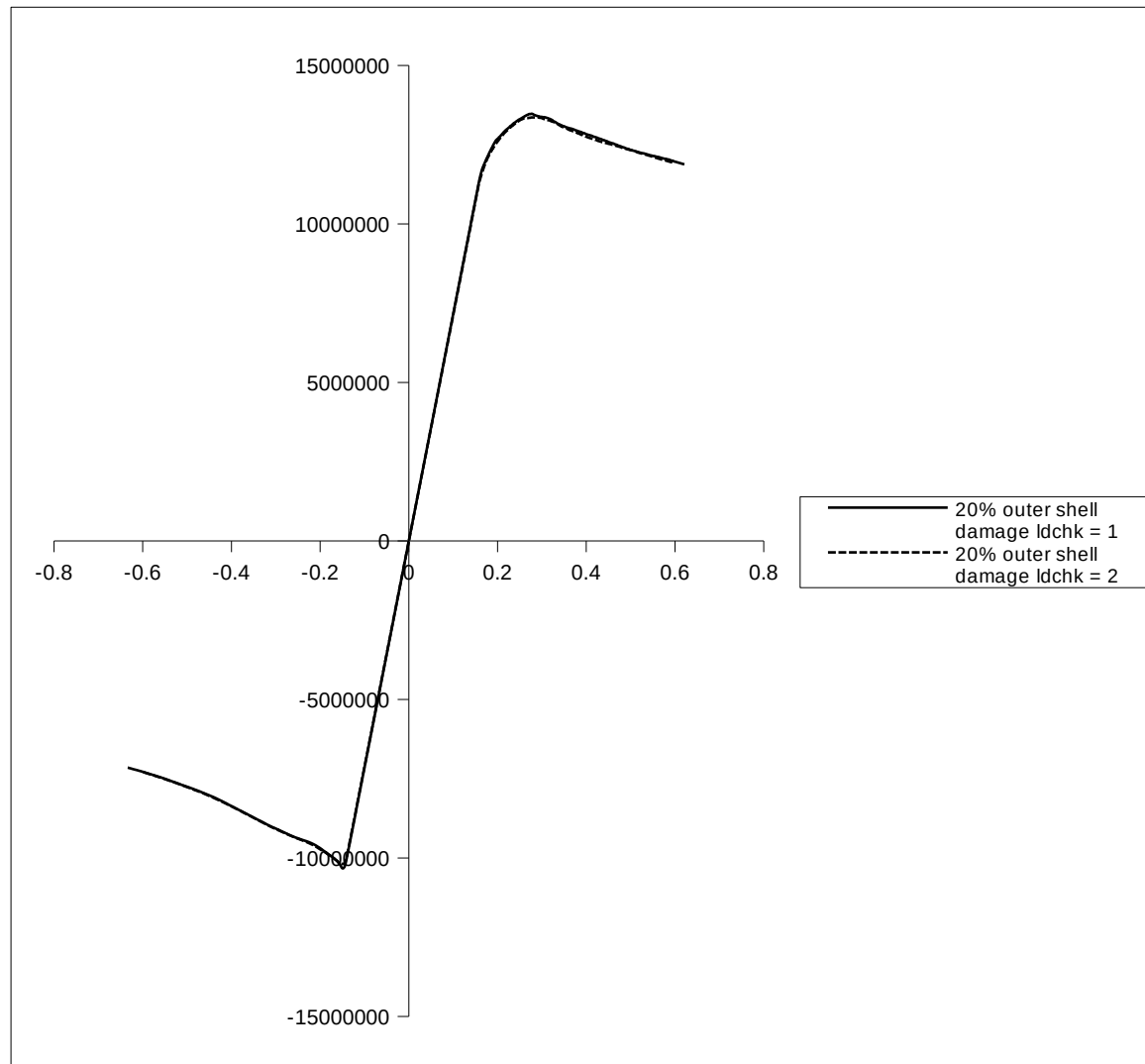
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-7.54E+11 -7391160 -2.52E-03 -0.602395

Tanker (T4) Idchk = 1			
20% outer shell damage			
frame spa	4.175	9.80E-06	1000
Moment	Rotation Curvature		
1.75E+09	17159.8	1.00E-06	0.00024
3.50E+09	34319.6	2.00E-06	0.000479
5.25E+09	51479.4	3.00E-06	0.000719

Tanker (T4) Idchk = 2			
20% outer shell damage			
frame spa	4.175	9.80E-06	1000
Moment	Rotation Curvature		
1.74E+09	17091.2	1.00E-06	0.00024
3.49E+09	34182.4	2.00E-06	0.000479
5.23E+09	51273.6	3.00E-06	0.000719



3.85E+11	3774960	2.20E-04	0.052695
4.03E+11	3946460	2.30E-04	0.05509
4.20E+11	4117960	2.40E-04	0.057485
4.38E+11	4289460	2.50E-04	0.05988
4.55E+11	4460960	2.60E-04	0.062275
4.73E+11	4632460	2.70E-04	0.064671
4.90E+11	4803960	2.80E-04	0.067066
5.08E+11	4975460	2.90E-04	0.069461
5.25E+11	5147940	3.00E-04	0.071856
5.43E+11	5319440	3.10E-04	0.074251

3.84E+11	3760260	2.20E-04	0.052695
4.01E+11	3930780	2.30E-04	0.05509
4.19E+11	4101300	2.40E-04	0.057485
4.36E+11	4272800	2.50E-04	0.05988
4.53E+11	4443320	2.60E-04	0.062275
4.71E+11	4613840	2.70E-04	0.064671
4.88E+11	4785340	2.80E-04	0.067066
5.06E+11	4955860	2.90E-04	0.069461
5.23E+11	5127360	3.00E-04	0.071856
5.41E+11	5297880	3.10E-04	0.074251

5.60E+11	5490940	3.20E-04	0.076647
5.78E+11	5662440	3.30E-04	0.079042
5.95E+11	5833940	3.40E-04	0.081437
6.13E+11	6005440	3.50E-04	0.083832
6.30E+11	6176940	3.60E-04	0.086228
6.48E+11	6348440	3.70E-04	0.088623
6.65E+11	6519940	3.80E-04	0.091018
6.83E+11	6691440	3.90E-04	0.093413
7.00E+11	6862940	4.00E-04	0.095808
7.18E+11	7034440	4.10E-04	0.098204
7.35E+11	7206920	4.20E-04	0.100599
7.53E+11	7378420	4.30E-04	0.102994
7.70E+11	7549920	4.40E-04	0.105389
7.88E+11	7721420	4.50E-04	0.107784
8.05E+11	7892920	4.60E-04	0.11018
8.23E+11	8064420	4.70E-04	0.112575
8.40E+11	8235920	4.80E-04	0.11497
8.58E+11	8407420	4.90E-04	0.117365
8.75E+11	8578920	5.00E-04	0.11976
8.93E+11	8750420	5.10E-04	0.122156
9.10E+11	8921920	5.20E-04	0.124551
9.28E+11	9093420	5.30E-04	0.126946
9.45E+11	9264920	5.40E-04	0.129341
9.63E+11	9436420	5.50E-04	0.131737
9.81E+11	9608900	5.60E-04	0.134132
9.98E+11	9780400	5.70E-04	0.136527
1.02E+12	9947000	5.80E-04	0.138922
1.03E+12	10123400	5.90E-04	0.141317
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1.07E+12	10466400	6.10E-04	0.146108
1.09E+12	10633000	6.20E-04	0.148503
1.10E+12	10809400	6.30E-04	0.150898
1.12E+12	10976000	6.40E-04	0.153293
1.14E+12	11152400	6.50E-04	0.155689
1.16E+12	11319000	6.60E-04	0.158036
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1.18E+12	11544400	6.75E-04	0.161725
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1.20E+12	11730600	6.90E-04	0.165341
1.20E+12	11789400	6.97E-04	0.16697
1.21E+12	11838400	7.03E-04	0.168383
1.21E+12	11887400	7.10E-04	0.169964
1.22E+12	11965800	7.20E-04	0.172359
1.23E+12	12044200	7.30E-04	0.174754
1.23E+12	12054000	7.31E-04	0.175066

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5.76E+11	5639900	3.30E-04	0.079042
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6.10E+11	5981920	3.50E-04	0.083832
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6.63E+11	6494460	3.80E-04	0.091018
6.80E+11	6664980	3.90E-04	0.093413
6.98E+11	6835500	4.00E-04	0.095808
7.15E+11	7007000	4.10E-04	0.098204
7.32E+11	7177520	4.20E-04	0.100599
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9.42E+11	9228660	5.40E-04	0.129341
9.59E+11	9399180	5.50E-04	0.131737
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9.94E+11	9741200	5.70E-04	0.136527
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1.06E+12	10427200	6.10E-04	0.146108
1.08E+12	10593800	6.20E-04	0.148503
1.10E+12	10770200	6.30E-04	0.150898
1.12E+12	10936800	6.40E-04	0.153293
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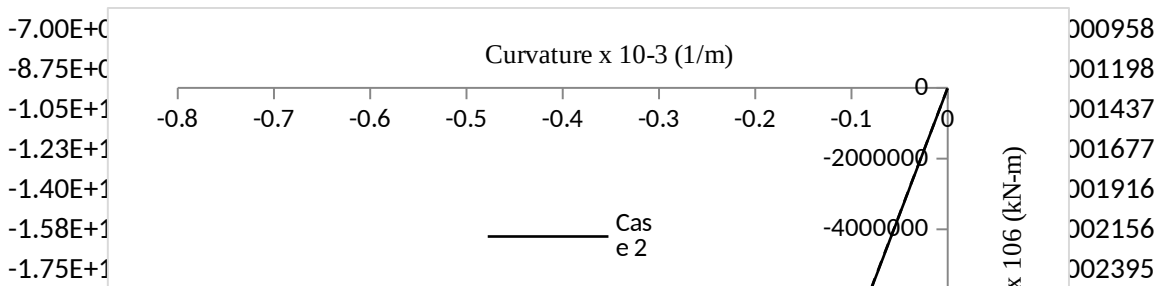
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1.29E+12	12661600	8.28E-04	0.198204	1.27E+12	12455800	8.06E-04	0.192934
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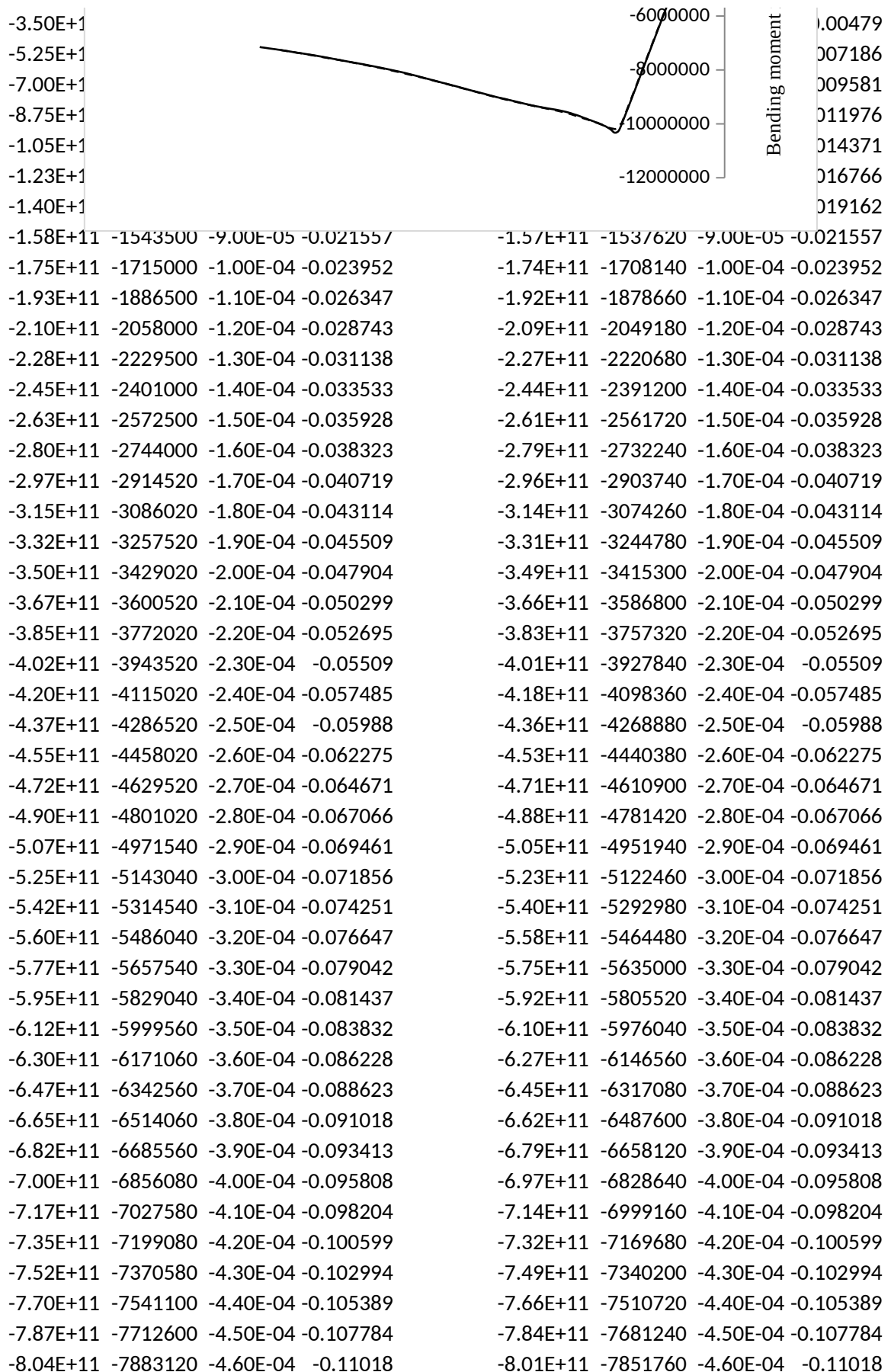
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1.37E+12	13435800	1.11E-03	0.266347	1.36E+12	13318200	1.08E-03	0.258204
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1.30E+12	12720400	1.77E-03	0.424671	1.30E+12	12749800	1.67E-03	0.400479
1.30E+12	12700800	1.78E-03	0.427066	1.30E+12	12740000	1.68E-03	0.401916
1.30E+12	12691000	1.79E-03	0.429461	1.30E+12	12730200	1.69E-03	0.403593
1.29E+12	12681200	1.80E-03	0.431856	1.30E+12	12720400	1.70E-03	0.405988
1.29E+12	12671400	1.81E-03	0.434251	1.30E+12	12710600	1.70E-03	0.407665
1.29E+12	12651800	1.82E-03	0.436647	1.30E+12	12700800	1.71E-03	0.41006
1.29E+12	12642000	1.83E-03	0.439042	1.30E+12	12691000	1.72E-03	0.412455
1.29E+12	12642000	1.84E-03	0.440479	1.29E+12	12681200	1.73E-03	0.41485
1.29E+12	12622400	1.85E-03	0.442874	1.29E+12	12671400	1.74E-03	0.417246
1.29E+12	12612600	1.86E-03	0.445269	1.29E+12	12651800	1.75E-03	0.419641
1.29E+12	12612600	1.86E-03	0.445269	1.29E+12	12651800	1.76E-03	0.421078
1.29E+12	12602800	1.87E-03	0.447665	1.29E+12	12642000	1.77E-03	0.423473

1.28E+12	12583200	1.88E-03	0.45006	1.29E+12	12622400	1.78E-03	0.425868
1.28E+12	12573400	1.89E-03	0.452455	1.29E+12	12612600	1.79E-03	0.428263
1.28E+12	12563600	1.90E-03	0.454132	1.29E+12	12602800	1.80E-03	0.430659
1.28E+12	12553800	1.91E-03	0.456527	1.29E+12	12593000	1.81E-03	0.433054
1.28E+12	12544000	1.92E-03	0.458922	1.28E+12	12583200	1.82E-03	0.435449
1.28E+12	12534200	1.93E-03	0.461317	1.28E+12	12573400	1.83E-03	0.437844
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1.28E+12	12514600	1.94E-03	0.464192	1.28E+12	12563600	1.84E-03	0.441198
1.28E+12	12504800	1.95E-03	0.466587	1.28E+12	12553800	1.85E-03	0.443593
1.28E+12	12495000	1.96E-03	0.468982	1.28E+12	12553800	1.85E-03	0.444072
1.27E+12	12475400	1.97E-03	0.471377	1.28E+12	12544000	1.86E-03	0.446467
1.27E+12	12465600	1.98E-03	0.473293	1.28E+12	12534200	1.87E-03	0.448862
1.27E+12	12455800	1.99E-03	0.475689	1.28E+12	12524400	1.88E-03	0.451257
1.27E+12	12446000	2.00E-03	0.478084	1.28E+12	12524400	1.89E-03	0.452216
1.27E+12	12426400	2.01E-03	0.480479	1.28E+12	12514600	1.90E-03	0.454611
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1.27E+12	12416600	2.02E-03	0.483593	1.28E+12	12495000	1.92E-03	0.459401
1.27E+12	12406800	2.03E-03	0.485988	1.27E+12	12485200	1.93E-03	0.461796
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1.26E+12	12377400	2.05E-03	0.490778	1.27E+12	12465600	1.95E-03	0.466587
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1.26E+12	12338200	2.09E-03	0.499641	1.27E+12	12426400	1.99E-03	0.476647
1.26E+12	12328400	2.10E-03	0.502036	1.27E+12	12416600	2.00E-03	0.479042
1.26E+12	12318600	2.11E-03	0.504431	1.27E+12	12406800	2.00E-03	0.47976
1.26E+12	12308800	2.12E-03	0.506826	1.27E+12	12397000	2.01E-03	0.482156
1.26E+12	12299000	2.13E-03	0.509222	1.27E+12	12397000	2.02E-03	0.482635
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1.25E+12	12279400	2.15E-03	0.514012	1.26E+12	12377400	2.04E-03	0.487425
1.25E+12	12269600	2.16E-03	0.516407	1.26E+12	12367600	2.05E-03	0.48982
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1.25E+12	12250000	2.18E-03	0.521198	1.26E+12	12348000	2.07E-03	0.494611
1.25E+12	12240200	2.19E-03	0.523593	1.26E+12	12348000	2.07E-03	0.49509
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1.25E+12	12230400	2.21E-03	0.528383	1.26E+12	12328400	2.09E-03	0.49988
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1.24E+12	12191200	2.25E-03	0.537964	1.26E+12	12299000	2.12E-03	0.507784
1.24E+12	12181400	2.26E-03	0.540359	1.25E+12	12289200	2.13E-03	0.51018
1.24E+12	12171600	2.27E-03	0.542754	1.25E+12	12279400	2.14E-03	0.512575
1.24E+12	12161800	2.28E-03	0.54515	1.25E+12	12259800	2.15E-03	0.51497
1.24E+12	12161800	2.28E-03	0.545868	1.25E+12	12250000	2.16E-03	0.517365

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1.24E+12	12142200	2.30E-03	0.550659	1.25E+12	12230400	2.18E-03	0.522156
1.24E+12	12142200	2.31E-03	0.553054	1.25E+12	12220600	2.19E-03	0.524551
1.24E+12	12132400	2.32E-03	0.555449	1.25E+12	12220600	2.20E-03	0.526228
1.24E+12	12122600	2.33E-03	0.557844	1.25E+12	12210800	2.21E-03	0.528623
1.24E+12	12112800	2.34E-03	0.56024	1.25E+12	12201000	2.22E-03	0.531018
1.24E+12	12112800	2.35E-03	0.562156	1.24E+12	12191200	2.22E-03	0.532455
1.24E+12	12103000	2.36E-03	0.564551	1.24E+12	12181400	2.23E-03	0.53485
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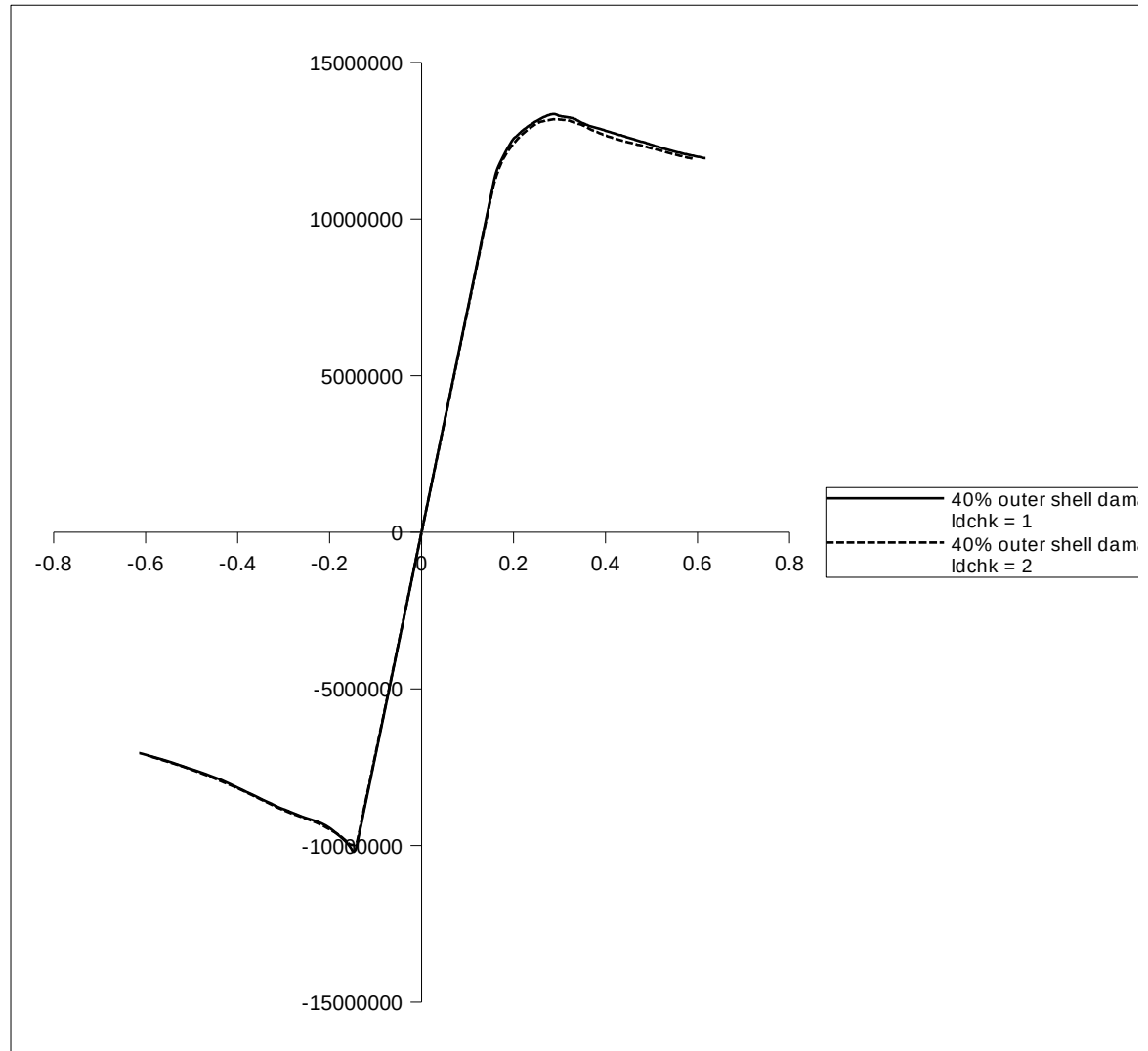
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-7.57E+11	-7414680	-2.38E-03	-0.569581	-7.70E+11	-7548940	-2.27E-03	-0.542515
-7.56E+11	-7403900	-2.39E-03	-0.571976	-7.70E+11	-7541100	-2.27E-03	-0.544431
-7.55E+11	-7394100	-2.40E-03	-0.574371	-7.68E+11	-7529340	-2.28E-03	-0.546826
-7.54E+11	-7384300	-2.41E-03	-0.576766	-7.67E+11	-7517580	-2.29E-03	-0.549222
-7.52E+11	-7373520	-2.42E-03	-0.579162	-7.66E+11	-7505820	-2.30E-03	-0.551617
-7.51E+11	-7363720	-2.43E-03	-0.581557	-7.65E+11	-7494060	-2.31E-03	-0.554012
-7.50E+11	-7352940	-2.44E-03	-0.583952	-7.64E+11	-7483280	-2.32E-03	-0.556407
-7.49E+11	-7343140	-2.45E-03	-0.586347	-7.62E+11	-7471520	-2.33E-03	-0.558802
-7.48E+11	-7333340	-2.46E-03	-0.588743	-7.61E+11	-7460740	-2.34E-03	-0.561198
-7.47E+11	-7322560	-2.47E-03	-0.591138	-7.60E+11	-7449960	-2.35E-03	-0.563593

-7.47E+11 -7315700 -2.48E-03 -0.592814
-7.45E+11 -7303940 -2.49E-03 -0.59521
-7.44E+11 -7293160 -2.50E-03 -0.597605
-7.43E+11 -7283360 -2.51E-03 -0.6
-7.42E+11 -7272580 -2.52E-03 -0.602395
-7.41E+11 -7262780 -2.53E-03 -0.60479
-7.40E+11 -7253960 -2.54E-03 -0.607186
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-7.37E+11 -7226520 -2.57E-03 -0.614371
-7.37E+11 -7217700 -2.58E-03 -0.616766
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-7.31E+11 -7160860 -2.64E-03 -0.631377
-7.30E+11 -7151060 -2.65E-03 -0.633772

-7.59E+11 -7439180 -2.36E-03 -0.565988
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-7.50E+11 -7353920 -2.44E-03 -0.58515
-7.49E+11 -7343140 -2.45E-03 -0.587545
-7.48E+11 -7332360 -2.46E-03 -0.58994
-7.47E+11 -7321580 -2.47E-03 -0.592335
-7.46E+11 -7310800 -2.48E-03 -0.594731
-7.46E+11 -7306880 -2.49E-03 -0.595449
-7.45E+11 -7297080 -2.50E-03 -0.597844
-7.44E+11 -7286300 -2.51E-03 -0.60024
-7.43E+11 -7276500 -2.52E-03 -0.602635
-7.42E+11 -7266700 -2.53E-03 -0.60503

Tanker (T4) Idchk = 1			
40% outer shell damage			
frame spa	4.175	9.80E-06	1000
Moment	Rotation Curvature		
1.74E+09	17061.8	1.00E-06	0.00024
3.48E+09	34113.8	2.00E-06	0.000479
5.22E+09	51175.6	3.00E-06	0.000719

Tanker (T4) Idchk = 2			
40% outer shell damage			
frame spa	4.175	9.80E-06	1000
Moment	Rotation Curvature		
1.73E+09	16954	1.00E-06	0.00024
3.46E+09	33898.2	2.00E-06	0.000479
5.19E+09	50852.2	3.00E-06	0.000719



3.83E+11	3752420	2.20E-04	0.052695
4.00E+11	3922940	2.30E-04	0.05509
4.18E+11	4093460	2.40E-04	0.057485
4.35E+11	4263980	2.50E-04	0.05988
4.53E+11	4434500	2.60E-04	0.062275
4.70E+11	4605020	2.70E-04	0.064671
4.87E+11	4775540	2.80E-04	0.067066
5.05E+11	4946060	2.90E-04	0.069461
5.22E+11	5116580	3.00E-04	0.071856
5.40E+11	5287100	3.10E-04	0.074251

3.81E+11	3728900	2.20E-04	0.052695
3.98E+11	3898440	2.30E-04	0.05509
4.15E+11	4067980	2.40E-04	0.057485
4.32E+11	4237520	2.50E-04	0.05988
4.50E+11	4407060	2.60E-04	0.062275
4.67E+11	4576600	2.70E-04	0.064671
4.84E+11	4746140	2.80E-04	0.067066
5.02E+11	4915680	2.90E-04	0.069461
5.19E+11	5085220	3.00E-04	0.071856
5.36E+11	5254760	3.10E-04	0.074251

5.57E+11	5457620	3.20E-04	0.076647
5.74E+11	5628140	3.30E-04	0.079042
5.92E+11	5798660	3.40E-04	0.081437
6.09E+11	5969180	3.50E-04	0.083832
6.27E+11	6139700	3.60E-04	0.086228
6.44E+11	6310220	3.70E-04	0.088623
6.61E+11	6480740	3.80E-04	0.091018
6.79E+11	6651260	3.90E-04	0.093413
6.96E+11	6821780	4.00E-04	0.095808
7.14E+11	6992300	4.10E-04	0.098204
7.31E+11	7163800	4.20E-04	0.100599
7.48E+11	7334320	4.30E-04	0.102994
7.66E+11	7504840	4.40E-04	0.105389
7.83E+11	7675360	4.50E-04	0.107784
8.01E+11	7845880	4.60E-04	0.11018
8.18E+11	8016400	4.70E-04	0.112575
8.35E+11	8186920	4.80E-04	0.11497
8.53E+11	8357440	4.90E-04	0.117365
8.70E+11	8527960	5.00E-04	0.11976
8.88E+11	8698480	5.10E-04	0.122156
9.05E+11	8869000	5.20E-04	0.124551
9.22E+11	9039520	5.30E-04	0.126946
9.40E+11	9210040	5.40E-04	0.129341
9.57E+11	9380560	5.50E-04	0.131737
9.75E+11	9551080	5.60E-04	0.134132
9.92E+11	9721600	5.70E-04	0.136527
1.01E+12	9888200	5.80E-04	0.138922
1.03E+12	10064600	5.90E-04	0.141317
1.04E+12	10231200	6.00E-04	0.143713
1.06E+12	10407600	6.10E-04	0.146108
1.08E+12	10574200	6.20E-04	0.148503
1.10E+12	10740800	6.30E-04	0.150898
1.11E+12	10917200	6.40E-04	0.153293
1.13E+12	11083800	6.50E-04	0.155689
1.14E+12	11191600	6.56E-04	0.15715
1.15E+12	11309200	6.64E-04	0.158946
1.17E+12	11417000	6.71E-04	0.16079
1.17E+12	11505200	6.79E-04	0.162587
1.18E+12	11583600	6.86E-04	0.164359
1.19E+12	11642400	6.93E-04	0.16594
1.19E+12	11691400	6.99E-04	0.167353
1.20E+12	11740400	7.05E-04	0.16891
1.21E+12	11818800	7.15E-04	0.171305
1.21E+12	11887400	7.25E-04	0.173701
1.21E+12	11897200	7.26E-04	0.173916

5.53E+11	5423320	3.20E-04	0.076647
5.71E+11	5592860	3.30E-04	0.079042
5.88E+11	5762400	3.40E-04	0.081437
6.05E+11	5931940	3.50E-04	0.083832
6.23E+11	6101480	3.60E-04	0.086228
6.40E+11	6271020	3.70E-04	0.088623
6.57E+11	6440560	3.80E-04	0.091018
6.75E+11	6610100	3.90E-04	0.093413
6.92E+11	6779640	4.00E-04	0.095808
7.09E+11	6949180	4.10E-04	0.098204
7.26E+11	7118720	4.20E-04	0.100599
7.44E+11	7288260	4.30E-04	0.102994
7.61E+11	7457800	4.40E-04	0.105389
7.78E+11	7627340	4.50E-04	0.107784
7.96E+11	7796880	4.60E-04	0.11018
8.13E+11	7966420	4.70E-04	0.112575
8.30E+11	8135960	4.80E-04	0.11497
8.48E+11	8305500	4.90E-04	0.117365
8.65E+11	8474060	5.00E-04	0.11976
8.82E+11	8643600	5.10E-04	0.122156
8.99E+11	8813140	5.20E-04	0.124551
9.17E+11	8982680	5.30E-04	0.126946
9.34E+11	9152220	5.40E-04	0.129341
9.51E+11	9321760	5.50E-04	0.131737
9.69E+11	9491300	5.60E-04	0.134132
9.86E+11	9660840	5.70E-04	0.136527
1.00E+12	9829400	5.80E-04	0.138922
1.02E+12	9996000	5.90E-04	0.141317
1.04E+12	10172400	6.00E-04	0.143713
1.06E+12	10339000	6.10E-04	0.146108
1.07E+12	10505600	6.20E-04	0.148503
1.09E+12	10682000	6.30E-04	0.150898
1.11E+12	10848600	6.40E-04	0.153293
1.11E+12	10887800	6.43E-04	0.15394
1.13E+12	11044600	6.52E-04	0.156096
1.13E+12	11113200	6.57E-04	0.157413
1.15E+12	11221000	6.66E-04	0.159569
1.15E+12	11309200	6.74E-04	0.161389
1.16E+12	11397400	6.82E-04	0.163257
1.17E+12	11475800	6.90E-04	0.165174
1.18E+12	11554200	6.98E-04	0.167162
1.19E+12	11642400	7.06E-04	0.169198
1.19E+12	11691400	7.13E-04	0.170659
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1.21E+12	11818800	7.28E-04	0.174419

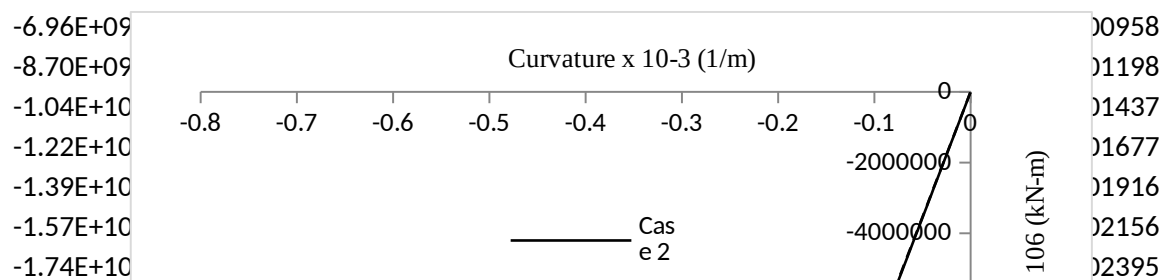
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1.24E+12	12103000	7.56E-04	0.181102	1.22E+12	11995200	7.54E-04	0.180671
1.24E+12	12171600	7.66E-04	0.183497	1.23E+12	12034400	7.61E-04	0.182228
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1.25E+12	12240200	7.77E-04	0.186618	1.24E+12	12103000	7.73E-04	0.185126
1.26E+12	12299000	7.87E-04	0.188575	1.24E+12	12161800	7.83E-04	0.187473
1.26E+12	12357800	7.97E-04	0.19097	1.25E+12	12201000	7.91E-04	0.189341
1.27E+12	12416600	8.07E-04	0.193365	1.25E+12	12250000	8.01E-04	0.191737
1.27E+12	12475400	8.17E-04	0.19576	1.25E+12	12250000	8.01E-04	0.191904
1.28E+12	12495000	8.21E-04	0.196623	1.25E+12	12289200	8.10E-04	0.19394
1.28E+12	12544000	8.31E-04	0.199018	1.26E+12	12338200	8.20E-04	0.196335
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1.29E+12	12622400	8.56E-04	0.205006	1.27E+12	12426400	8.40E-04	0.201293
1.29E+12	12632200	8.60E-04	0.205916	1.27E+12	12465600	8.50E-04	0.203689
1.29E+12	12671400	8.70E-04	0.208311	1.27E+12	12475400	8.52E-04	0.204024
1.30E+12	12691000	8.75E-04	0.209677	1.28E+12	12514600	8.62E-04	0.206419
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1.30E+12	12759600	8.97E-04	0.214778	1.28E+12	12583200	8.80E-04	0.210826
1.31E+12	12789000	9.05E-04	0.216743	1.29E+12	12622400	8.90E-04	0.213222
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1.31E+12	12847800	9.25E-04	0.221485	1.29E+12	12681200	9.09E-04	0.217725
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1.32E+12	12926200	9.55E-04	0.22879	1.30E+12	12769400	9.36E-04	0.224263
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1.33E+12	12994800	9.82E-04	0.235257	1.31E+12	12857600	9.68E-04	0.231952
1.33E+12	13014400	9.92E-04	0.237653	1.31E+12	12867400	9.72E-04	0.23291
1.33E+12	13024200	9.95E-04	0.238275	1.32E+12	12896800	9.82E-04	0.235305
1.33E+12	13043800	1.01E-03	0.240719	1.32E+12	12906600	9.86E-04	0.236048
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1.34E+12	13171200	1.07E-03	0.255569	1.33E+12	13053600	1.05E-03	0.251257
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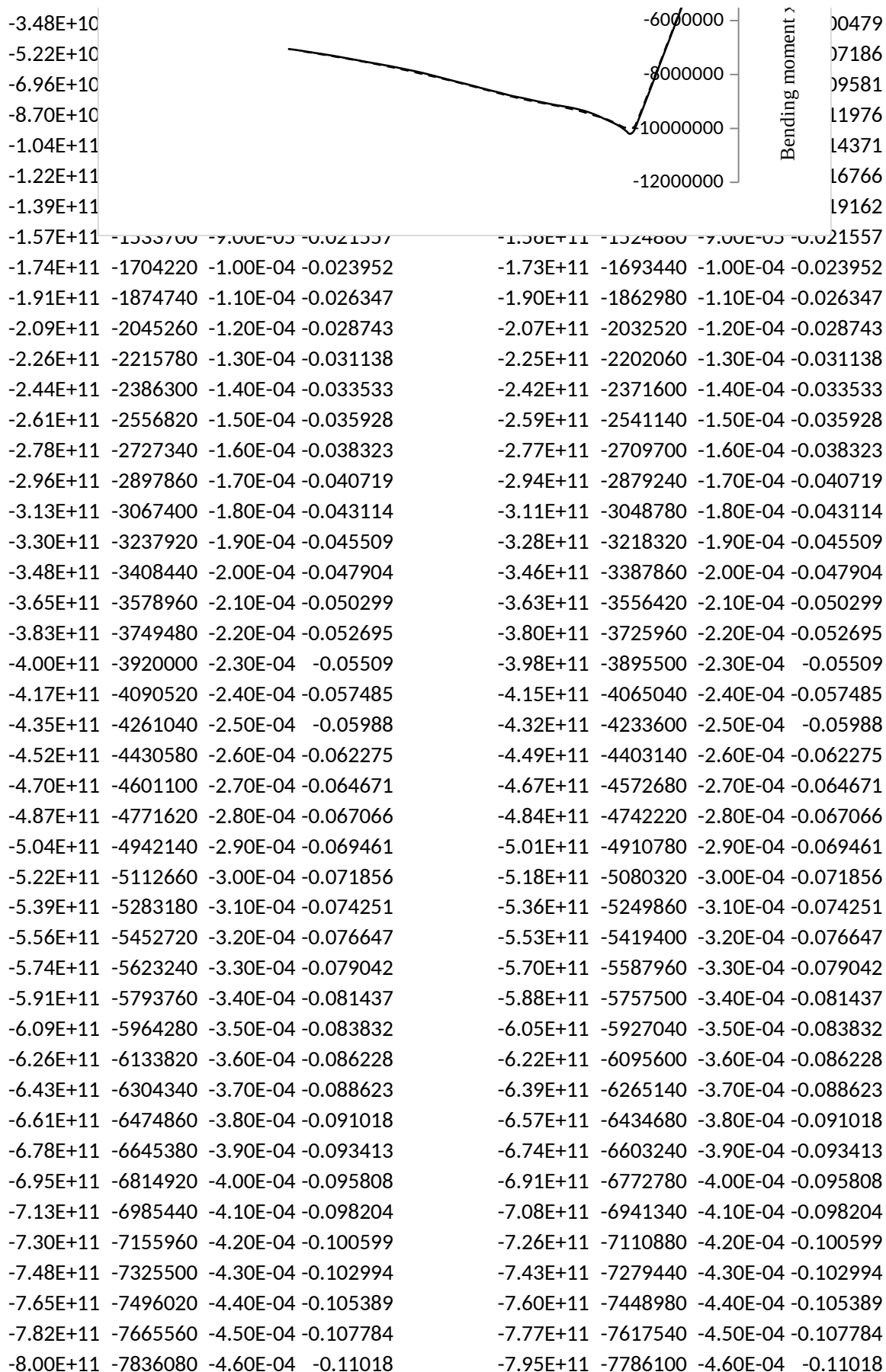
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1.36E+12	13288800	1.13E-03	0.271617	1.34E+12	13132000	1.11E-03	0.266347
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1.36E+12	13308400	1.15E-03	0.274491	1.34E+12	13141800	1.13E-03	0.269461
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1.36E+12	13318200	1.16E-03	0.277605	1.34E+12	13151600	1.14E-03	0.273054
1.36E+12	13337800	1.17E-03	0.28	1.34E+12	13151600	1.15E-03	0.275449
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1.36E+12	13347600	1.19E-03	0.28479	1.34E+12	13161400	1.17E-03	0.279521
1.36E+12	13347600	1.20E-03	0.287186	1.34E+12	13171200	1.18E-03	0.281916
1.36E+12	13347600	1.21E-03	0.289341	1.34E+12	13171200	1.18E-03	0.283353
1.36E+12	13337800	1.22E-03	0.291497	1.35E+12	13181000	1.19E-03	0.285749
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1.36E+12	13318200	1.23E-03	0.29509	1.35E+12	13181000	1.21E-03	0.288862
1.36E+12	13298600	1.24E-03	0.297485	1.35E+12	13181000	1.22E-03	0.291257
1.36E+12	13288800	1.25E-03	0.298683	1.35E+12	13181000	1.22E-03	0.291976
1.36E+12	13288800	1.26E-03	0.301078	1.35E+12	13181000	1.23E-03	0.294371
1.36E+12	13279000	1.27E-03	0.303473	1.35E+12	13181000	1.23E-03	0.294611
1.35E+12	13269200	1.28E-03	0.305868	1.35E+12	13181000	1.24E-03	0.297006
1.35E+12	13269200	1.29E-03	0.308263	1.35E+12	13181000	1.24E-03	0.297725
1.35E+12	13259400	1.30E-03	0.310659	1.34E+12	13171200	1.25E-03	0.30012
1.35E+12	13259400	1.31E-03	0.313054	1.34E+12	13171200	1.26E-03	0.300599
1.35E+12	13249600	1.32E-03	0.315449	1.34E+12	13171200	1.27E-03	0.302994
1.35E+12	13249600	1.32E-03	0.317126	1.34E+12	13171200	1.27E-03	0.304192
1.35E+12	13239800	1.33E-03	0.319521	1.34E+12	13161400	1.28E-03	0.306587
1.35E+12	13239800	1.34E-03	0.321437	1.34E+12	13161400	1.28E-03	0.307305
1.35E+12	13230000	1.35E-03	0.323832	1.34E+12	13161400	1.29E-03	0.309701
1.35E+12	13220200	1.36E-03	0.326228	1.34E+12	13161400	1.30E-03	0.311377
1.35E+12	13220200	1.37E-03	0.328144	1.34E+12	13151600	1.31E-03	0.313772
1.35E+12	13200600	1.38E-03	0.330539	1.34E+12	13151600	1.32E-03	0.316168
1.35E+12	13190800	1.39E-03	0.332934	1.34E+12	13151600	1.33E-03	0.317605
1.35E+12	13181000	1.40E-03	0.335329	1.34E+12	13141800	1.34E-03	0.32
1.34E+12	13151600	1.41E-03	0.337725	1.34E+12	13141800	1.34E-03	0.320479
1.34E+12	13151600	1.41E-03	0.337964	1.34E+12	13132000	1.35E-03	0.322635
1.34E+12	13141800	1.42E-03	0.339641	1.34E+12	13112400	1.36E-03	0.32503
1.34E+12	13122200	1.43E-03	0.341796	1.34E+12	13112400	1.36E-03	0.325749
1.34E+12	13102600	1.44E-03	0.344192	1.34E+12	13102600	1.37E-03	0.328144
1.34E+12	13083000	1.45E-03	0.346587	1.34E+12	13092800	1.37E-03	0.328623
1.34E+12	13083000	1.45E-03	0.346826	1.34E+12	13083000	1.38E-03	0.331018

1.33E+12	13063400	1.46E-03	0.349222	1.33E+12	13073200	1.39E-03	0.332695
1.33E+12	13063400	1.46E-03	0.349461	1.33E+12	13063400	1.40E-03	0.33509
1.33E+12	13053600	1.47E-03	0.351856	1.33E+12	13053600	1.41E-03	0.337485
1.33E+12	13043800	1.47E-03	0.352575	1.33E+12	13043800	1.41E-03	0.338683
1.33E+12	13034000	1.48E-03	0.35497	1.33E+12	13034000	1.42E-03	0.341078
1.33E+12	13014400	1.49E-03	0.357365	1.33E+12	13034000	1.43E-03	0.341796
1.33E+12	13004600	1.50E-03	0.35976	1.33E+12	13024200	1.44E-03	0.344192
1.33E+12	12994800	1.51E-03	0.361198	1.33E+12	13014400	1.45E-03	0.346587
1.32E+12	12975200	1.52E-03	0.363593	1.33E+12	13004600	1.45E-03	0.348263
1.32E+12	12965400	1.53E-03	0.365988	1.33E+12	12985000	1.46E-03	0.350659
1.32E+12	12955600	1.54E-03	0.368383	1.32E+12	12975200	1.47E-03	0.353054
1.32E+12	12945800	1.55E-03	0.370778	1.32E+12	12975200	1.47E-03	0.353054
1.32E+12	12936000	1.56E-03	0.373174	1.32E+12	12955600	1.48E-03	0.355449
1.32E+12	12926200	1.57E-03	0.375569	1.32E+12	12955600	1.49E-03	0.355689
1.32E+12	12916400	1.58E-03	0.377964	1.32E+12	12936000	1.50E-03	0.358084
1.32E+12	12906600	1.59E-03	0.380359	1.32E+12	12926200	1.50E-03	0.35976
1.32E+12	12896800	1.60E-03	0.382754	1.32E+12	12906600	1.51E-03	0.361437
1.32E+12	12896800	1.60E-03	0.383234	1.32E+12	12887000	1.52E-03	0.363832
1.32E+12	12887000	1.61E-03	0.385629	1.31E+12	12867400	1.53E-03	0.366228
1.31E+12	12877200	1.62E-03	0.388024	1.31E+12	12857600	1.54E-03	0.367904
1.31E+12	12867400	1.63E-03	0.390419	1.31E+12	12838000	1.55E-03	0.370299
1.31E+12	12857600	1.64E-03	0.392335	1.31E+12	12828200	1.56E-03	0.372695
1.31E+12	12847800	1.65E-03	0.394731	1.31E+12	12808600	1.57E-03	0.37509
1.31E+12	12838000	1.66E-03	0.397126	1.31E+12	12798800	1.58E-03	0.377485
1.31E+12	12818400	1.67E-03	0.399521	1.31E+12	12789000	1.58E-03	0.378443
1.31E+12	12808600	1.68E-03	0.401916	1.30E+12	12779200	1.59E-03	0.380838
1.31E+12	12798800	1.69E-03	0.404311	1.30E+12	12769400	1.59E-03	0.381796
1.31E+12	12789000	1.70E-03	0.406707	1.30E+12	12759600	1.60E-03	0.384192
1.30E+12	12779200	1.71E-03	0.409102	1.30E+12	12740000	1.61E-03	0.386587
1.30E+12	12769400	1.72E-03	0.411497	1.30E+12	12730200	1.62E-03	0.388982
1.30E+12	12759600	1.72E-03	0.412934	1.30E+12	12720400	1.63E-03	0.390419
1.30E+12	12749800	1.73E-03	0.415329	1.30E+12	12710600	1.64E-03	0.392814
1.30E+12	12740000	1.74E-03	0.417725	1.30E+12	12691000	1.65E-03	0.39521
1.30E+12	12730200	1.75E-03	0.42012	1.30E+12	12691000	1.66E-03	0.396407
1.30E+12	12720400	1.76E-03	0.422515	1.29E+12	12671400	1.67E-03	0.398802
1.30E+12	12710600	1.77E-03	0.423234	1.29E+12	12671400	1.67E-03	0.399281
1.30E+12	12700800	1.78E-03	0.425629	1.29E+12	12661600	1.68E-03	0.401677
1.30E+12	12691000	1.79E-03	0.428024	1.29E+12	12642000	1.69E-03	0.404072
1.29E+12	12681200	1.80E-03	0.430419	1.29E+12	12632200	1.70E-03	0.406467
1.29E+12	12681200	1.81E-03	0.432814	1.29E+12	12622400	1.71E-03	0.408862
1.29E+12	12671400	1.82E-03	0.43521	1.29E+12	12612600	1.72E-03	0.411257
1.29E+12	12661600	1.82E-03	0.436168	1.29E+12	12602800	1.73E-03	0.413653
1.29E+12	12651800	1.83E-03	0.438563	1.29E+12	12593000	1.73E-03	0.41509
1.29E+12	12642000	1.84E-03	0.440958	1.28E+12	12583200	1.74E-03	0.417485
1.29E+12	12632200	1.85E-03	0.443353	1.28E+12	12573400	1.75E-03	0.418683

1.29E+12	12612600	1.86E-03	0.445749	1.28E+12	12563600	1.76E-03	0.421078
1.29E+12	12602800	1.87E-03	0.448144	1.28E+12	12553800	1.77E-03	0.423473
1.29E+12	12593000	1.88E-03	0.450539	1.28E+12	12544000	1.78E-03	0.425868
1.28E+12	12583200	1.89E-03	0.452934	1.28E+12	12534200	1.79E-03	0.428263
1.28E+12	12573400	1.90E-03	0.455329	1.28E+12	12524400	1.80E-03	0.430659
1.28E+12	12563600	1.91E-03	0.457725	1.28E+12	12514600	1.81E-03	0.433054
1.28E+12	12553800	1.92E-03	0.46012	1.28E+12	12504800	1.82E-03	0.435449
1.28E+12	12544000	1.93E-03	0.462515	1.28E+12	12495000	1.83E-03	0.437844
1.28E+12	12524400	1.94E-03	0.46491	1.27E+12	12485200	1.84E-03	0.44024
1.28E+12	12514600	1.95E-03	0.467305	1.27E+12	12475400	1.85E-03	0.442635
1.28E+12	12504800	1.96E-03	0.469461	1.27E+12	12465600	1.86E-03	0.44503
1.28E+12	12495000	1.97E-03	0.471856	1.27E+12	12455800	1.87E-03	0.447425
1.27E+12	12485200	1.98E-03	0.474251	1.27E+12	12446000	1.88E-03	0.44982
1.27E+12	12475400	1.99E-03	0.475689	1.27E+12	12446000	1.88E-03	0.450539
1.27E+12	12465600	2.00E-03	0.478084	1.27E+12	12436200	1.89E-03	0.452934
1.27E+12	12465600	2.01E-03	0.48024	1.27E+12	12436200	1.90E-03	0.453892
1.27E+12	12455800	2.02E-03	0.482635	1.27E+12	12426400	1.91E-03	0.456287
1.27E+12	12446000	2.03E-03	0.48503	1.27E+12	12416600	1.92E-03	0.458683
1.27E+12	12436200	2.04E-03	0.487425	1.27E+12	12406800	1.92E-03	0.46012
1.27E+12	12416600	2.05E-03	0.48982	1.27E+12	12406800	1.93E-03	0.462515
1.27E+12	12406800	2.06E-03	0.492216	1.27E+12	12397000	1.94E-03	0.464671
1.27E+12	12406800	2.06E-03	0.493653	1.26E+12	12387200	1.95E-03	0.467066
1.26E+12	12387200	2.07E-03	0.496048	1.26E+12	12377400	1.96E-03	0.468263
1.26E+12	12377400	2.08E-03	0.498443	1.26E+12	12367600	1.97E-03	0.470659
1.26E+12	12367600	2.09E-03	0.500838	1.26E+12	12367600	1.98E-03	0.473054
1.26E+12	12357800	2.10E-03	0.503234	1.26E+12	12357800	1.99E-03	0.475449
1.26E+12	12348000	2.11E-03	0.505629	1.26E+12	12348000	2.00E-03	0.477844
1.26E+12	12338200	2.11E-03	0.506347	1.26E+12	12348000	2.00E-03	0.478084
1.26E+12	12328400	2.12E-03	0.508743	1.26E+12	12338200	2.01E-03	0.480479
1.26E+12	12318600	2.13E-03	0.511138	1.26E+12	12328400	2.02E-03	0.482635
1.26E+12	12308800	2.14E-03	0.513533	1.26E+12	12318600	2.03E-03	0.48503
1.26E+12	12299000	2.15E-03	0.515928	1.26E+12	12308800	2.04E-03	0.487425
1.25E+12	12289200	2.16E-03	0.517126	1.26E+12	12299000	2.05E-03	0.48982
1.25E+12	12279400	2.17E-03	0.519521	1.25E+12	12289200	2.05E-03	0.491497
1.25E+12	12269600	2.18E-03	0.521916	1.25E+12	12279400	2.06E-03	0.493892
1.25E+12	12259800	2.19E-03	0.524311	1.25E+12	12269600	2.07E-03	0.496287
1.25E+12	12250000	2.20E-03	0.526707	1.25E+12	12269600	2.08E-03	0.498683
1.25E+12	12250000	2.20E-03	0.526946	1.25E+12	12259800	2.08E-03	0.498922
1.25E+12	12240200	2.21E-03	0.529341	1.25E+12	12250000	2.09E-03	0.501317
1.25E+12	12230400	2.22E-03	0.531737	1.25E+12	12240200	2.10E-03	0.503713
1.25E+12	12220600	2.23E-03	0.534132	1.25E+12	12240200	2.11E-03	0.506108
1.25E+12	12210800	2.24E-03	0.536527	1.25E+12	12230400	2.12E-03	0.508503
1.25E+12	12201000	2.25E-03	0.538922	1.25E+12	12220600	2.13E-03	0.510898
1.24E+12	12191200	2.26E-03	0.541317	1.25E+12	12210800	2.14E-03	0.513293
1.24E+12	12181400	2.27E-03	0.543713	1.25E+12	12201000	2.15E-03	0.515689

1.24E+12	12171600	2.28E-03	0.546108	1.24E+12	12191200	2.16E-03	0.518084
1.24E+12	12161800	2.29E-03	0.548503	1.24E+12	12191200	2.17E-03	0.518563
1.24E+12	12152000	2.30E-03	0.550898	1.24E+12	12181400	2.18E-03	0.520958
1.24E+12	12142200	2.31E-03	0.553293	1.24E+12	12171600	2.19E-03	0.523353
1.24E+12	12132400	2.32E-03	0.555689	1.24E+12	12161800	2.20E-03	0.525749
1.24E+12	12122600	2.33E-03	0.558084	1.24E+12	12152000	2.21E-03	0.528144
1.24E+12	12122600	2.34E-03	0.560479	1.24E+12	12142200	2.21E-03	0.52982
1.24E+12	12112800	2.35E-03	0.562874	1.24E+12	12132400	2.22E-03	0.532216
1.24E+12	12103000	2.36E-03	0.565269	1.24E+12	12122600	2.23E-03	0.534611
1.23E+12	12093200	2.37E-03	0.567665	1.24E+12	12112800	2.24E-03	0.537006
1.23E+12	12083400	2.38E-03	0.57006	1.24E+12	12103000	2.25E-03	0.539401
1.23E+12	12073600	2.39E-03	0.572455	1.23E+12	12093200	2.26E-03	0.541796
1.23E+12	12073600	2.40E-03	0.57485	1.23E+12	12083400	2.27E-03	0.544192
1.23E+12	12063800	2.41E-03	0.577246	1.23E+12	12073600	2.28E-03	0.546587
1.23E+12	12054000	2.42E-03	0.579641	1.23E+12	12063800	2.29E-03	0.548982
1.23E+12	12044200	2.43E-03	0.582036	1.23E+12	12054000	2.30E-03	0.551377
1.23E+12	12044200	2.43E-03	0.582994	1.23E+12	12054000	2.31E-03	0.552575
1.23E+12	12034400	2.44E-03	0.585389	1.23E+12	12044200	2.32E-03	0.55497
1.23E+12	12024600	2.45E-03	0.587784	1.23E+12	12034400	2.33E-03	0.557365
1.23E+12	12024600	2.46E-03	0.59018	1.23E+12	12024600	2.34E-03	0.55976
1.23E+12	12014800	2.47E-03	0.592575	1.23E+12	12014800	2.35E-03	0.562156
1.23E+12	12005000	2.48E-03	0.59497	1.23E+12	12014800	2.36E-03	0.564551
1.22E+12	11995200	2.49E-03	0.597365	1.23E+12	12005000	2.37E-03	0.566946
1.22E+12	11995200	2.50E-03	0.598563	1.22E+12	11995200	2.38E-03	0.569341
1.22E+12	11985400	2.51E-03	0.600958	1.22E+12	11985400	2.39E-03	0.571737
1.22E+12	11985400	2.52E-03	0.603353	1.22E+12	11975600	2.40E-03	0.574132
1.22E+12	11975600	2.53E-03	0.605749	1.22E+12	11965800	2.41E-03	0.576527
1.22E+12	11975600	2.53E-03	0.606228	1.22E+12	11956000	2.42E-03	0.578922
1.22E+12	11965800	2.54E-03	0.608623	1.22E+12	11956000	2.43E-03	0.581317
1.22E+12	11956000	2.55E-03	0.611018	1.22E+12	11946200	2.44E-03	0.583713
1.22E+12	11946200	2.56E-03	0.613413	1.22E+12	11936400	2.45E-03	0.586108
1.22E+12	11946200	2.57E-03	0.615808	1.22E+12	11936400	2.45E-03	0.586587
1.22E+12	11946200	2.57E-03	0.616048	1.22E+12	11926600	2.46E-03	0.588982
1.22E+12	11936400	2.58E-03	0.618443	1.22E+12	11916800	2.47E-03	0.591377
0.00E+00	0	0.00E+00		0.00E+00	0	0.00E+00	
-1.74E+09	-17061.8	-1.00E-06	-0.00024	-1.73E+09	-16954	-1.00E-06	-0.00024
-3.48E+09	-34104	-2.00E-06	-0.000479	-3.46E+09	-33888.4	-2.00E-06	-0.000479
-5.22E+09	-51146.2	-3.00E-06	-0.000719	-5.19E+09	-50832.6	-3.00E-06	-0.000719





-8.17E+11 -8005620 -4.70E-04 -0.112575
-8.34E+11 -8175160 -4.80E-04 -0.11497
-8.52E+11 -8344700 -4.90E-04 -0.117365
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-8.86E+11 -8683780 -5.10E-04 -0.122156
-9.03E+11 -8852340 -5.20E-04 -0.124551
-9.21E+11 -9021880 -5.30E-04 -0.126946
-9.38E+11 -9190440 -5.40E-04 -0.129341
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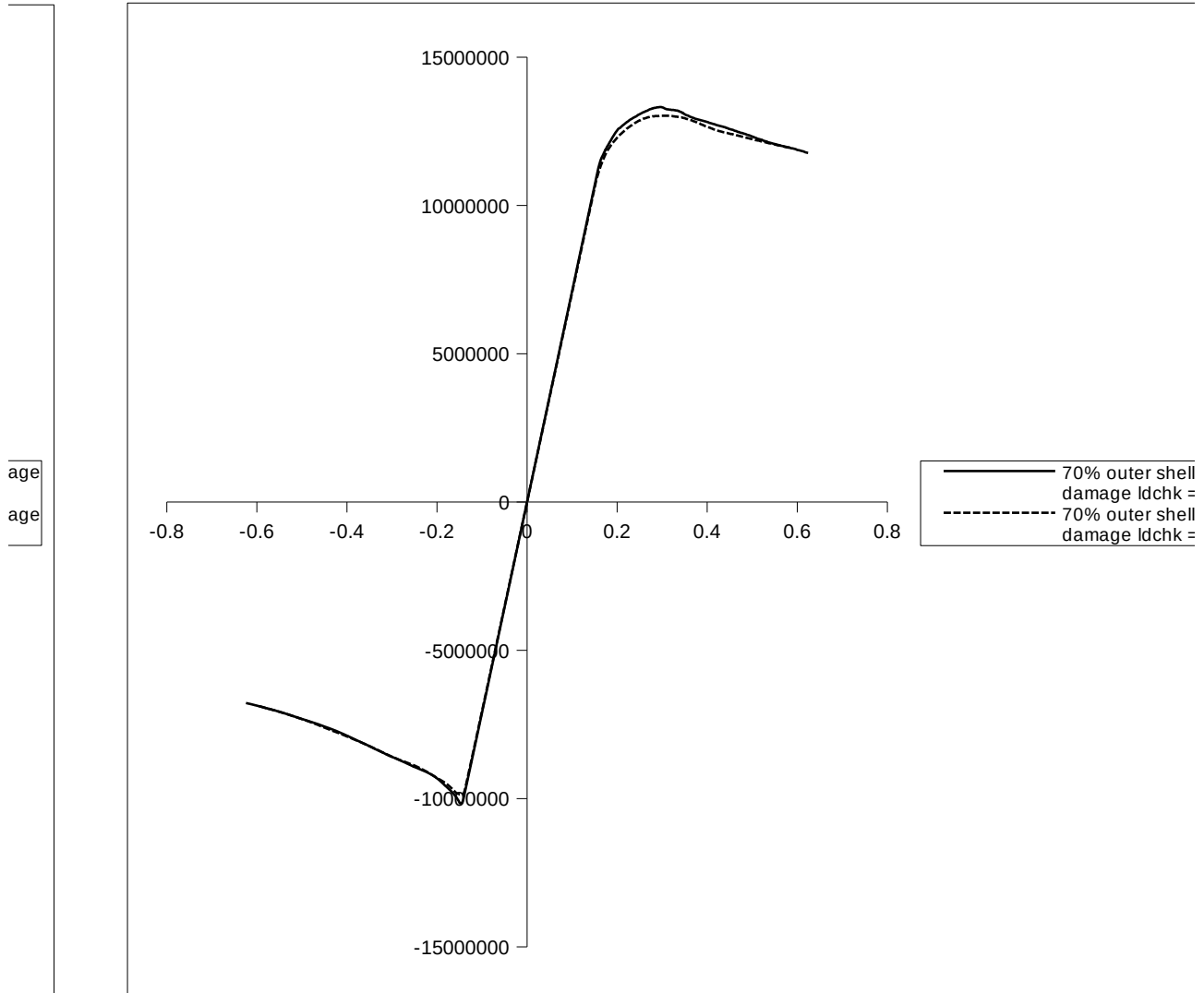
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-7.28E+11 -7137340 -2.48E-03 -0.594251
-7.27E+11 -7126560 -2.49E-03 -0.596647

Tanker (T4) Idchk = 1			
70% outer shell damage			
frame spa	4.175	9.80E-06	1000
Moment	Rotation Curvature		
1.74E+09	17042.2	1.00E-06	0.00024
3.48E+09	34084.4	2.00E-06	0.000479
5.22E+09	51116.8	3.00E-06	0.000719

Tanker (T4) Idchk = 2			
70% outer shell damage			
frame spa	4.175	9.80E-06	1000
Moment	Rotation Curvature		
1.73E+09	16914.8	1.00E-06	0.00024
3.45E+09	33829.6	2.00E-06	0.000479
5.18E+09	50744.4	3.00E-06	0.000719



3.83E+11	3748500	2.20E-04	0.052695
4.00E+11	3919020	2.30E-04	0.05509
4.17E+11	4089540	2.40E-04	0.057485
4.35E+11	4260060	2.50E-04	0.05988
4.52E+11	4429600	2.60E-04	0.062275
4.69E+11	4600120	2.70E-04	0.064671
4.87E+11	4770640	2.80E-04	0.067066
5.04E+11	4941160	2.90E-04	0.069461
5.22E+11	5111680	3.00E-04	0.071856
5.39E+11	5282200	3.10E-04	0.074251

3.80E+11	3721060	2.20E-04	0.052695
3.97E+11	3889620	2.30E-04	0.05509
4.14E+11	4059160	2.40E-04	0.057485
4.31E+11	4227720	2.50E-04	0.05988
4.49E+11	4397260	2.60E-04	0.062275
4.66E+11	4566800	2.70E-04	0.064671
4.83E+11	4735360	2.80E-04	0.067066
5.01E+11	4904900	2.90E-04	0.069461
5.18E+11	5073460	3.00E-04	0.071856
5.35E+11	5243000	3.10E-04	0.074251

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7.48E+11	7326480	4.30E-04	0.102994
7.65E+11	7497000	4.40E-04	0.105389
7.82E+11	7667520	4.50E-04	0.107784
8.00E+11	7837060	4.60E-04	0.11018
8.17E+11	8007580	4.70E-04	0.112575
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1.04E+12	10221400	6.00E-04	0.143713
1.06E+12	10397800	6.10E-04	0.146108
1.08E+12	10564400	6.20E-04	0.148503
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6.90E+11	6764940	4.00E-04	0.095808
7.08E+11	6934480	4.10E-04	0.098204
7.25E+11	7103040	4.20E-04	0.100599
7.42E+11	7272580	4.30E-04	0.102994
7.59E+11	7441140	4.40E-04	0.105389
7.77E+11	7610680	4.50E-04	0.107784
7.94E+11	7779240	4.60E-04	0.11018
8.11E+11	7948780	4.70E-04	0.112575
8.28E+11	8118320	4.80E-04	0.11497
8.46E+11	8286880	4.90E-04	0.117365
8.63E+11	8456420	5.00E-04	0.11976
8.80E+11	8624980	5.10E-04	0.122156
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1.16E+12	11368000	6.86E-04	0.164359
1.17E+12	11426800	6.93E-04	0.165988
1.17E+12	11505200	7.01E-04	0.167976
1.18E+12	11564000	7.08E-04	0.169533
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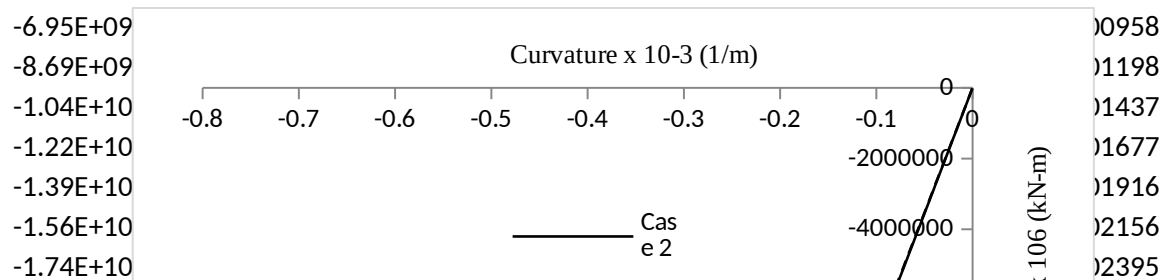
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1.23E+12	12054000	7.55E-04	0.180719	1.21E+12	11838400	7.44E-04	0.178156
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1.27E+12	12446000	8.18E-04	0.195952	1.24E+12	12103000	7.93E-04	0.189988
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1.30E+12	12710600	8.91E-04	0.213413	1.27E+12	12406800	8.69E-04	0.20824
1.30E+12	12730200	8.98E-04	0.215114	1.27E+12	12416600	8.71E-04	0.208719
1.30E+12	12759600	9.08E-04	0.217437	1.27E+12	12446000	8.81E-04	0.211114
1.31E+12	12789000	9.18E-04	0.219832	1.27E+12	12475400	8.89E-04	0.213006
1.31E+12	12818400	9.28E-04	0.222204	1.28E+12	12504800	8.99E-04	0.215401
1.31E+12	12838000	9.38E-04	0.224599	1.28E+12	12524400	9.05E-04	0.216719
1.31E+12	12857600	9.43E-04	0.225964	1.28E+12	12553800	9.15E-04	0.219114
1.32E+12	12887000	9.53E-04	0.228359	1.28E+12	12583200	9.22E-04	0.220766
1.32E+12	12906600	9.63E-04	0.230754	1.29E+12	12602800	9.31E-04	0.222922
1.32E+12	12926200	9.73E-04	0.23315	1.29E+12	12632200	9.41E-04	0.225317
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1.32E+12	12975200	9.95E-04	0.238395	1.30E+12	12691000	9.63E-04	0.230683
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1.33E+12	13043800	1.03E-03	0.245749	1.30E+12	12769400	9.97E-04	0.238731
1.33E+12	13063400	1.04E-03	0.248144	1.31E+12	12789000	1.00E-03	0.240479
1.33E+12	13063400	1.04E-03	0.248383	1.31E+12	12808600	1.01E-03	0.242874
1.34E+12	13083000	1.05E-03	0.250778	1.31E+12	12828200	1.02E-03	0.245269
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1.34E+12	13151600	1.09E-03	0.260359	1.32E+12	12887000	1.06E-03	0.253174
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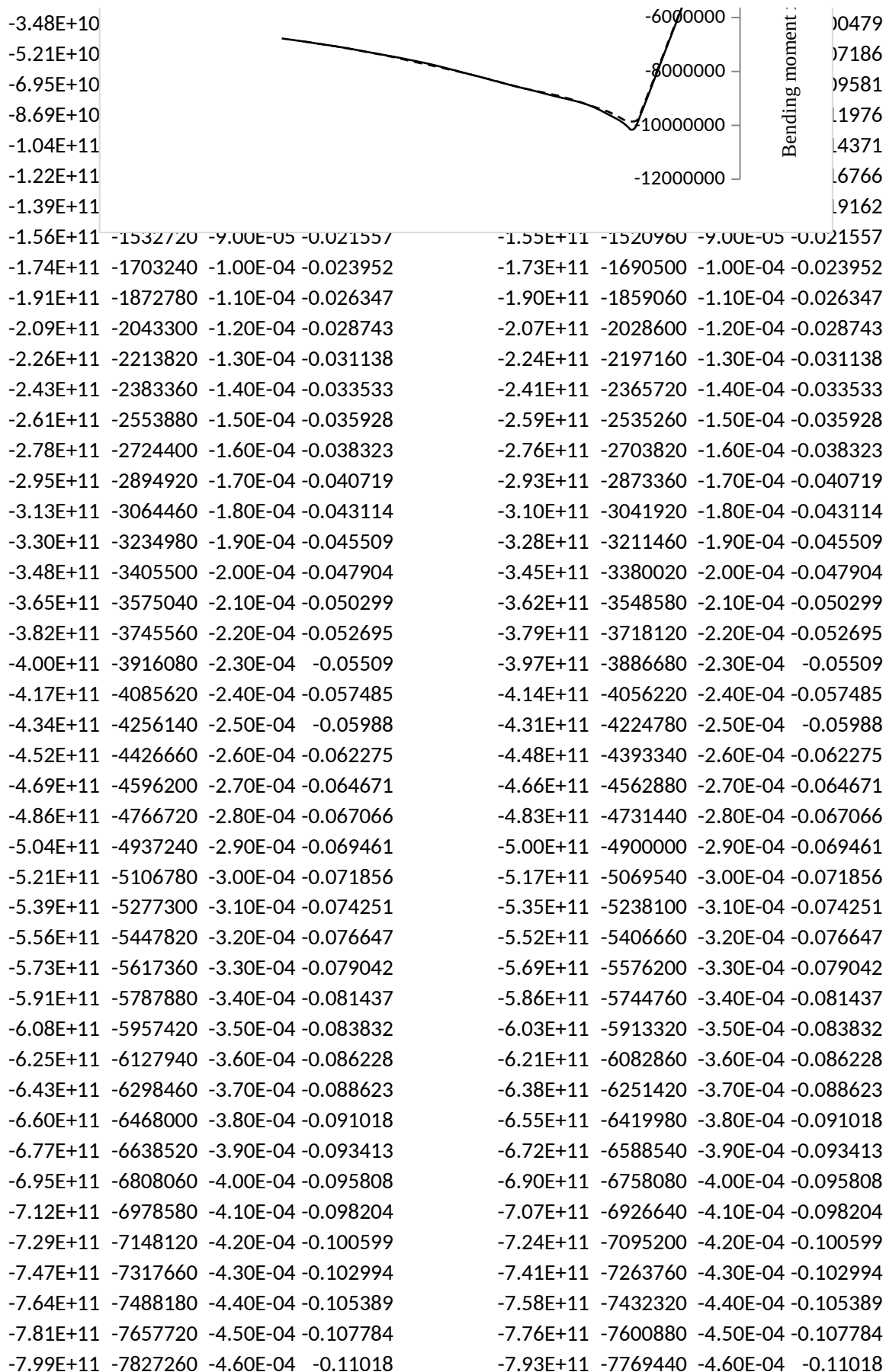
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1.33E+12	13043800	1.48E-03	0.353772	1.33E+12	12985000	1.40E-03	0.334611
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1.32E+12	12906600	1.58E-03	0.377964	1.32E+12	12916400	1.49E-03	0.355689
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1.31E+12	12838000	1.65E-03	0.394731	1.31E+12	12847800	1.54E-03	0.368383
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1.23E+12	12014800	2.35E-03	0.563832	1.24E+12	12161800	2.17E-03	0.52
1.23E+12	12005000	2.36E-03	0.566228	1.24E+12	12152000	2.18E-03	0.522395
1.23E+12	12005000	2.37E-03	0.567186	1.24E+12	12142200	2.19E-03	0.52479
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1.21E+12	11867800	2.51E-03	0.601437	1.23E+12	12024600	2.34E-03	0.56024
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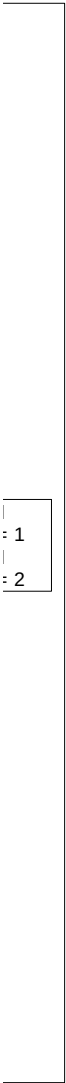
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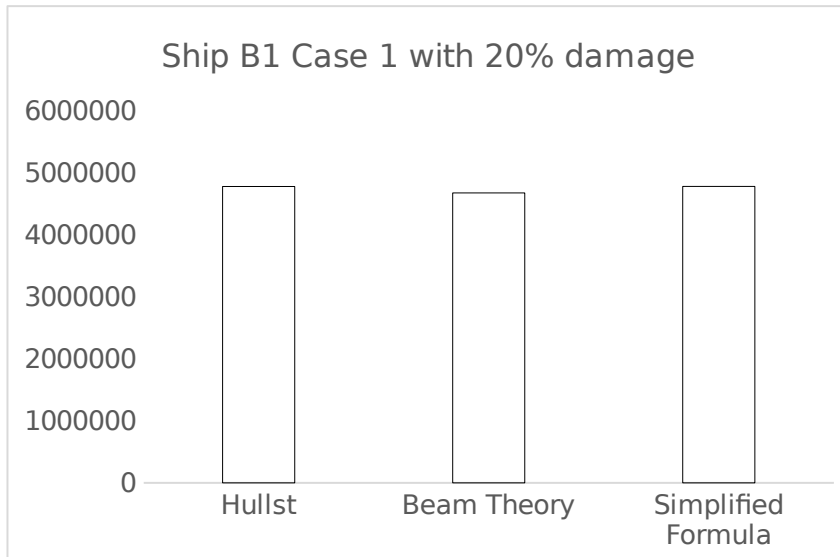
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$\vdash 2$

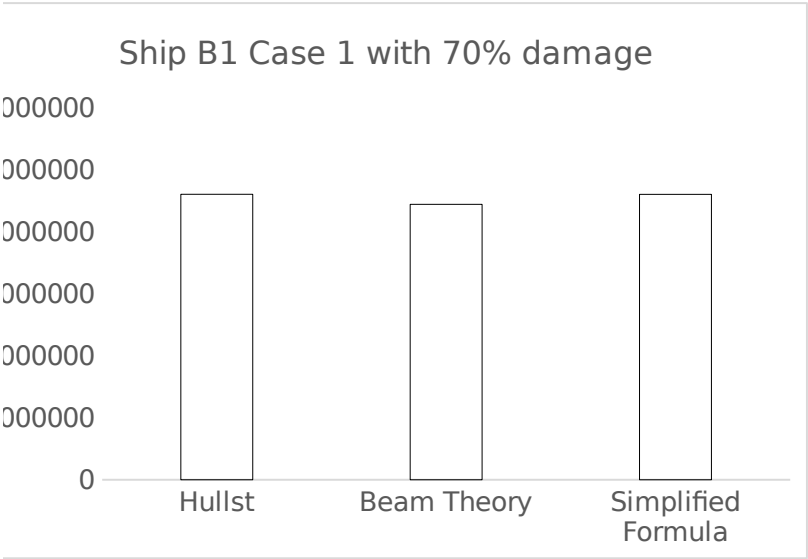
Ship B1 Case 1 with 20% Damage

Hullst	Beam Theory	Simplified Formula
4774560	4670974	4775760



Ship B1 Case 1 with 70% Damage

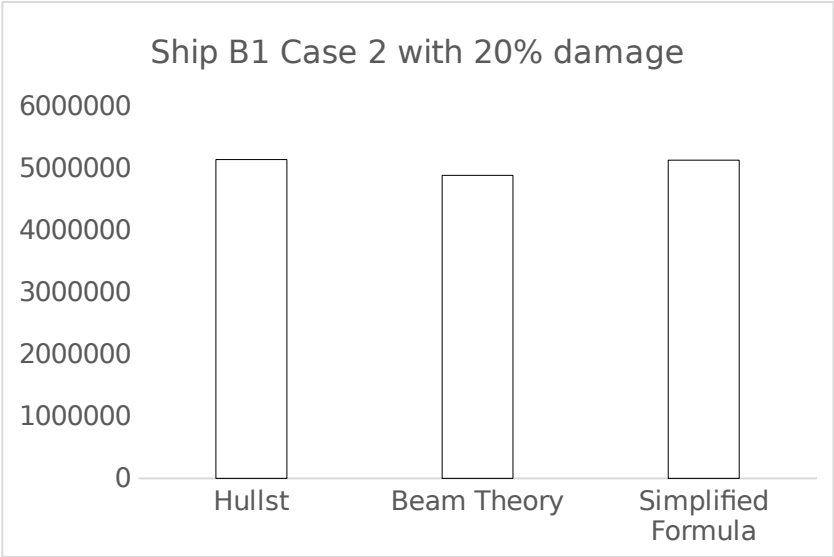
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4600120	4438126	4599100



Ship B1 Case 2 with 20% Damage

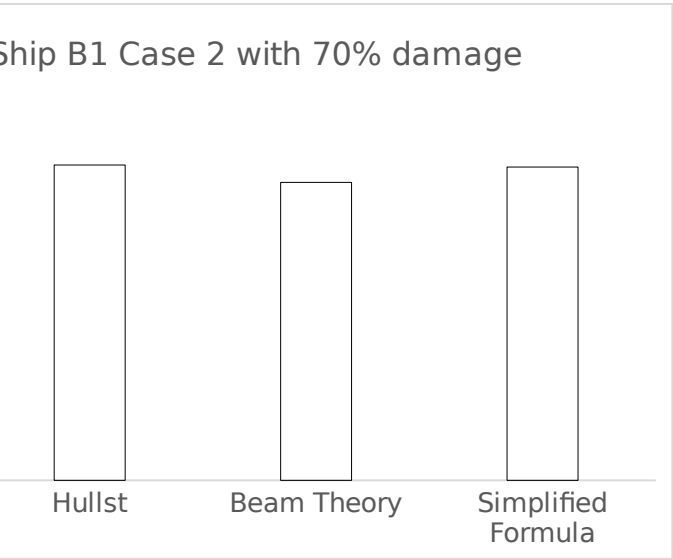
Hullst	Beam Theory	Simplified Formula
5139120	4885888	5130111

Hullst
5083260



Ship B1 Case 2 with 70% Damage

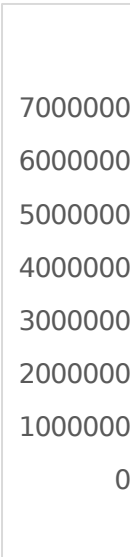
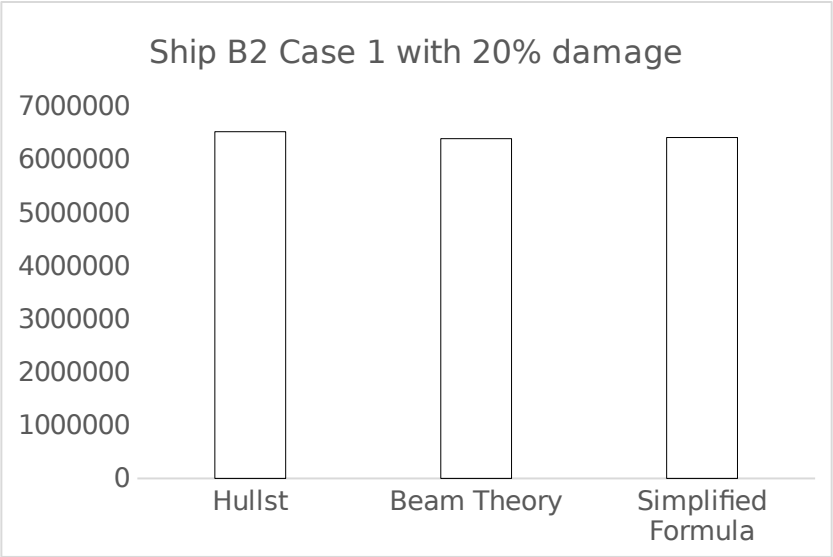
Beam Theory	Simplified Formula
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Ship B2 Case 1 with 20% Damage

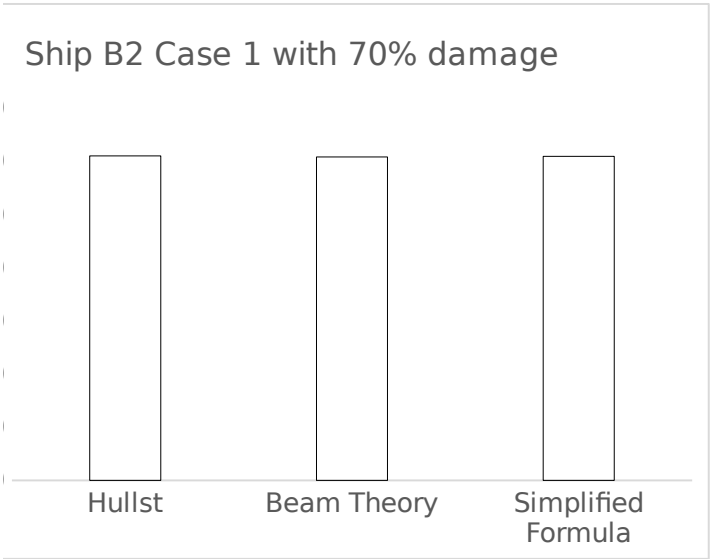
Hullst	Beam Theory	Simplified Formula
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Hullst
6104420



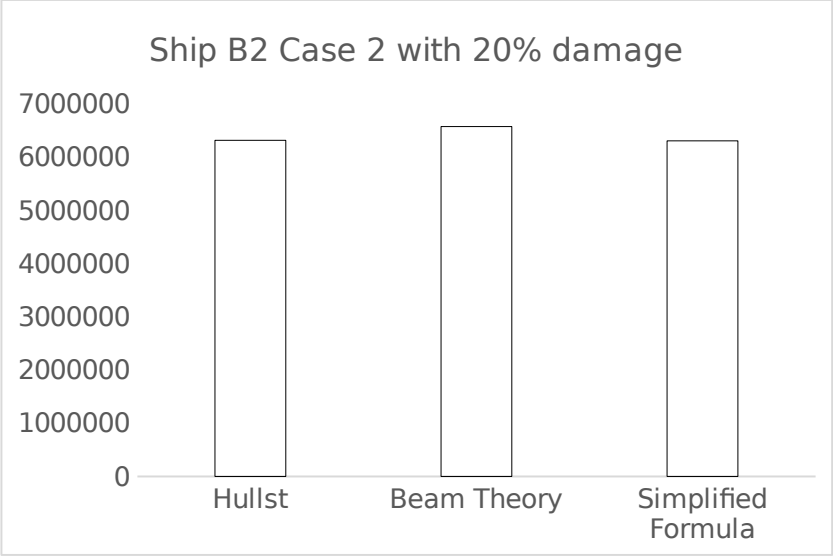
Ship B2 Case 1 with 70% Damage

Beam Theory	Simplified Formula
6083546	6095237



Ship B2 Case 2 with 20% Damage

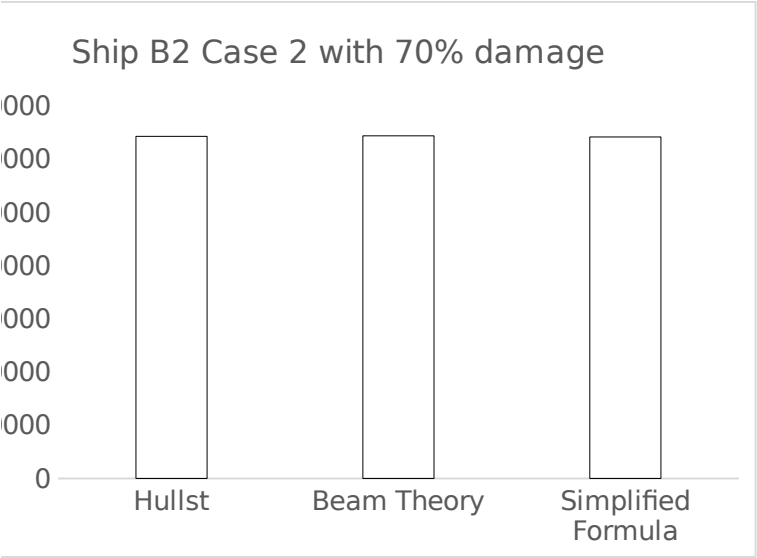
Hullst	Beam Theory	Simplified Formula	Hullst
6321000	6579916	6310231	6432720



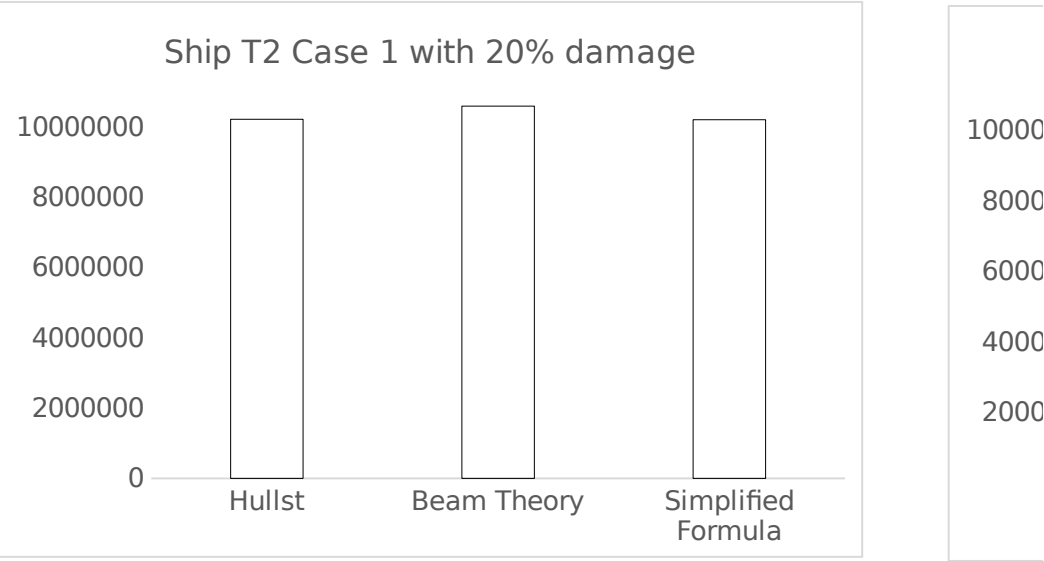
7000
6000
5000
4000
3000
2000
1000

Ship B2 Case 2 with 70% Damage

Beam Theory	Simplified Formula
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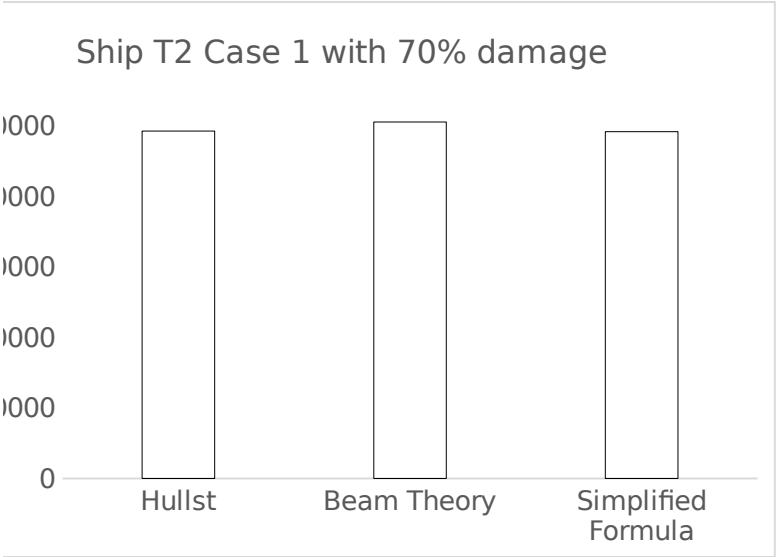


Ship T2 Case 1 with 20% Damage				:
Hullst	Beam Theory	Simplified Formula		Hullst
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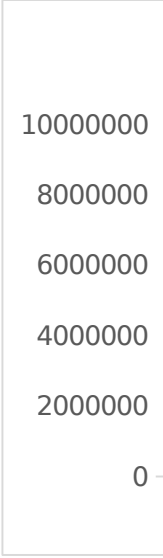
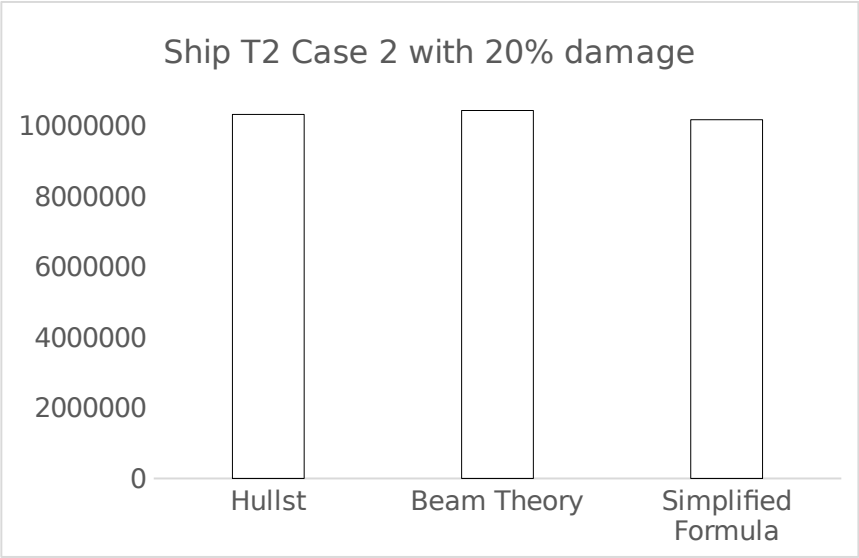
Ship T2 Case 1 with 70% Damage

Beam Theory	Simplified Formula
10126340	9851315



Ship T2 Case 2 with 20% Damage

Hullst	Beam Theory	Simplified Formula	Hullst
10339000	10453660	10191107	10172400



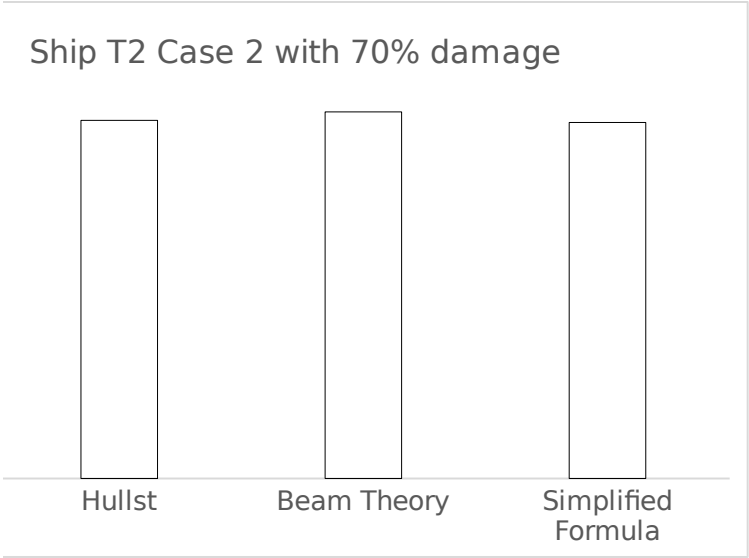
Ship T2 Case 2 with 70% Damage

Beam Theory

10414460

Simplified Formula

10112135



Category (1)

No comment for category (1) from the reviewer.

Category (2)

Question No. 1

Why the author selected only the sagging condition for ultimate hull girder strength estimation. Under the hogging condition, the damaged part is in tension side of the hull girder bending. This may cause the further extension of the damaged part and further reduction of the ultimate hull girder strength. The author is recommended to say something about this and describe the reason when only the sagging condition is selected in this paper.

Answer No. 1

In sagging condition, it is well recognized that the ultimate hull girder strength is almost attained when the primary deck members in longitudinal compression reached their ultimate strength. Also, because the damage takes place at the asymmetric position, in other word, collision damage is place at the side shell through to the deck part (B/16) and there is no damage located at the bottom part, so that it is very important to investigate the critical member under sagging condition.

Recommendation No. 2

P.2; left Column; L.35: The chapter title: “ESTIMATION OF THE ULTIMATE HULL GIRDER STRENGTH NEUTRAL AXIS EFFECT” is difficult to understand. It could be “EFFECT OF NEUTRAL AXIS ROTATION ON ESTIMATION OF THE ULTIMATE HULL GIRDER STRENGTH”.

Answer No. 2

Has been corrected, see the article.

Recommendation No. 3

P.2; right column; 1st line: “relationship in given in” → “relationship is given in”

Answer No. 3

Has been corrected, see the article.

Recommendation No. 4

A cross-section of a ship’s hull girder is in general symmetric with respect to the centreline of the cross-section. Therefore, $EIHV = EIVH = 0$ when a cross-section is not damaged. It is when the cross-section is damaged that $EIHV$ and $EIVH$ become not zero. From this aspect, it is recommended to describe that Eqs.(4) through (8) are for the asymmetrically damaged cross-section and Eqs.(9) and (10) are for intact cross-section.

Answer No. 4

Has been modified, see the article.

Recommendation No. 5

Another important point is a floating condition. When a collision is large, there could be a water ingress which results in non-upright condition of the hull girder. In this case, both vertical and horizontal bending moments acts on the cross section of a hull girder when only vertical bending moment acts on an inclined hull girder. Something has to be mentioned about this and what assumption is made for your calculation.

Respond No. 5

The water ingress correspond to the damage stability. In the present study, the ultimate strength is analyzed after damaged. The water ingress is not considered in the analysis. Result and Discussion have been modified.

Correction No. 6

P.3; left column; 3rd line in “RESULT AND DISCUSSEION”: “Case1” → Case 1”

Respond No. 6

Has been corrected, see the article.

Correction No. 7

P.3; left column; 3rd line in “RESULT AND DISCUSSEION”: “is given as follows,” → “is given as follows.” And what is “as follows.” No description can be found.

Respond No. 7

Has been modified, see the article.

Correction No. 8

P.3; right column; last line: it is described that “because the horizontal curvature is constrained.” However, explanation is necessary how the constraint of the horizontal curvature makes higher ultimate hull girder strength of Case 2 compared to that of Case 1.

Respond No. 8

Additional explanation is added on the result and discussion, see the article.

Recommendation No. 9

For the damaged condition, not only the vertical bending moment but the resultant bending moment has to be discussed. Actually working bending moment is the resultant bending moment of vertical and horizontal bending moments in the η - ξ coordinate system in Fig. 1.

Respond No. 9

Additional discussion is attached in the article regarding the resultant of bending moment.

Correction No. 10

P.4; right column; 15th line: “curvature induce by” → “curvature induced by”

Respond No. 10

Has been corrected, see the article.

Correction No. 11

P.4; right column; 28th line: “in ship structural.” → “in ship structures.”

Respond No. 11

Has been corrected, see the article.

Correction No. 12

P.4; Fig. 11 (b): The overlapping of letters has to be revised.

Respond No. 12

Has been revised, see the article.

Correction No. 13

P.5; Fig. 12 (b): The overlapping of letters has to be reviced.

Respond No. 13

Has been revised, see the article.

Correction No. 14

P.5; CONCLUSIONS; 2nd line: “with asymmetrically damaged has” → “with asymmetrically damaged cross section has”

Respond No. 14

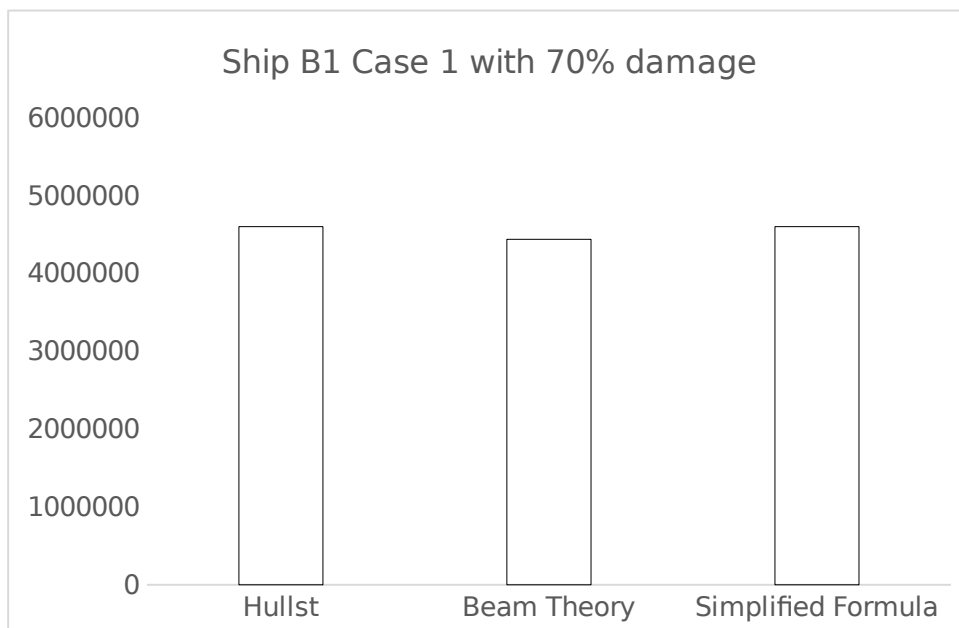
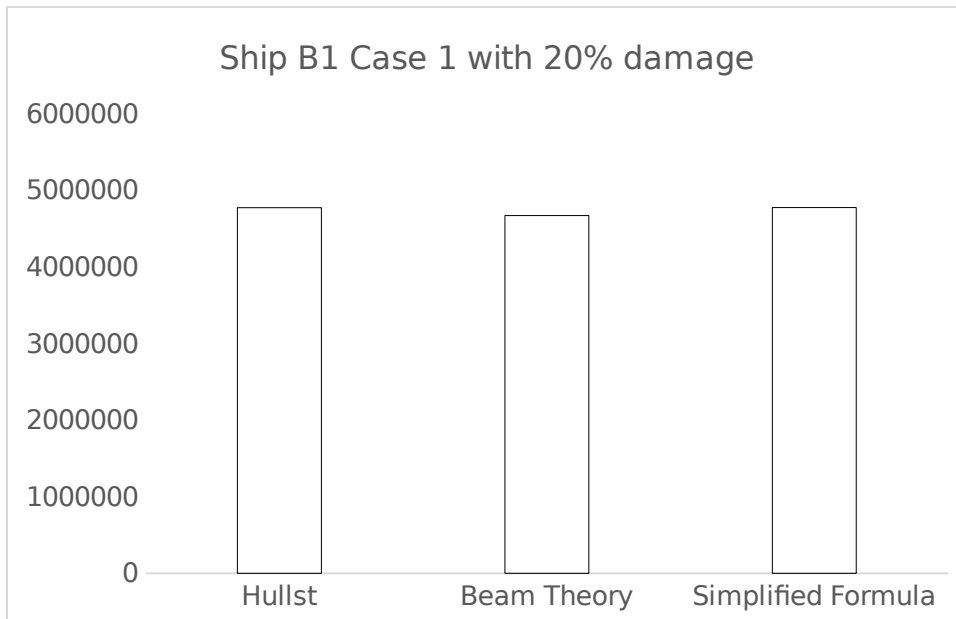
Has been revised, see the article.

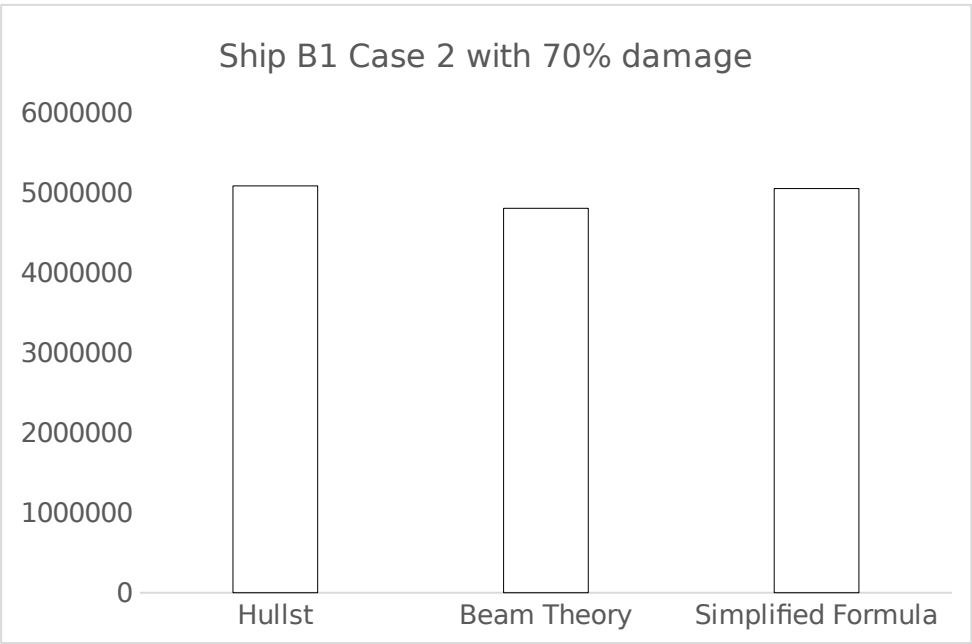
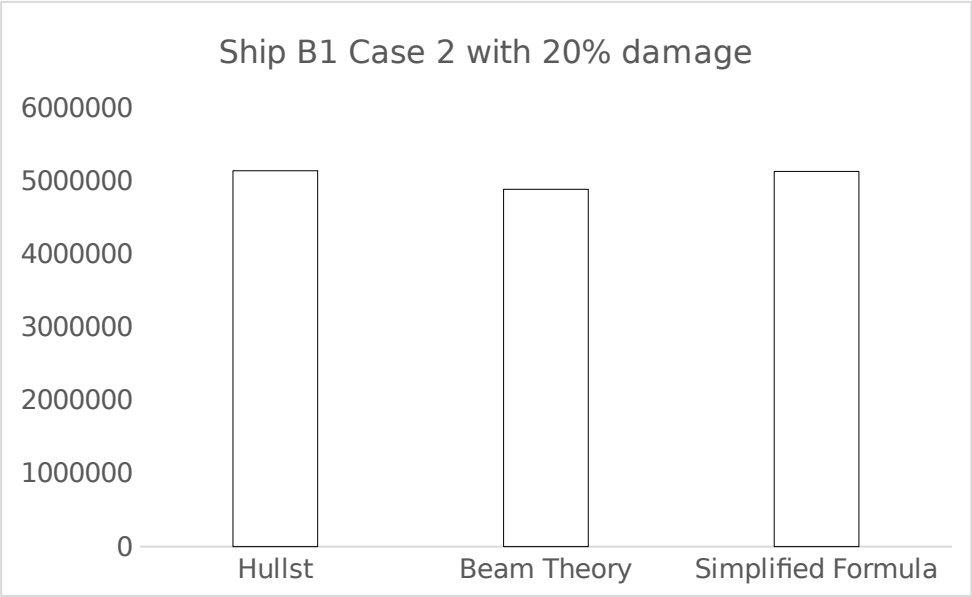
Recommendation No. 15

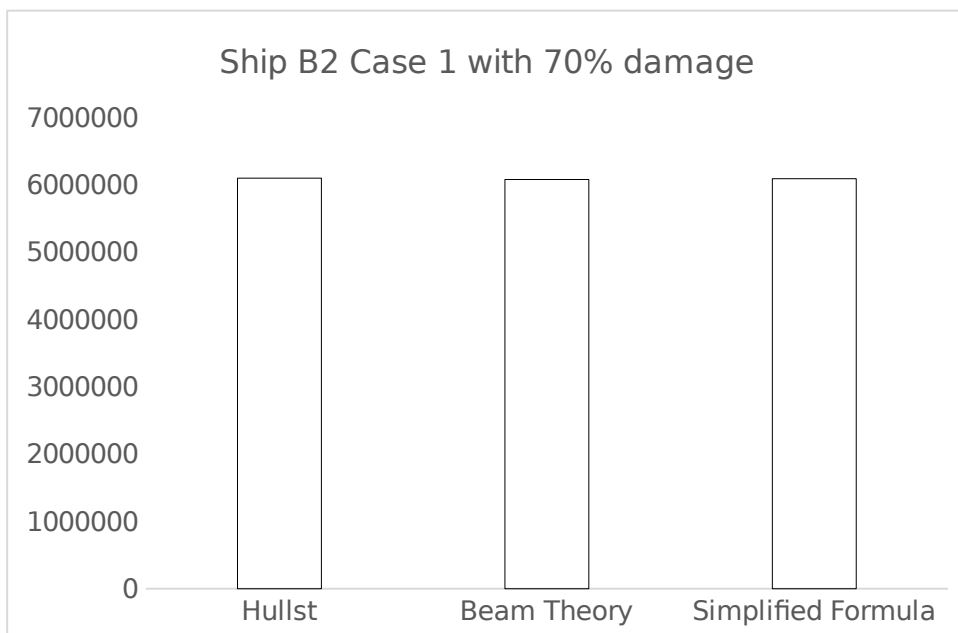
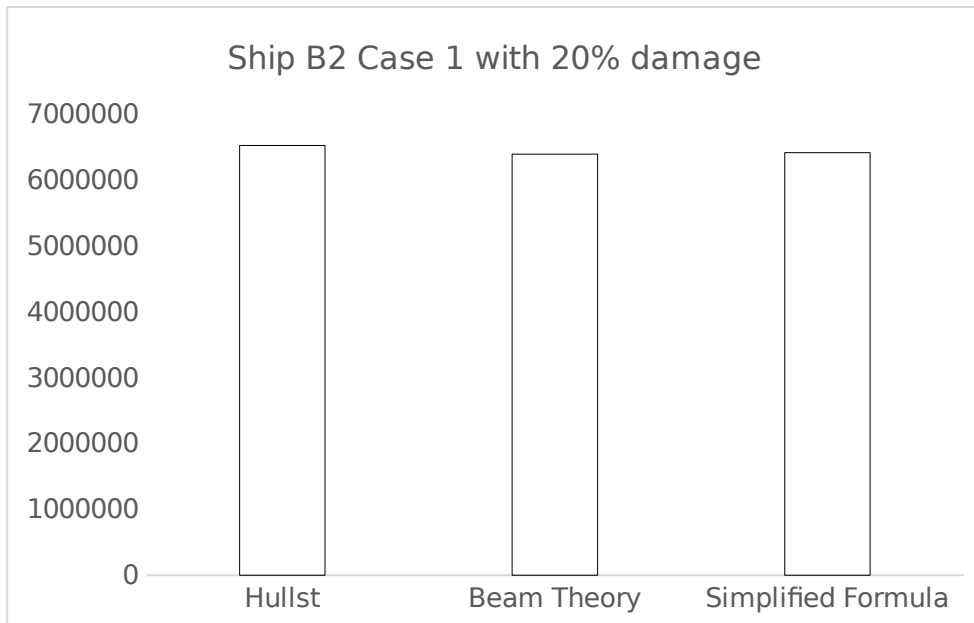
P.5; CONCLUSIONS; 13rd – 14th lines: “because the horizontal curvature is constrained.”
As was mentioned in (8), the real reason which is derived from the constrained horizontal curvature has to be described here.

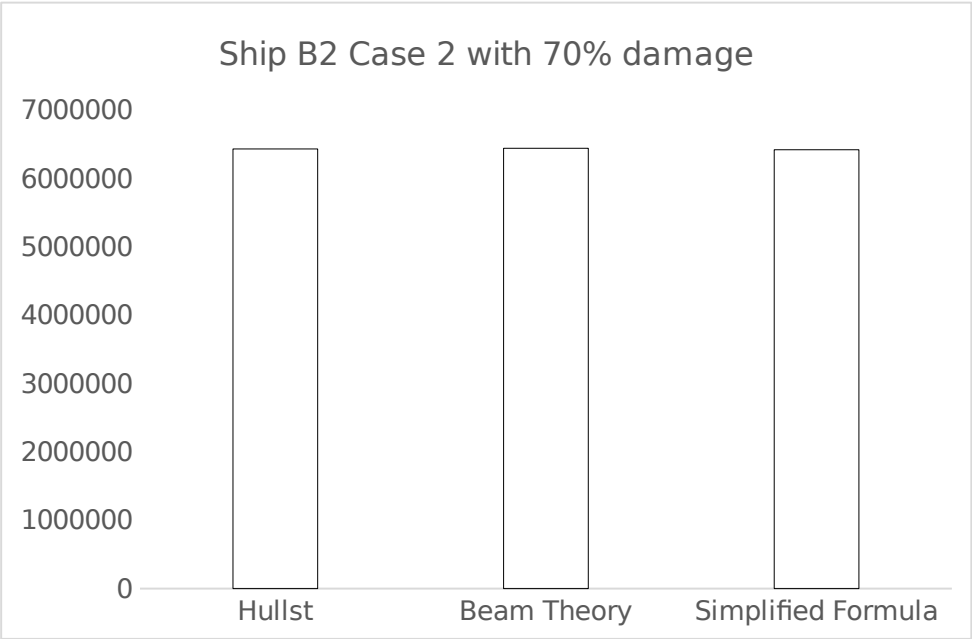
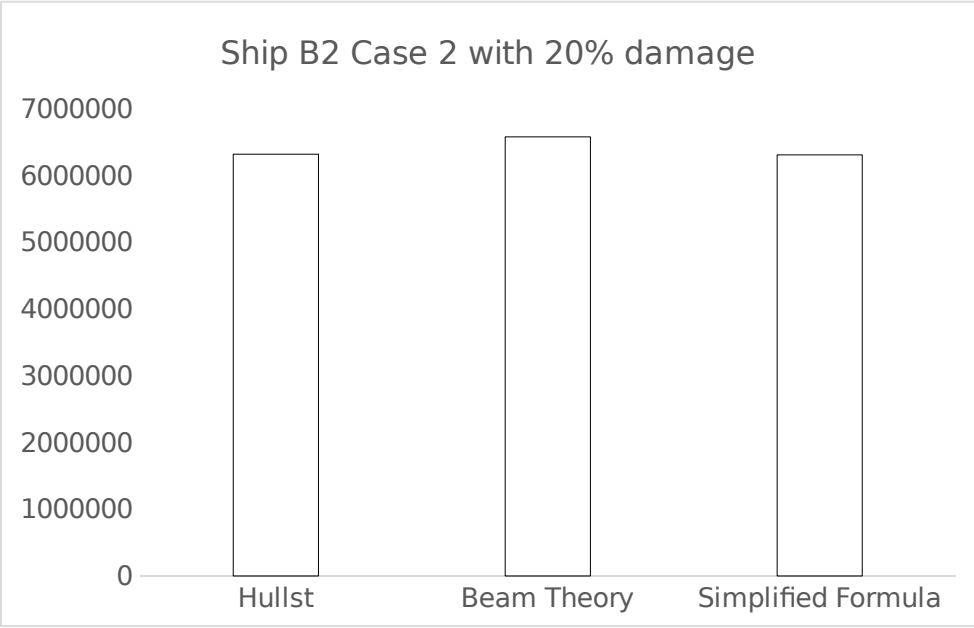
Respond No. 15

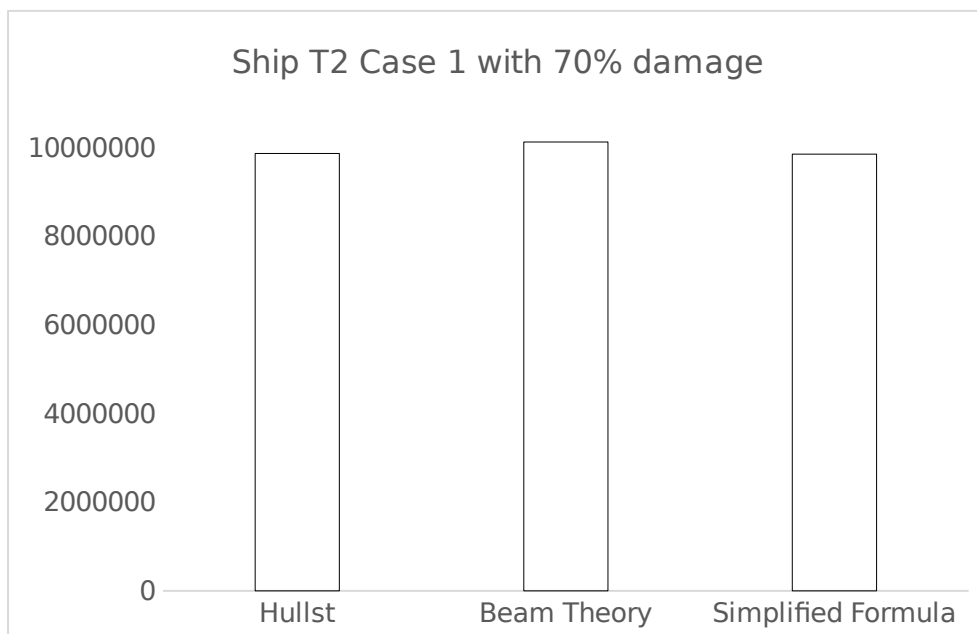
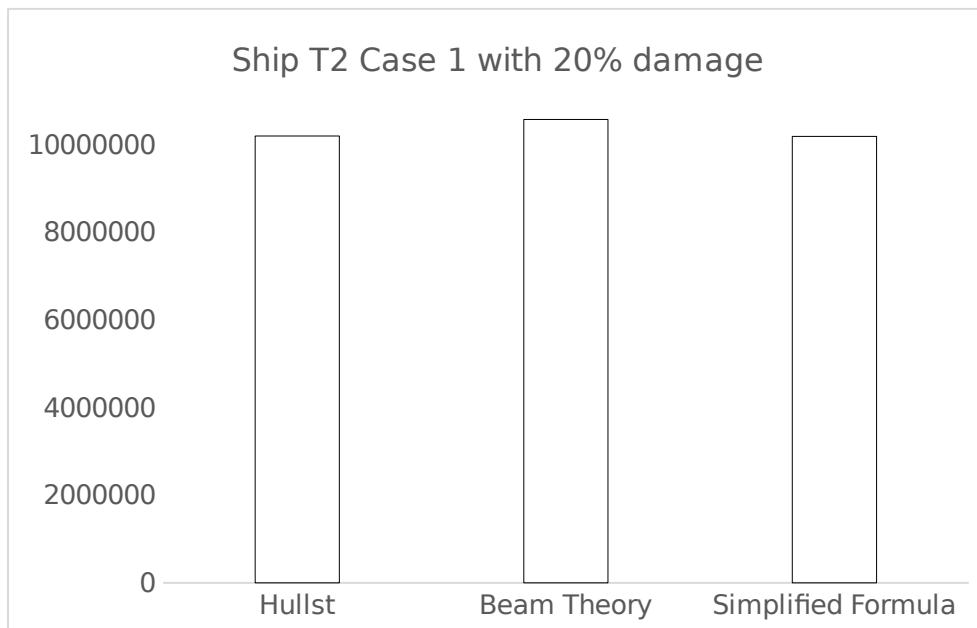
The conclusion is modified according to recommendation No. (8).

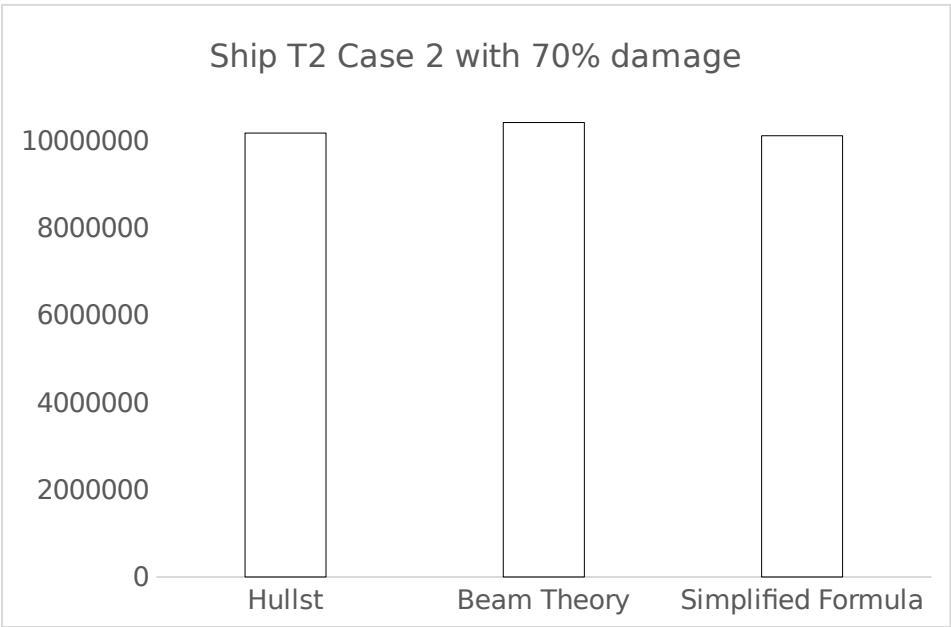
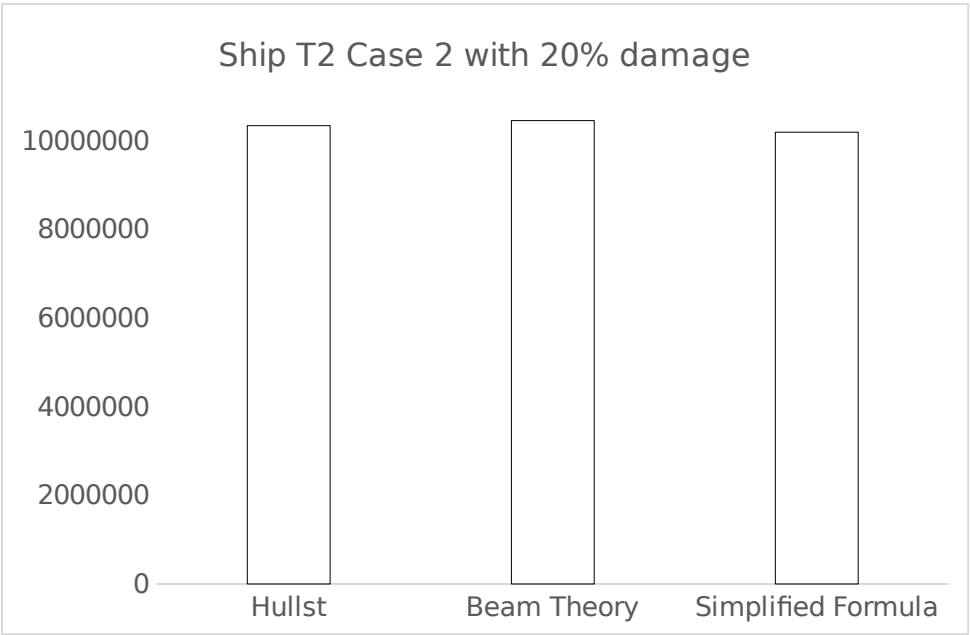












Category (1)

Question No. 1

This paper employs three basic assumptions. Please add some comments if you have any idea that how the results change according to the employment of the second assumption? If we have some comments, your results will be easier to recognize.

Answer No. 1

The ultimate strength of cross section is attained when the plate or stiffened plate elements reach their ultimate strength at the specified location. The plate and/or stiffened plate element i.e. critical element is under compression when the hull cross section is under sagging condition. The result is absolutely changed depending on the plate and/or stiffened plate behavior.

Question No. 2

You made explanations of L1 and L2 before Fig.11 is referred. If you move them to before or after Fig.4, it will be easier to recognize.

Answer No. 2

The explanations of L1 and L2 have been already moved before Fig. 4, see the article.

Question No. 3

You compared the effects of damage between B1, B4 and T2, based on the Fig.7 and Fig.8. Whereas the results of B4 is not shown in this paper. This comparison is also referred in conclusion. If you want to refer the results of B4, you should include the graphs of B4.

Answer No. 3

The symbol of Ship B4 was incorrect, must be Ship B2.

Question No. 4

If you add captions in Fig.11 and Fig.12, they will be easier to recognize.

Answer No. 4

Captions on Fig.11 and Fig. 12 have been added.

Question No. 5

In the second paragraph of conclusions, you use 'symbols' such as case1, case2, B1, B4 and T2. If you use more general expression, your conclusions will be easier to recognize.

Answer No. 5

All the symbols such as Case 1, Case 2, B1, B4 and T2 in conclusions have been modified, see the article.

Category (2)

Question No. 1

All the symbols should be explained at the time of reference. Please add explanations to M and I in eq.(4), for example.

Answer No. 1

All the symbols have been explained.

Question No. 2

The equation numbers just above the eq.(13) are incorrect. Please correct them.

Answer No. 2

Has been corrected, see the article.

Question No. 3

The figures (a) and (b) in Fig.2 are the same. Perhaps, (a) is incorrect. Please change it.

Answer No. 3

Fig. 2 has been corrected, see the article.

Question No. 4

The figure (b) in Fig.11 is digit shifted. Please correct it.

Answer No. 4

Fig. 11 has been corrected, see the article.

Category (1)

Question No. 1

- No definition about D_i , A_i , y_i in Eq. (2) (3)

Answer No. 1

Have been defined, see the article.

Category (2)

Statement No. 1

The paper proposed a method based on the assumptions that the ultimate sagging strength is attained when a stiffened panel element at the critical element reached the ultimate strength and the ultimate strength of the critical member is predicted from the average axial stress and average axial strain relationship calculated by HULLST. However, this method is quite simple and far from a progressive failure method since the change of neutral axis is not reflected in the method. Most of all, the approach needs to be verified with CSR's incremental-iterative approach or nonlinear FE analysis even if only vertical bending moment is taken into account. Then, the effect of rotation and translation needs to be verified further. In addition, the assumption that the hull girder cross section is elastic until the failure of the critical member is too rough to use in the actual design. It is recommended to reflect the progressive failure process.

Response No. 1

However this method is quite simple, but at least, for the time being, this method has been validated with the other analytical solution performed by HULLST. For the next research work will be compared with the FE analysis.

Category (1)

No Comments

Category (2)

Question No. 2

3rd line in ABSTRACT: “simply supported of boundary condition” → “simply supported boundary condition”

Answer No. 2

Has been corrected, see the article.

Question No. 3

Page 1; left column; 4th – 5th line: “safety ship” → “safety of ship”

Answer No. 3

Has been corrected, see the article.

Question No. 4

Page 1; right column; 3rd line: “base on” → “based on”

Answer No. 4

Has been corrected, see the article.

Question No. 5

Page 1; right column; 12th line: “applying the progressive collapse method and finding an” → “applying the progressive collapse calculation method and found an”

Answer No. 5

Has been corrected, see the article.

Category (1)

No comment for category (1) from the reviewer.

Category (2)

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Answer No. 2

Has been corrected, see the article.

Recommendation No. 3

P.2; right column; 1st line: “relationship in given in” → “relationship is given in”

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Has been corrected, see the article.

Recommendation No. 4

A cross-section of a ship’s hull girder is in general symmetric with respect to the centreline of the cross-section. Therefore, $EIHV = EIVH = 0$ when a cross-section is not damaged. It is when the cross-section is damaged that $EIHV$ and $EIVH$ become not zero. From this aspect, it is recommended to describe that Eqs.(4) through (8) are for the asymmetrically damaged cross-section and Eqs.(9) and (10) are for intact cross-section.

Answer No. 4

Has been modified, see the article.

Recommendation No. 5

Another important point is a floating condition. When a collision is large, there could be a water ingress which results in non-upright condition of the hull girder. In this case, both vertical and horizontal bending moments acts on the cross section of a hull girder when only vertical bending moment acts on an inclined hull girder. Something has to be mentioned about this and what assumption is made for your calculation.

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P.4; Fig. 11 (b): The overlapping of letters has to be revised.

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Respond No. 14

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Recommendation No. 15

P.5; CONCLUSIONS; 13rd – 14th lines: “because the horizontal curvature is constrained.” As was mentioned in (8), the real reason which is derived from the constrained horizontal curvature has to be described here.

Respond No. 15

The conclusion is modified according to recommendation No. (8).

Category (1)

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Answer No. 1

Have been defined, see the article.

Category (2)

Statement No. 1

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Captions on Fig.11 and Fig. 12 have been added.

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Answer No. 5

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Category (2)

Question No. 1

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All the symbols have been explained.

Question No. 2

The equation numbers just above the eq.(13) are incorrect. Please correct them.

Answer No. 2

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Question No. 3

The figures (a) and (b) in Fig.2 are the same. Perhaps, (a) is incorrect. Please change it.

Answer No. 3

Fig. 2 has been corrected, see the article.

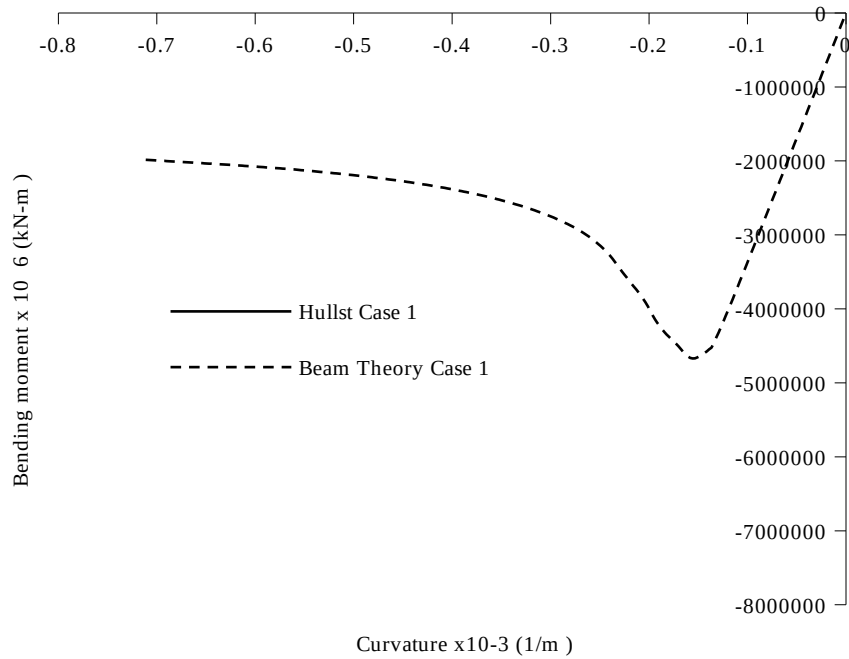
Question No. 4

The figure (b) in Fig.11 is digit shifted. Please correct it.

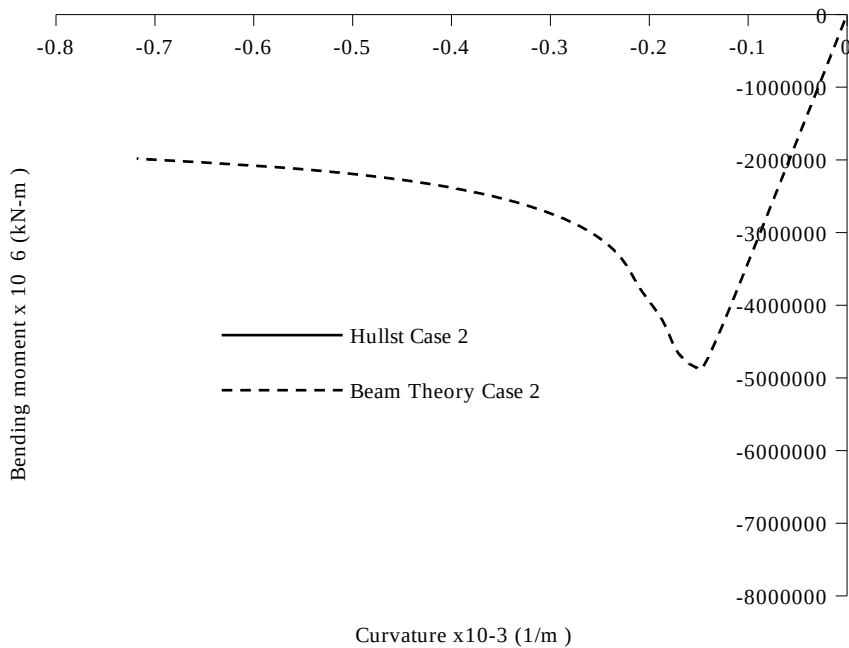
Answer No. 4

Fig. 11 has been corrected, see the article.

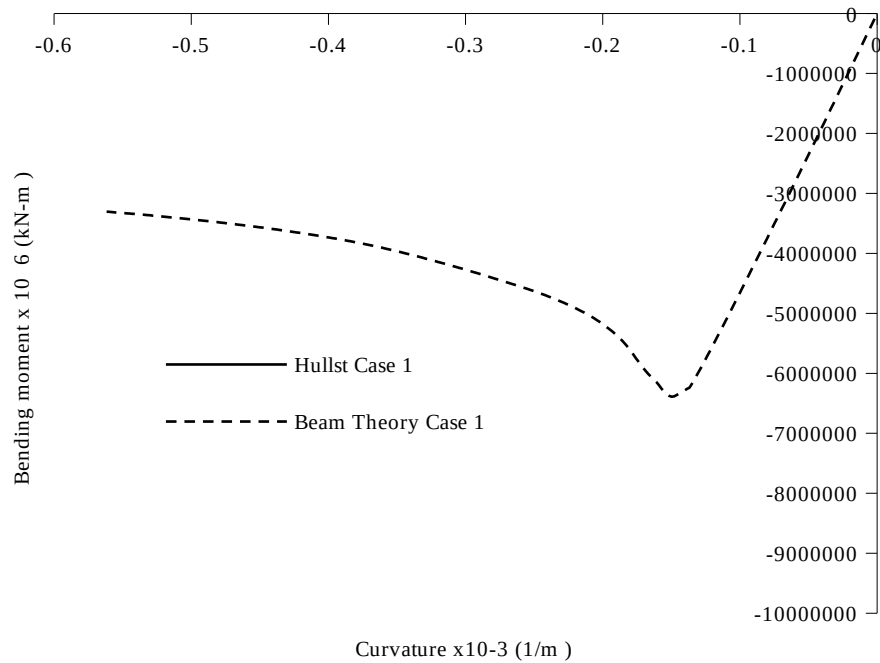
Category (2)	
Statement	Argument
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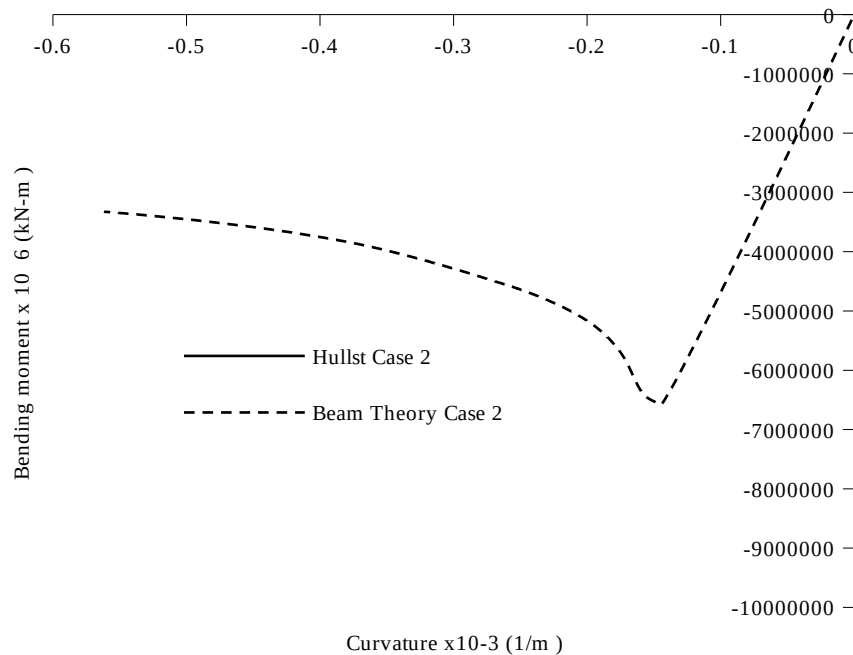
Validation of **HULLST** with **Beam Theory** for the ultimate strength in Sagging condition of single hull bulk carrier (Ship B1) with 20% damage for Case 1.



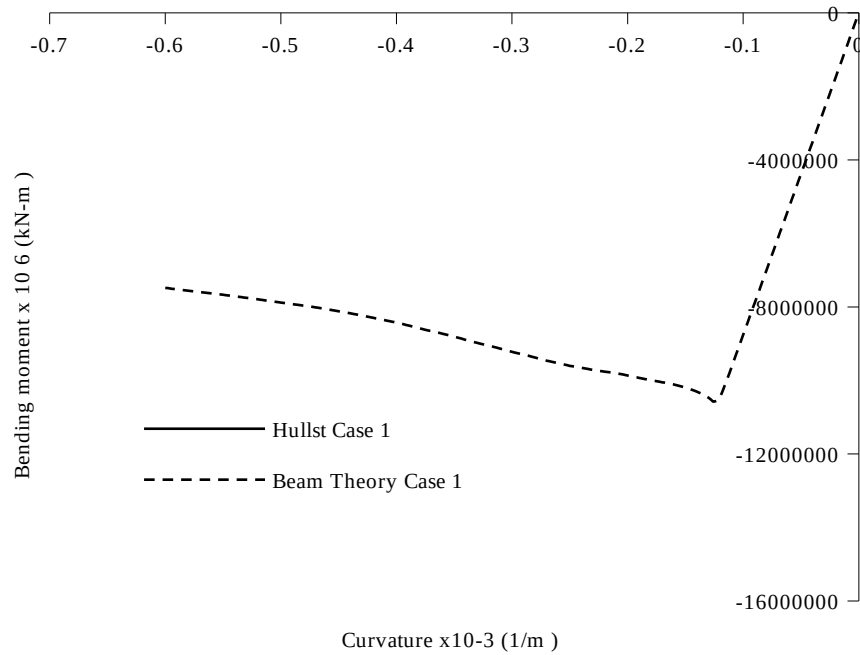
Validation of **HULLST** with **Beam Theory** for the ultimate strength in Sagging condition of single hull bulk carrier (Ship B1) with 20% damage for Case 2.



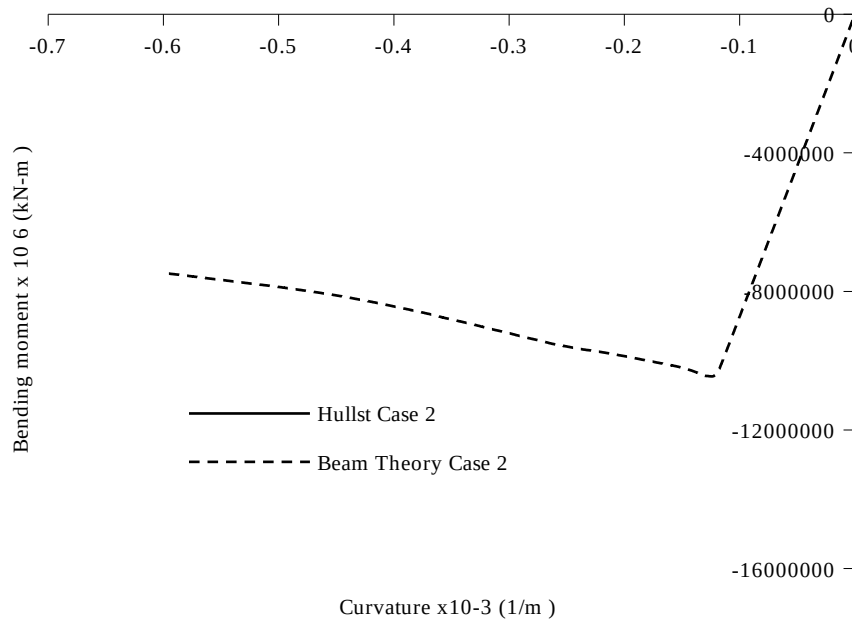
Validation of **HULLST** with **Beam Theory** for the ultimate strength in Sagging condition of single hull bulk carrier (Ship B2) with 20% damage for Case 1.



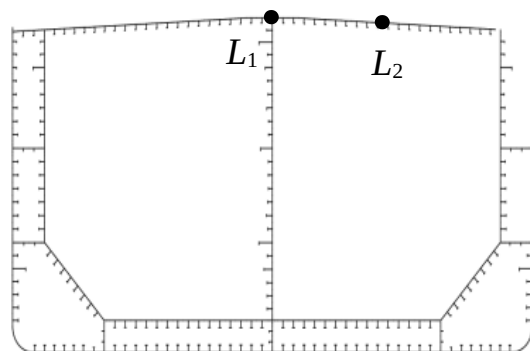
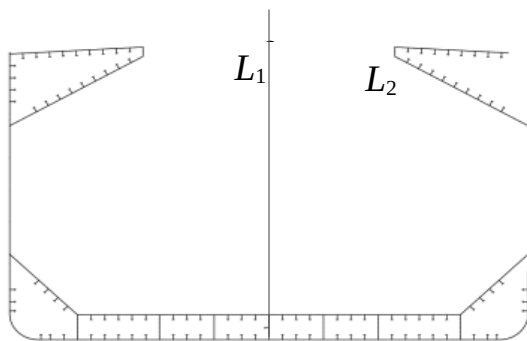
Validation of **HULLST** with **Beam Theory** for the ultimate strength in Sagging condition of single hull bulk carrier (Ship B2) with 20% damage for Case 2.

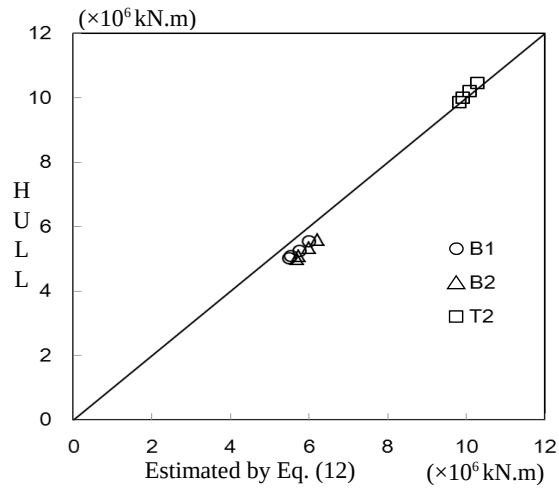


Validation of **HULLST** with **Beam Theory** for the ultimate strength in Sagging condition of double hull oil tanker (Ship T2) with 20% damage for Case 1.

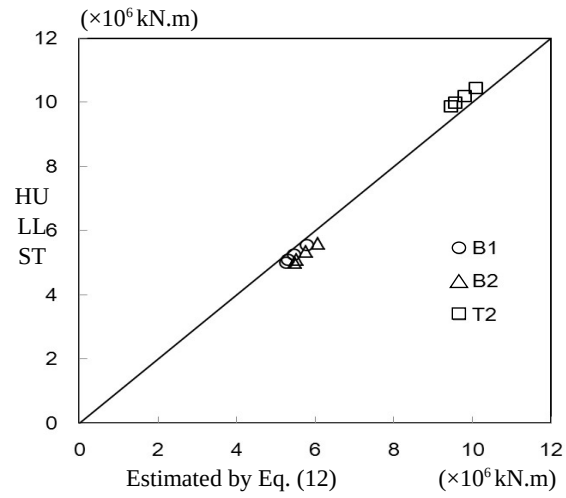


Validation of **HULLST** with **Beam Theory** for the ultimate strength in Sagging condition of double hull oil tanker (Ship T2) with 20% damage for Case 2.



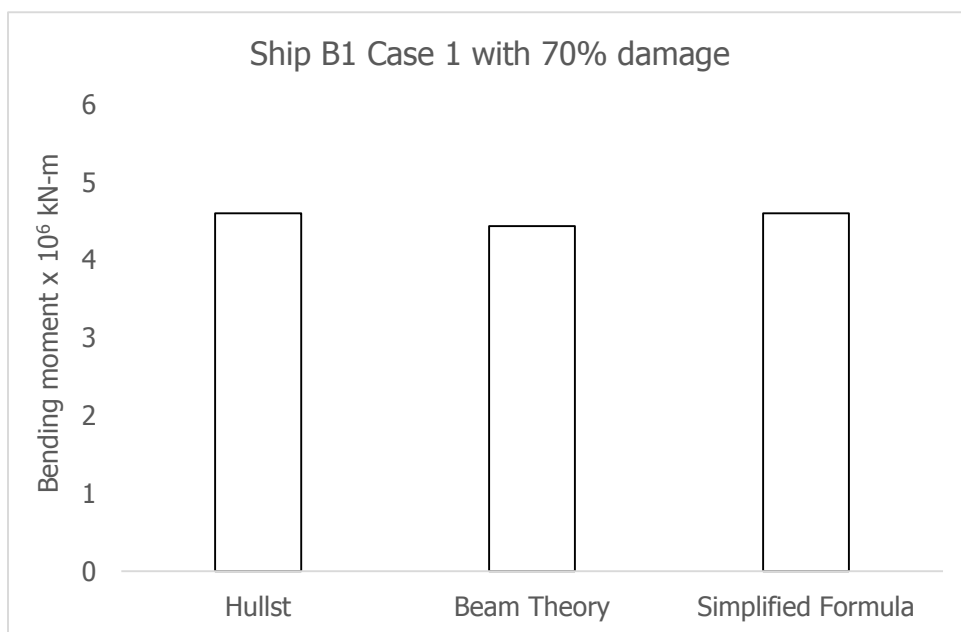
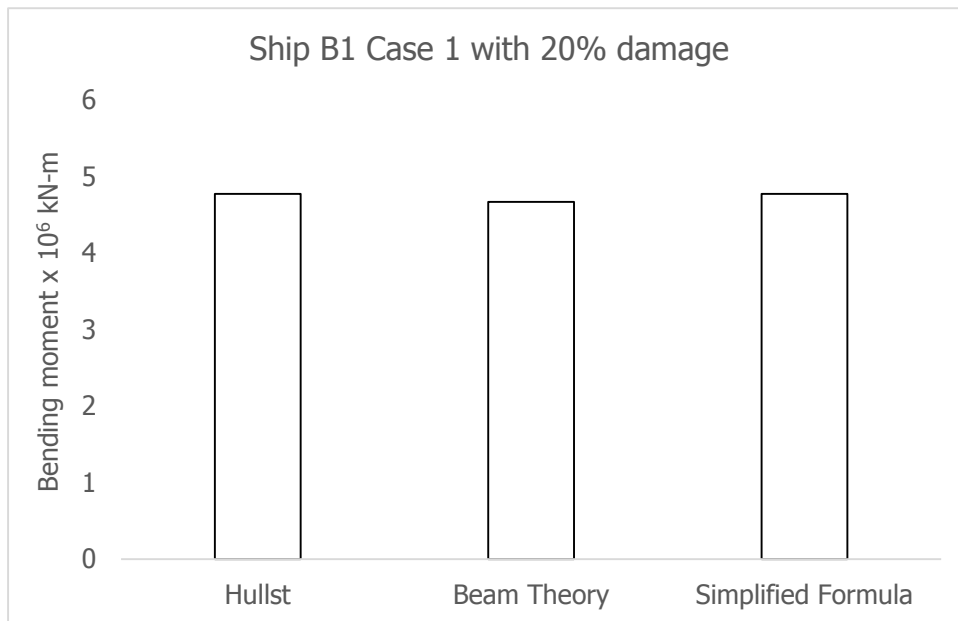


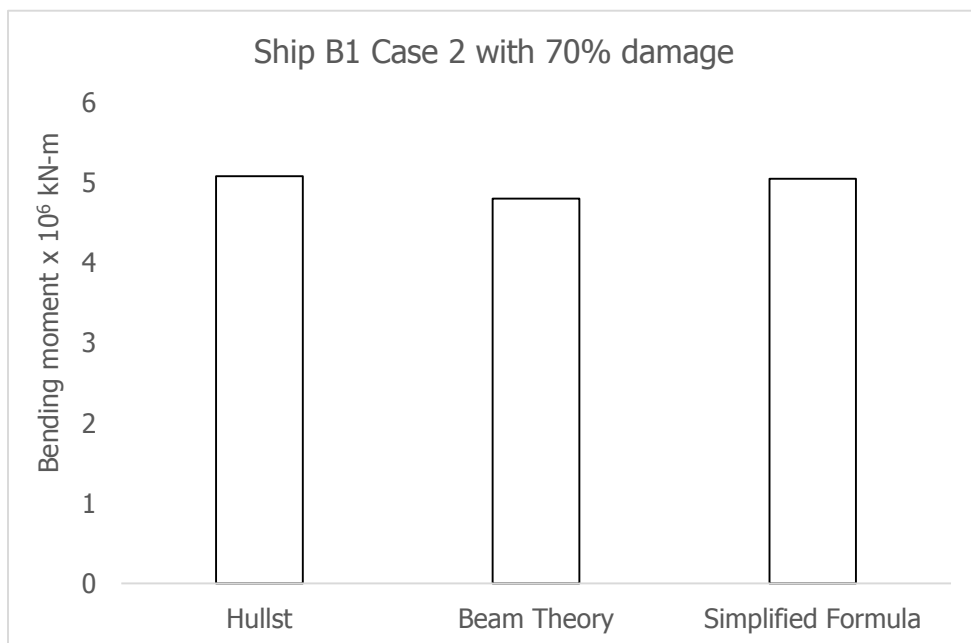
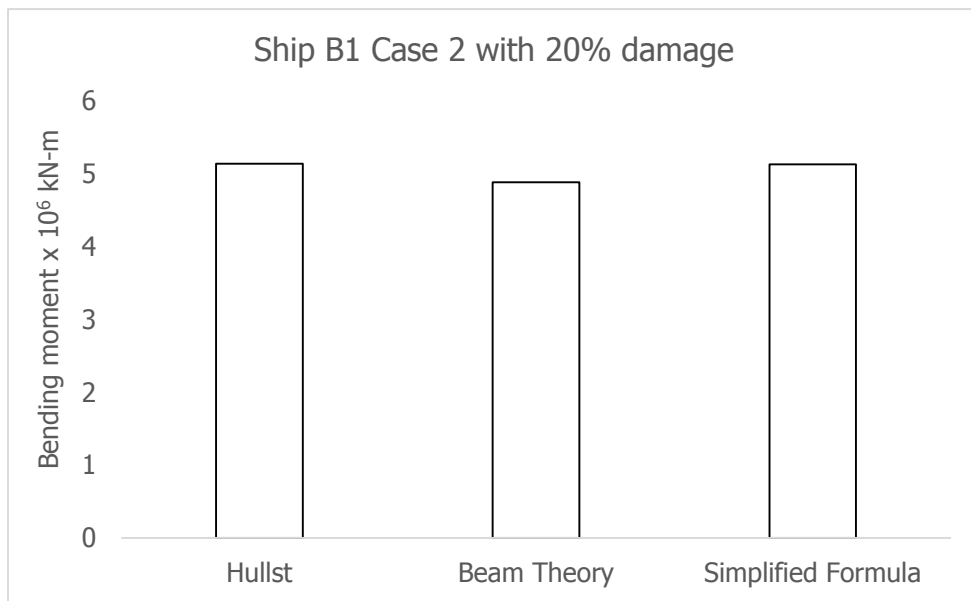
(a) Location L_1

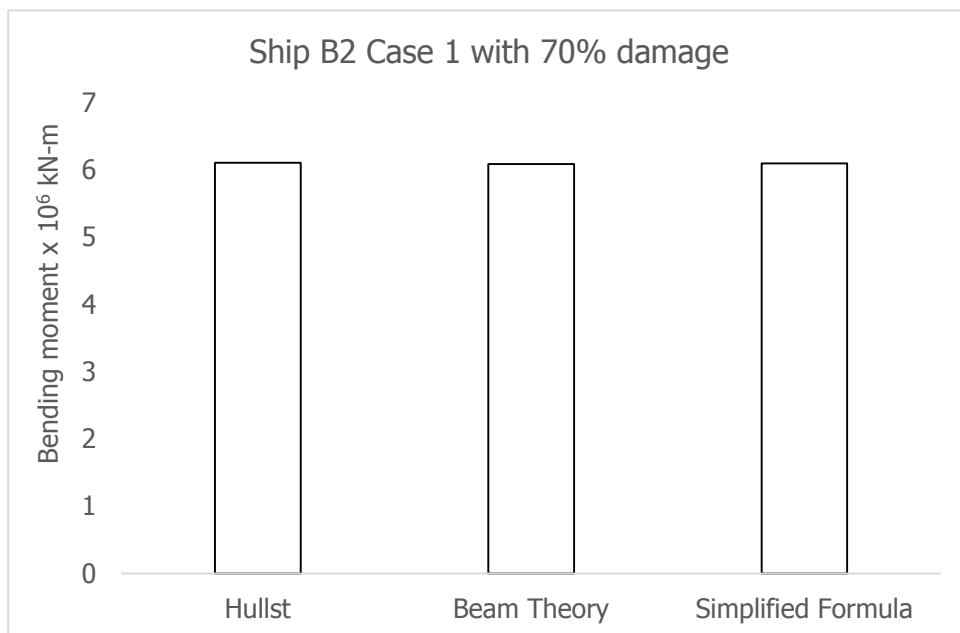
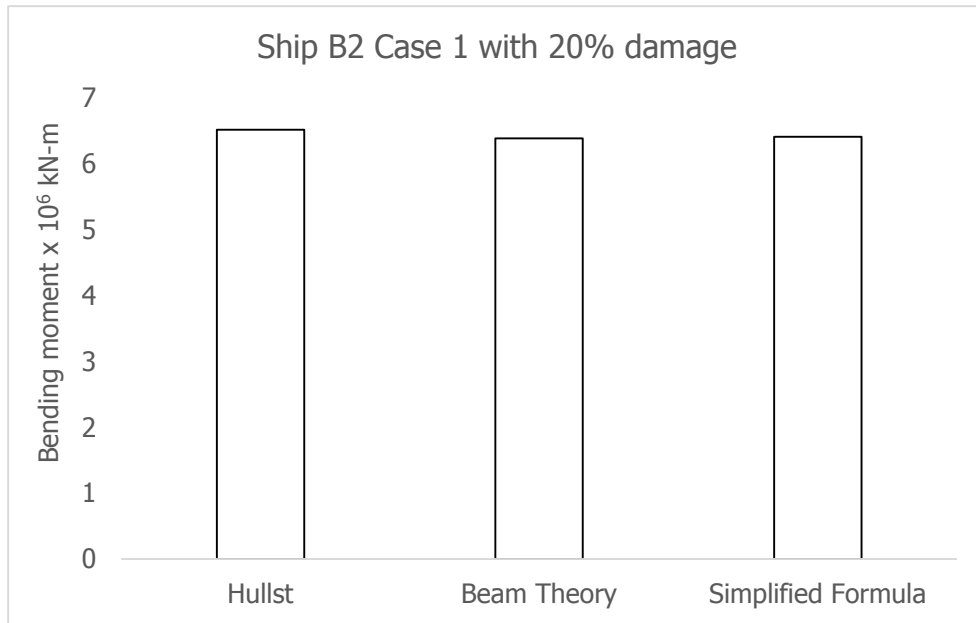


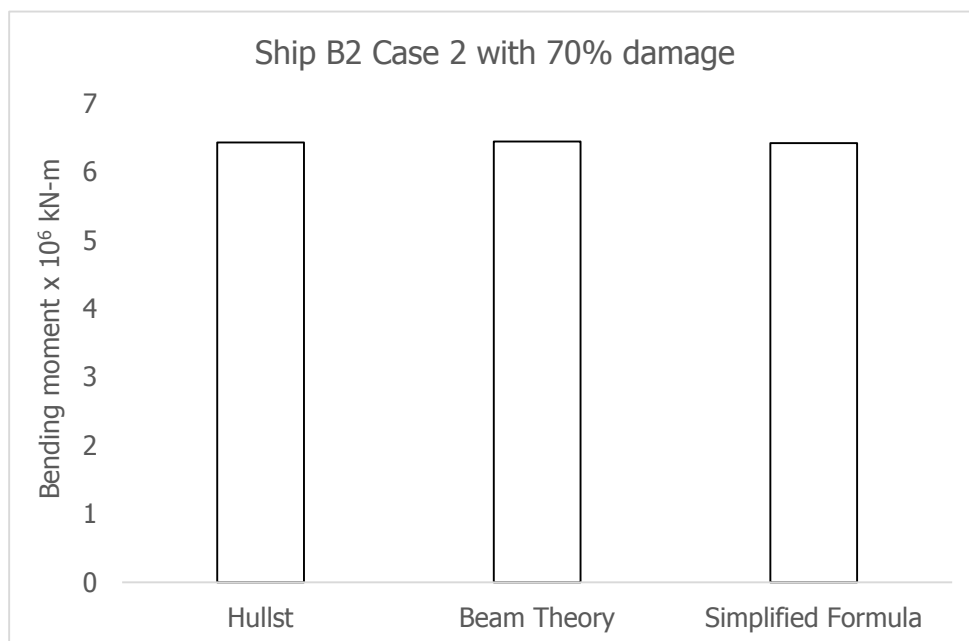
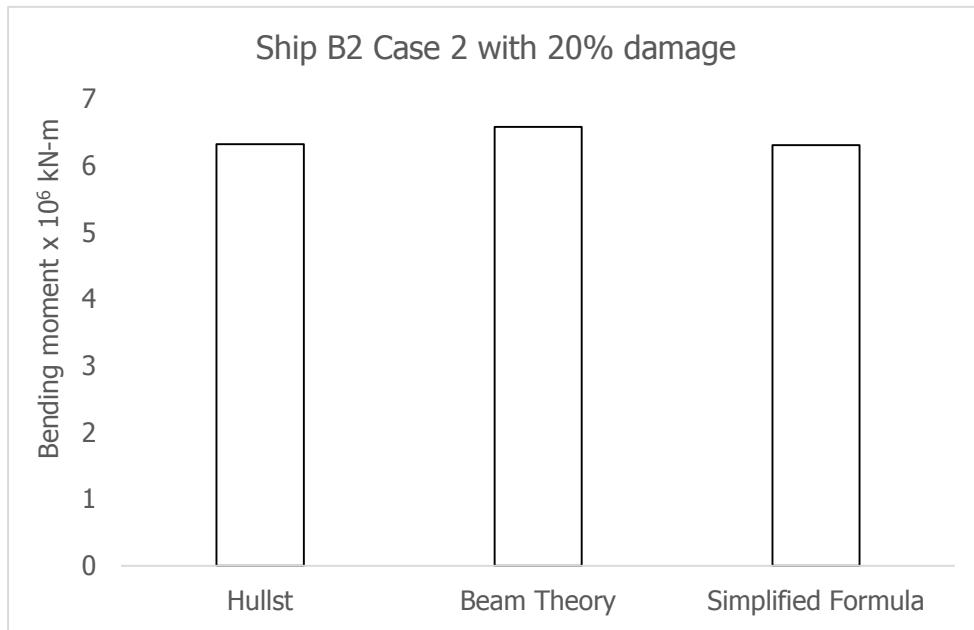
(b) Location L_2

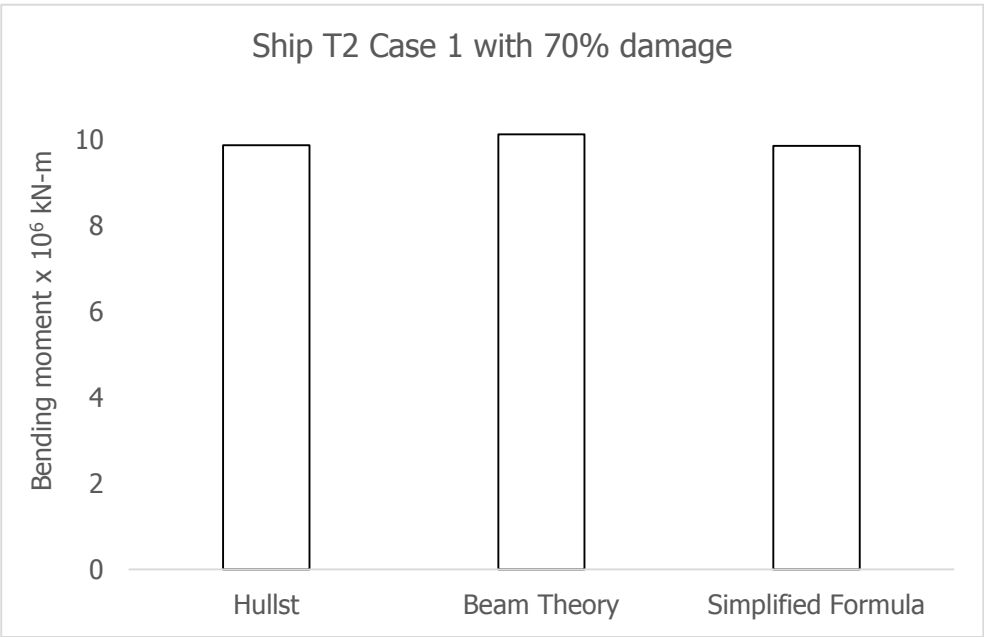
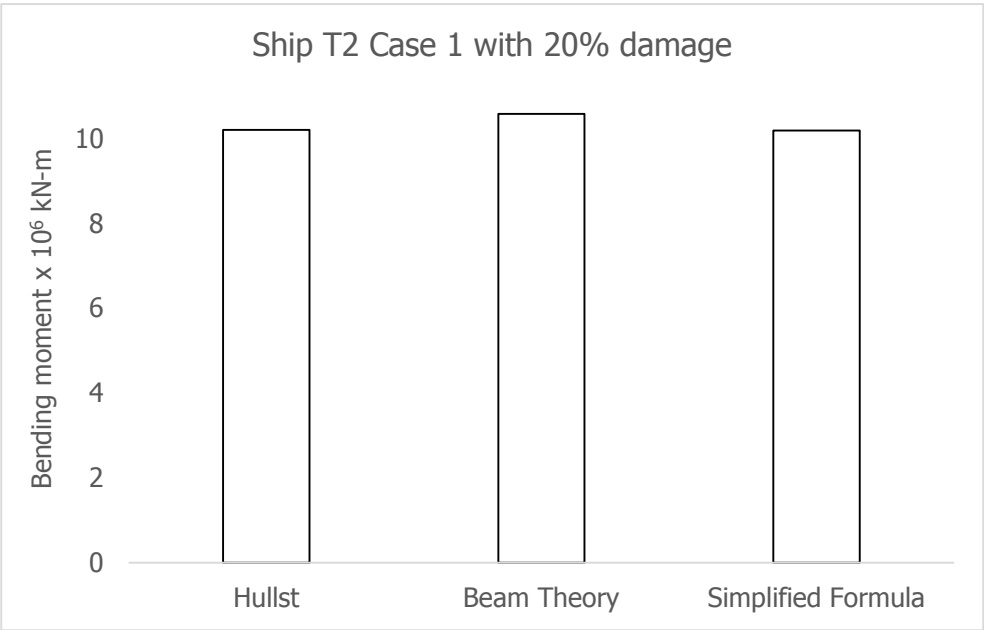
Fig. 11 Comparison of residual hull girder strength M_V between the simplified method and the progressive collapse analysis

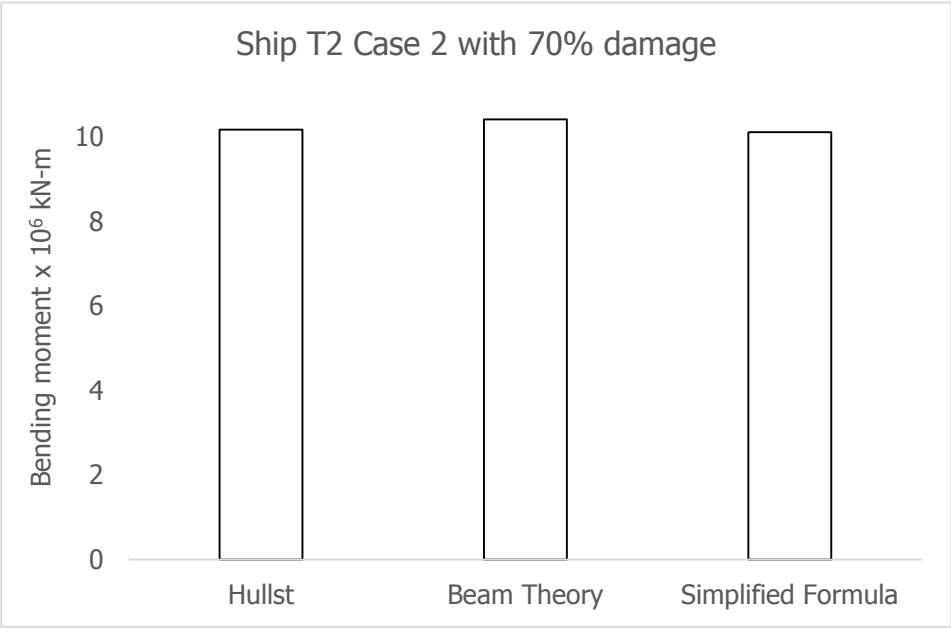
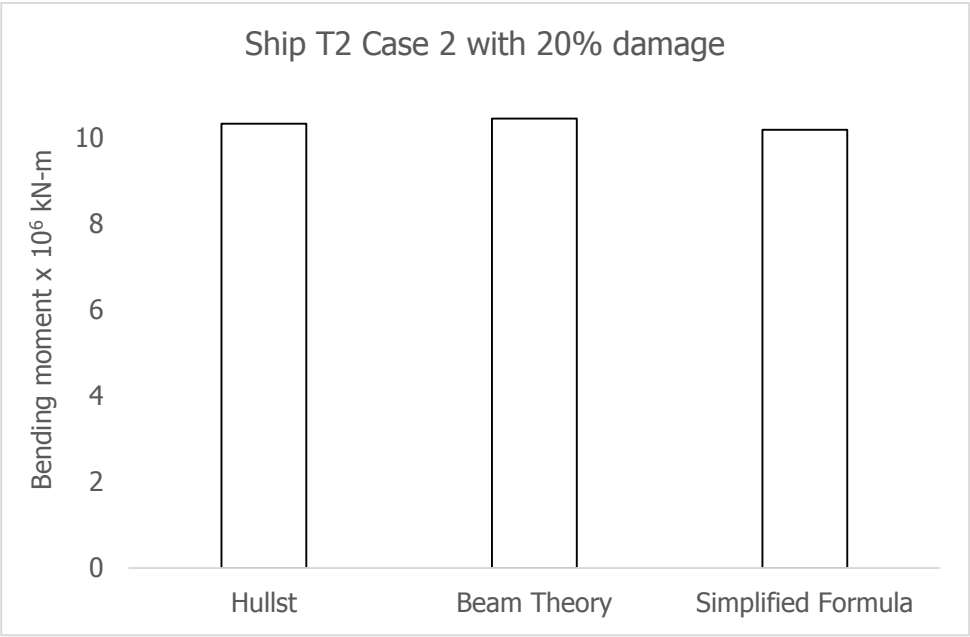












Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships

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ABSTRACT

The objective of the present study is to investigate the ultimate hull girder strength of asymmetrically damaged ship under sagging condition. Two kinds of ship are taken as the object of the analysis. The cross section of the ship is considered and assumed to be remained plane. The simply supported of boundary condition is applied to both sides of the cross section. The ultimate hull girder strength is attained when a plate and/or stiffened plate element at the specified location called “critical element” reach their ultimate strength. To investigate the ultimate hull girder strength, a simplified approach is proposed. The result obtained by simplified approach is compared to the progressive collapse analysis for the effectiveness and validation.

KEY WORDS: Single hull bulk carrier, double hull oil tanker, cross section, neutral axis, asymmetrically damaged, ultimate strength, simplified approach.

INTRODUCTION

The ability to predict accurately the ultimate strength of ship hull girder when subjected to longitudinal bending is one of the most important aspects of ship structural design. A collision and grounding damages may takes place on ship's hull, which may threaten safety ship and surrounding environment. In this regard, to enhance the safety of ship's structure and minimize the risks, the International Maritime Organization (IMO, 2009) has required in Goal Based Standard for New Ship Construction (GBS) to consider the residual strength of the hull girder in specified damage conditions as one of the functional requirements for the structural rules for bulk carriers and tankers.

Many studies have been conducted on the analyses of the residual hull girder strength due to collision and grounding damaged. Pedersen (1994) presented a mathematical modeling to estimate the contact pressure between the grounded ship and the sea bottom. The grounded contact force was compared to the force which would crush the forward bottom of the ship. The sectional bending moment due to grounding was determined and compared to the ultimate hull girder strengths. The model experiments and full-scale controlled grounding experiments were also performed to validate the mathematical model. Paik et al. (1998) developed a rapid procedure to identify the possibility of hull girder failure after collision and grounding damages based on the closed-form formulae of the ultimate hull girder strength and section modulus after the damages. Soares et al. (2008) evaluated the ability of simplified structural analysis methods based on the Smith's formulation to predict the ultimate strength of damage ship's hull. Toh et al. (2012) developed simplified calculation program to calculate the ultimate strength in intact and damage condition and the reduction of hull girder ultimate strength is investigated. The calculation result of simplified method is compared to the FE result for both intact and damage condition. Muis Alie, M.Z et al. (2012) investigated the incidence of neutral axis rotation on residual hull

girder strength for asymmetrical damaged ships under longitudinal bending, applying the progressive collapse method and finding an explicit expression of neutral axis rotation. After performing a series of progressive collapse analyses on several bulk carriers and tanker, it was found that residual hull girder strength, considering the instantaneous neutral axis is generally lower than the relevant one, obtained by constraining the rotation, as it is commonly assumed in classical procedures. Ohtsubo et al. (1994) showed the experimental and numerical work on the ship structural damages due to collision and grounding. This was one of the first attempts to apply the explicit Finite Element Method codes, such as LS-DYNA and DYTRAN, to the collision and grounding problems of ships. Ozguc et al. (2005) investigated the collision resistance and residual strength of single skin and double skin bulk carriers subjected to damages. Lee et al. (2008) calculate the ultimate strength with collision damage using LS-DYNA and compared with the experiment results. It is found that the ultimate strength is reduced as a damage size increased as expected. Notaro et al. (2010) carried out full nonlinear FE assessments of hull girder capacity in intact and damage conditions. The effects of several influences factors such as model extend and complexity, damage representations and model imperfections are investigated on the different vessels. It was found that the effect of damage extent in vertical direction is more critical than in longitudinal direction, and the damage varies the location of the neutral axes including higher stresses in proximity of the damage areas. The various probability levels are considered for the damage extent estimation.

When a hull-girder cross section is symmetric with respect to the centerline and subjected to pure vertical bending moment, the neutral axis for vertical bending is always horizontal and moves only vertically during the progressive collapse behavior. However, when the cross section is asymmetrically damaged due, for example, to a collision, the neutral axis rotates. Both rotation and translation need to be taken into account during the progressive collapse behavior even when only a vertical bending moment is applied, and the problem needs to be treated as a biaxial bending problem. Previous studies using the Smith's method on the ultimate strength of hull girders under biaxial thrust (Ozguc and Barltrop, 2008) and the residual strength of damaged hulls (Fang and Das, 2004; Hussein and Guedes

Soares, 2009; Choung et al, 2011) consider the rotation and translation of neutral axis in a reasonable way. However, they employ a trial and error approach to detect the position of neutral axis. More easy approach to detect the position of neutral axis is demanded.

BASIC ASSUMPTION

1 The following assumption is made for the prediction of the residual hull girder strength under the sagging condition:

- (1) The ultimate sagging strength is attained when a stiffened panel element at the specified location (hereafter called ‘critical element’) reached the ultimate strength.
- (2) The hull girder cross section is elastic until the failure of the critical member.
- (3) The ultimate strength of the critical member is predicted from the average axial stress and average axial strain relationship calculated by HULLST (Yao and Nikolov).

EFFECT OF NEUTRAL AXIS ROTATION ON ESTIMATION OF THE ULTIMATE HULL GIRDER STRENGTH

In the elastic cross section, the bending stress at the i -th element (see Fig.1), σ_i , is expressed as

$$\sigma_i = E \left[(y_i - y_G) \varphi_H + (z_i - z_G) \varphi_V \right] \quad (1)$$

where E is Young's modulus, y_G and z_G the centroid coordinates, and φ_H and φ_V the horizontal and vertical curvatures, respectively. y_G and z_G are given by

$$y_G = \frac{\left(\sum_{i=1}^N y_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (2)$$

$$z_G = \frac{\left(\sum_{i=1}^N z_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (3)$$

Where D_i , A_i , y_i and z_i are the tangential stiffeners obtained as a slope of the average stress-strain relationship, cross section and the coordinate position of the individual elements, respectively.

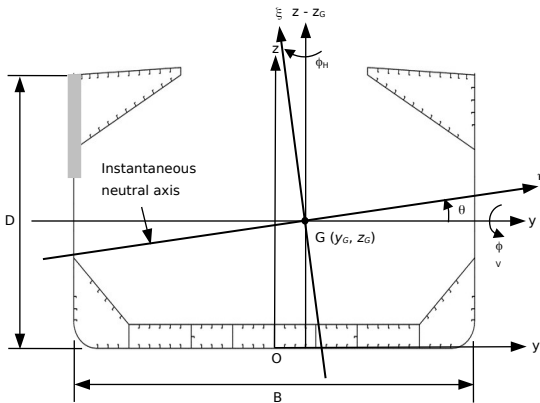


Fig. 1 Neutral axes of the elastic hull girder cross section with asymmetric damage

For the case of asymmetric damage cross section, the equations are used from Eqs. (4) to (8), and for the intact one, the expressions are given in Eqs. 9 and (10). The biaxial moment and curvature relationship is given in the form

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \varphi_H \\ \varphi_V \end{Bmatrix} \quad (4)$$

where

$$\begin{aligned} I_{HV} &= I_{VH} = \sum_{i=1}^N (y_i - y_G)(z_i - z_G) A_i \\ I_{HH} &= \sum_{i=1}^N (y_i - y_G)^2 A_i \\ I_{VV} &= \sum_{i=1}^N (z_i - z_G)^2 A_i \end{aligned} \quad (5)$$

Where I and M is the moment of inertia and bending moment, respectively. When the vertical bending moment M_V is applied to the cross section with no constraint on the horizontal curvature (Case 1), the horizontal curvature as well as the vertical curvature is induced under the condition of horizontal bending moment $M_H = 0$. The incremental equation to be solved is

$$\begin{Bmatrix} 0 \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \varphi_H \\ \varphi_V \end{Bmatrix} \quad (6)$$

Therefore,

$$\begin{Bmatrix} \varphi_H \\ \varphi_V \end{Bmatrix} = \frac{1}{E \begin{vmatrix} I_{HH} & I_{VV} - I_{HV}^2 \end{vmatrix}} \begin{Bmatrix} -I_{HV} M_V \\ I_{HH} M_V \end{Bmatrix} \quad (7)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{-(y_i - y_G) I_{HV} + (z_i - z_G) I_{HH}}{(I_{HH} I_{VV} - I_{HV}^2)} M_V \quad (8)$$

The terms including the moment of inertia, I_{HV} , represent the effect of the rotation of the neutral axis.

On the other hand, when the vertical bending moment is applied to the cross section with the horizontal curvature constrained (Case 2), the bending moment are induced under the condition of $\varphi_H = 0$, that is,

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} 0 \\ \varphi_V \end{Bmatrix} \quad (9)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{(z_i - z_G)}{I_{VV}} M_V \quad (10)$$

Here, it is assumed that the residual hull girder strength in the sagging condition M_V^u is attained when a critical member at the location of $(y_C - z_C)$ reached its ultimate strength, σ_C^u , namely for Case 1

$$M_V^u|_{CASE\ 1} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \sigma_C^u \quad (11)$$

And for Case 2

$$M_V^u|_{CASE\ 2} = \frac{I_{VV}}{(z_C - z_G)} \sigma_C^u \quad (12)$$

Therefore, the reduction rate of the residual strength due to the rotation of the neutral axis in the framework of the proposed approximate approach is given by ratio of Eq. (11) to Eq. (12) as

$$\frac{M_V^u|_{CASE\ 1}}{M_V^u|_{CASE\ 2}} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \frac{(z_C - z_G)}{I_{VV}} \quad (13)$$

CASE STUDY

Two single-hull bulk carriers, B1 and B2, and one double-hull oil tanker, T2, are taken as the subject ships as shown in Table 1. Ship B1 is designed according to Pre-UR rule and built in 1987 and Ship B2 according to CSR-B having larger cross section and scantling sizes. Ship T2 is designed according to CSR-T.

Ship	B1	B2	T2
L (mm)	217,000	219,000	234,000
B (mm)	32,236	32,240	44,000
D (mm)	18,300	19,900	21,200
Design criteria	Pre-IACS UR	IACS CSR-B	IACS CSR-T

Table 1 Subject ships

The damage of the upper part of side shell due to collision is assumed. The vertical damage extent is taken as 10%, 20%, 40% and 70% of the depth D for both bulk carrier and tanker. The horizontal damage extent is taken as $B/16$, and it is kept constant for all damaged cases. The damaged cross sections of Ship B1 are illustrated in Fig. 2 and those of Ship T2 in Fig. 3. The stiffness of the elements in the damaged area is completely removed. For the double hull tanker, only outer side shell is assumed to be damaged. The locations of the critical deck element are presented in Fig. 4 for single hull bulk carrier and double hull oil tanker, respectively.

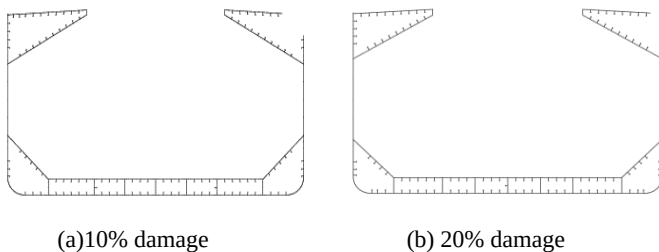


Fig. 2 Single hull bulk carrier (Ship B1)

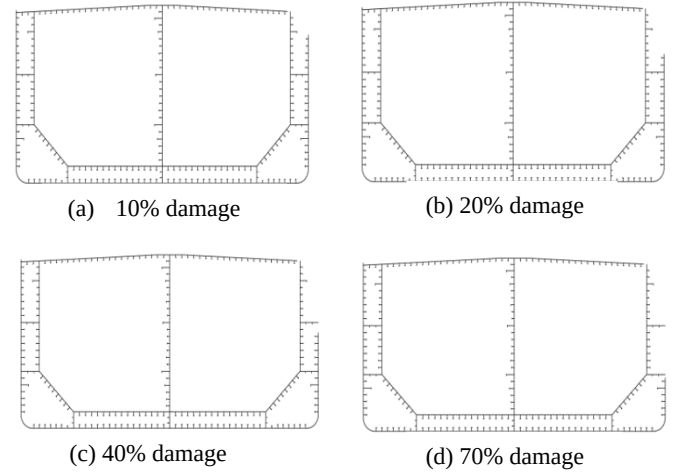
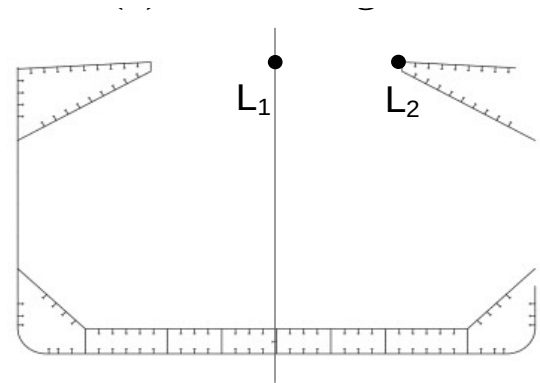
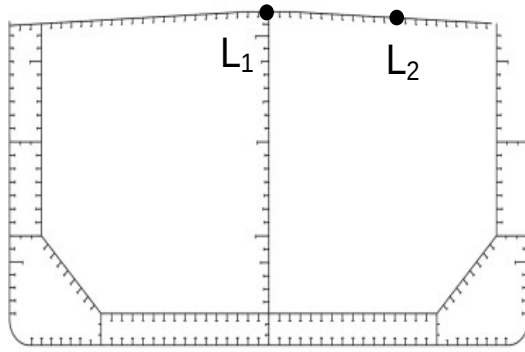


Fig. 3 Double hull oil tanker (Ship T2)

The investigation of the residual hull girder strength under sagging condition is performed by taking two locations of the critical deck elements as shown in Fig. 4. Single hull bulk carrier (B1 and B2), the locations of the critical element are L_1 and L_2 , L_1 is located at the center line and L_2 at the hatch coaming on the damage side. For the case of double hull oil tanker (T2), L_1 is located at the center line and L_2 at the distance of $B/4$ from the damage side shell.



(a) Single hull bulk carrier



(b) Double hull oil tanker

Fig. 4 Locations of the critical deck elements

RESULT AND DISCUSSION

In sagging condition, it is well recognized that the ultimate hull girder strength is almost attained when the primary deck members in longitudinal compression reached their ultimate strength. Also, because the damage takes place at the asymmetric position, in other word, collision damage is place at the side shell through to the deck part (B/16) and there is no damage located at the bottom part, so that it is very important to investigate the critical member under sagging condition. In the present study, the ultimate strength is analyzed after damaged takes place. The water ingress is not considered in the analysis.

The results obtained by progressive collapse analysis under sagging condition for 20% and 70% damage are presented in Fig. 5 and Fig. 6, respectively. Case 1 considers the rotation of neutral axis and Case 2 does not. The moment-curvature relationship is given by

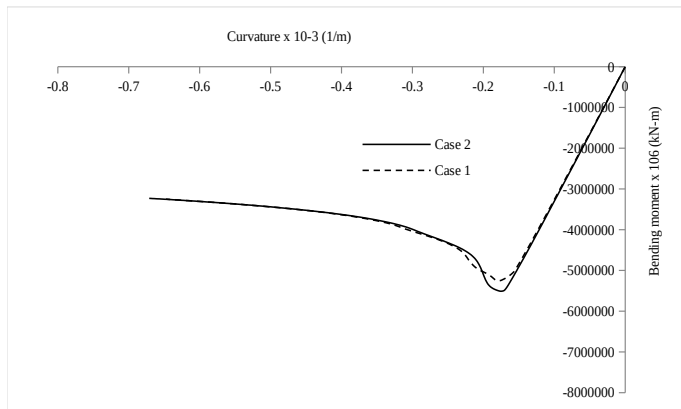


Fig. 5 Single hull bulk carrier (Ship B1) with 20% damage

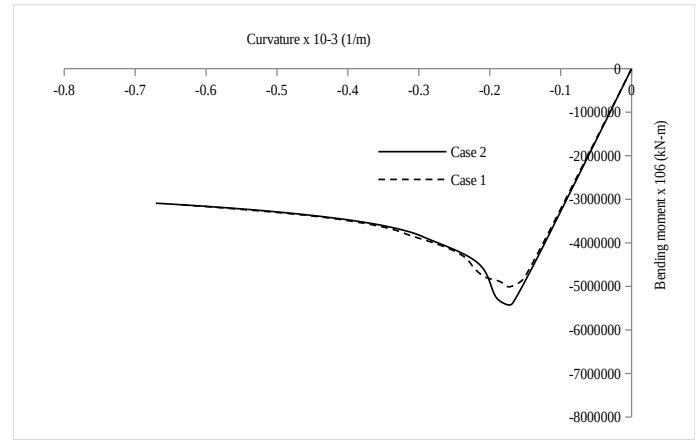


Fig. 6 Single hull bulk carrier (Ship B1) with 70% damage

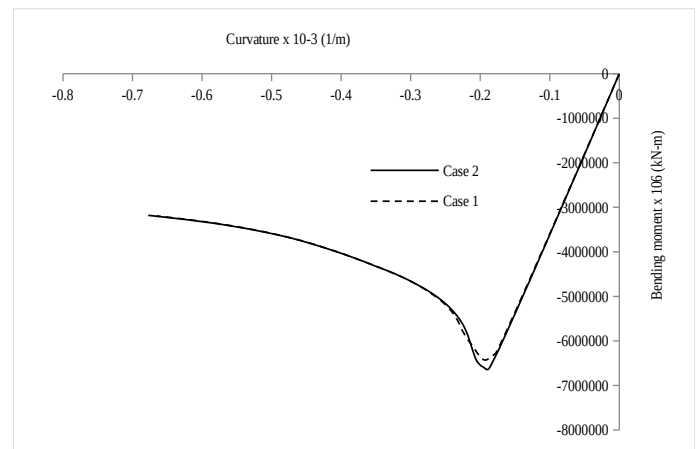


Fig. 7 Single hull bulk carrier (Ship B2) with 20% damage

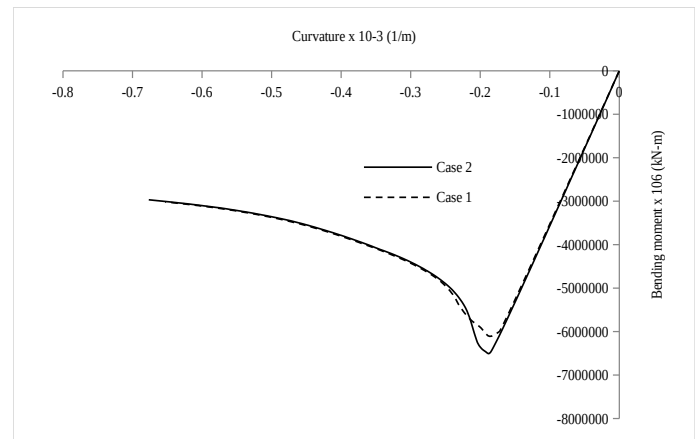


Fig. 8 Single hull bulk carrier (Ship B2) with 70% damage

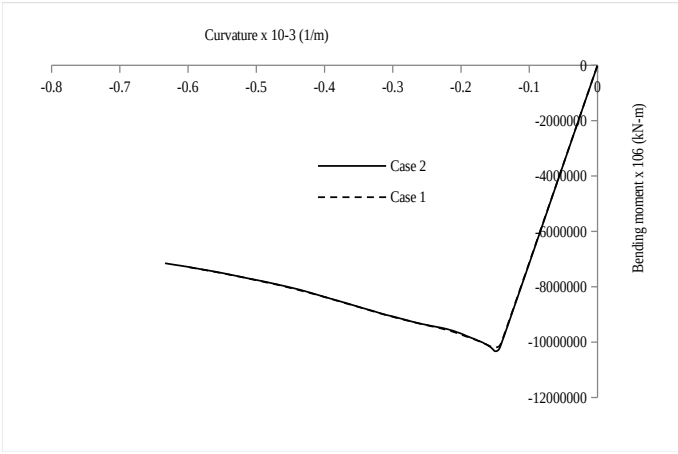


Fig. 9 Double hull oil tanker (Ship T2) with 20% damage

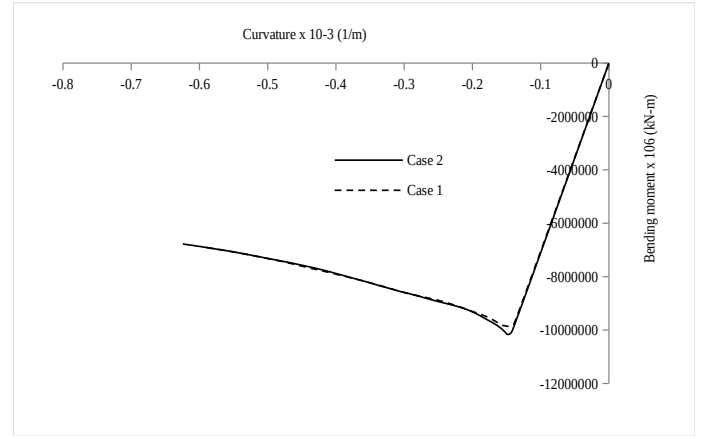


Fig. 10 Double hull oil tanker (T2) with 70% damage

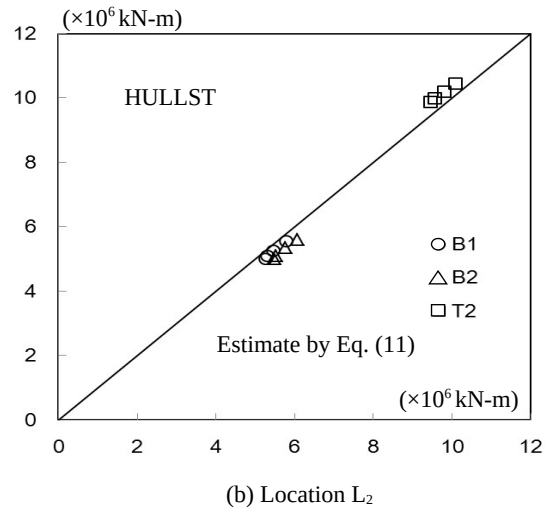
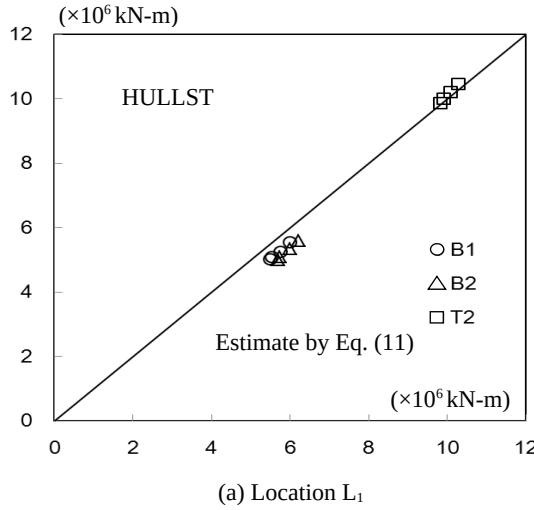


Fig. 11 Comparison of residual hull girder strength M_V between the simplified method and the progressive collapse analysis. Fig. 11(a) and Fig. 8 shows the results of the moment-curvature relationship obtained by progressive collapse analysis for single hull bulk carrier (B2). It is found that Case 2 generally gives larger ultimate strength than Case 1 because the horizontal curvature is constrained. The ultimate hull girder strength is attained even the horizontal curvature is constrained because of the horizontal bending moment is induced by the stiffened matrix interaction for horizontal and vertical and this makes the ultimate hull girder strength becomes higher. The effect is largest in Ship B1, smaller in Ship B2, and almost negligible in Ship T2. For Ship B1, Case 1 strength is 7.3% smaller than Case 2 in sagging condition. The difference between Ship B1 and Ship B2 may be related to that of the depth to breadth ratio, member scantlings etc. Fig. 9 and Fig. 10 represent the moment-curvature relationship under sagging condition for double hull oil tanker (T2) for 20% and 70% of damaged, respectively. According to the result obtained by progressive collapse analysis of double hull oil tanker (Ship T2), the effect of rotation of neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

The residual strengths of Ship B1, Ship B2 and Ship T2 obtained for the four different damage extents are summarized in Fig. 11. It is found that Eq. (11) gives an estimate of the residual strength which is in good agreement with the result of the progressive collapse analysis.

For bulk carriers, the critical element at the location L_2 gives a better estimate of the residual strength. This is consistent with the observed collapse behavior in which the ultimate strength is attained when topside tank region of the damage side almost fully failed. The location L_1 cannot well take account of the effect of the horizontal curvature induced by M_V , resulting in the slight overestimate of the strength. In the case of tankers, the location L_1 gives better estimate of the residual strength than L_2 . This is also consistent with the failure behavior of T2 in which the ultimate strength is attained when the deck part almost fully failed.

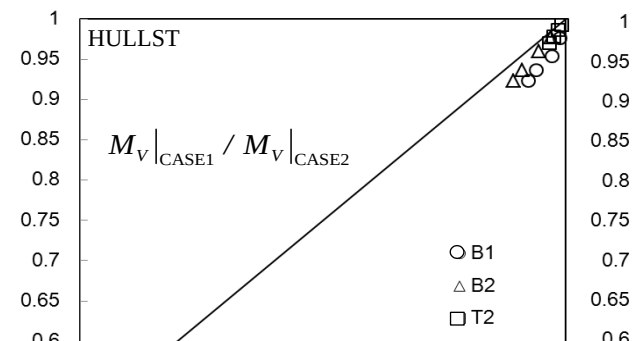


Fig. 12 Comparison of reduction ratio of residual hull girder due to rotation of neutral axis between the simplified method and the progressive collapse analysis (Case 1/Case 2)

CONCLUSIONS

The ultimate hull girder strength analysis of single hull bulk carriers and a double hull oil tanker with asymmetrically damaged cross section has been performed using the simplified approach under sagging condition by performing the elastic cross-sectional properties and critical member elements. A closed form formulae of residual strength and that of the reduction ratio of the residual strength due to the rotation of neutral axis are proposed. It is found through a comparison with the results obtained by the progressive collapse analysis that the residual hull girder strength of asymmetrically damaged ships under sagging bending moment can be predicted by the proposed formulae with a reasonable accuracy. The ultimate strength obtained with the horizontal curvature constrained is larger than without constrained one. The ultimate hull girder strength is attained even the horizontal curvature is constrained because of the horizontal bending moment is induced by the stiffened matrix interaction for horizontal and vertical and this makes the ultimate hull girder strength becomes higher. The effect is largest for single hull bulk carrier and almost negligible for double hull oil tanker. The difference characteristic for two single hull bulk carrier may be related to that of the depth to breadth ratio, member scantlings etc.

The resultant of bending moment is induced by the accumulation of the horizontal and vertical bending moment based on the reference coordinate system. Fig. 12 shows the comparison the reduction rates of the residual strength due to rotation of the neutral axis obtained by Eq. (13) and progressive collapse analysis. The influence of the rotation of the neutral axis is larger for a larger damage extent in general. For the case of the subject ships and damages under consideration, the influence is larger in bulk carriers than in tankers. Eq. (13) gives a relatively good estimate of the reduction rate. It can be a good basis of a rational expression of the influence of the rotation of the neutral axis on the reserved hull girder strength, as required in ship structures. More systematic analyses are definitely needed to develop the formula having larger applicability in ship types and damaged cases.

According to the result obtained by progressive collapse analysis of double hull oil tanker, the effect of rotation of neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

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INTRODUCTION

The ability to predict accurately the ultimate strength of ship hull girder when subjected to longitudinal bending is one of the most important aspects of ship structural design. Collision and grounding damage may take place on ship's hull, which may threaten safety of ships and surrounding environment. In this regard, to enhance the safety of ship's structure and minimize the risks, the International Maritime Organization (IMO, 2009) has required in Goal Based Standard for New Ship Construction (GBS) to consider the residual strength of the hull girder in specified damage conditions as one of the functional requirements for the structural rules for bulk carriers and tankers.

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(2017). The cross section of Ro-Ro ship was taken to be analyzed. The collision and grounding damages were assumed to be located on the side and bottom areas, respectively. The damages were created by removing the element from the side shell and bottom part. Ohtsubo et al. (1994) showed the experimental and numerical works on the ship structural damages due to collision and grounding. This was one of the first attempts to apply the explicit finite element method codes, such as LS-DYNA and MSC Dytran, to the collision and grounding problems of ships. Ozguc et al. (2005) investigated the collision resistance and residual strength of single skin and double skin bulk carriers subjected to damages. Notaro et al. (2010) carried out full nonlinear finite element assessments of hull girder capacity in intact and damage conditions. The effects of several influential factors such as model extend and complexity, damage representations and model imperfections were investigated on the different vessels. It was found that the effect of damage extent in a vertical direction is more critical than in a longitudinal direction, and the damage varies according to the location of the neutral axes including higher stresses in proximity of the damage areas. The various probability levels were considered for the damage extent estimation.

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BASIC ASSUMPTION

1 The following assumption is made for the prediction of the residual hull girder strength under the sagging condition:

- (1) The ultimate sagging strength is attained when a stiffened panel element at the specified location (hereafter called ‘critical element’) reached the ultimate strength.
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- (3) The ultimate strength of the critical member is predicted from the average axial stress and average axial strain relationship calculated by HULLST (Yao and Nikolov, 1992).

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where E is Young's modulus, y_G and z_G the centroid coordinates, and ϕ_H and ϕ_V the horizontal and vertical curvatures, respectively. y_G and z_G are given by

$$y_G = \frac{\left(\sum_{i=1}^N y_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (2)$$

$$z_G = \frac{\left(\sum_{i=1}^N z_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (3)$$

where D_i , A_i , and (y_i, z_i) are the tangential stiffness obtained as a slope of the average stress-average strain curve, cross sectional area and the coordinates of the centroid of individual elements, respectively.

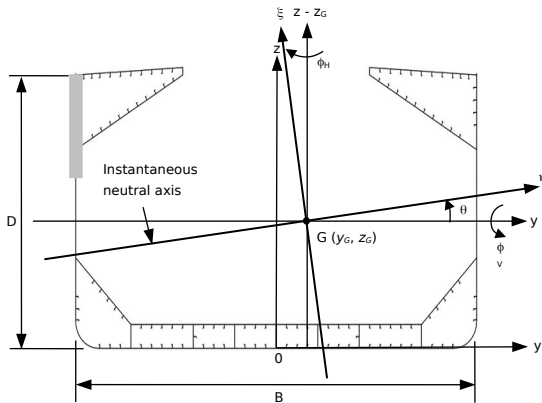


Fig. 1 Neutral axes of the elastic hull girder cross section with asymmetric damage

For the case of an asymmetrically damaged cross section, Eqs (4) through (8) are used, and for the intact one, the expressions are given in Eqs (9) and (10). The biaxial moment and curvature relationship is given in the form

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (4)$$

where

$$\begin{aligned} I_{HV} &= I_{VH} = \sum_{i=1}^N (y_i - y_G)(z_i - z_G) A_i \\ I_{HH} &= \sum_{i=1}^N (y_i - y_G)^2 A_i \\ I_{VV} &= \sum_{i=1}^N (z_i - z_G)^2 A_i \end{aligned} \quad (5)$$

where I and M are the moment of inertia and bending moment, respectively. When the vertical bending moment M_V is applied to the cross section with no constraint on the horizontal curvature (Case 1), the horizontal curvature as well as the vertical curvature is induced under the condition of horizontal bending moment $M_H = 0$. The incremental equation to be solved is

$$\begin{Bmatrix} 0 \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (6)$$

Therefore,

$$\begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} = \frac{1}{E(I_{HH} I_{VV} - I_{HV}^2)} \begin{Bmatrix} -I_{HV} M_V \\ I_{HH} M_V \end{Bmatrix} \quad (7)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{-(y_i - y_G) I_{HV} + (z_i - z_G) I_{HH}}{(I_{HH} I_{VV} - I_{HV}^2)} M_V \quad (8)$$

The terms including the moment of inertia, I_{HV} , represent the effect of the rotation of the neutral axis.

On the other hand, when the vertical bending moment is applied to the cross section with the horizontal curvature constrained (Case 2), the bending moment is induced under the condition of $\phi_H = 0$, that is,

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} 0 \\ \phi_V \end{Bmatrix} \quad (9)$$

Therefore,

$$\phi_V = \frac{M_V}{EI_{VV}} \quad (10)$$

Substituting Eq. (10) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{(z_i - z_G)}{I_{VV}} M_V \quad (11)$$

Here, it is assumed that the residual hull girder strength in the sagging condition M_V^u is attained when a critical member at the location of (y_C, z_C) reached its ultimate strength, σ_C^u , namely for Case 1

$$M_V^u|_{CASE\ 1} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \sigma_C^u \quad (12)$$

And for Case 2

$$M_V^u|_{CASE\ 2} = \frac{I_{VV}}{(z_C - z_G)} \sigma_C^u \quad (13)$$

Therefore, the reduction rate of the residual strength due to the rotation of the neutral axis in the framework of the proposed approximate approach is given by ratio of Eq. (12) to Eq. (13) as

$$\frac{M_V^u|_{CASE\ 1}}{M_V^u|_{CASE\ 2}} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \frac{(z_C - z_G)}{I_{VV}} \quad (14)$$

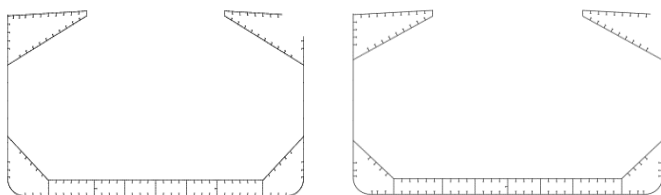
CASE STUDY

Two single-hull bulk carriers, B1 and B2, and one double-hull oil tanker, T2, are taken as the subject ships as shown in Table 1. Ship B1 is designed according to Pre-UR rule and built in 1987 and Ship B2 according to CSR-B having larger cross section and scantling sizes. Ship T2 is designed according to CSR-T.

Table 1 Subject ships

Ship	B1	B2	T2
L (mm)	217,000	219,000	234,000
B (mm)	32,236	32,240	44,000
D (mm)	18,300	19,900	21,200
Design criteria	Pre-IACS UR	IACS CSR-B	IACS CSR-T

The damage of the upper part of side shell due to collision is assumed. The vertical damage extent is taken as 10%, 20%, 40% and 70% of the depth D for both bulk carriers and tanker. The horizontal damage extent is taken as $B/16$, and it is kept constant for all damaged cases. The damaged cross sections of Ship B1 are illustrated in Fig. 2 and those of Ship T2 in Fig. 3. The stiffness of the elements in the damaged area is completely removed. For the double-hull tanker, only outer side shell is assumed to be damaged. The locations of the critical deck element are presented in Fig. 4 for single-hull bulk carrier and double-hull oil tanker, respectively.



(a) 10% damage

(b) 20% damage

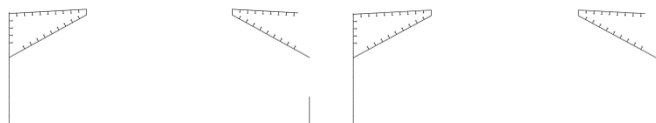
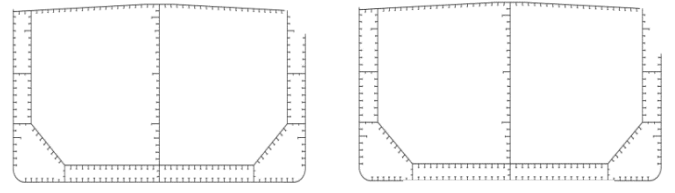
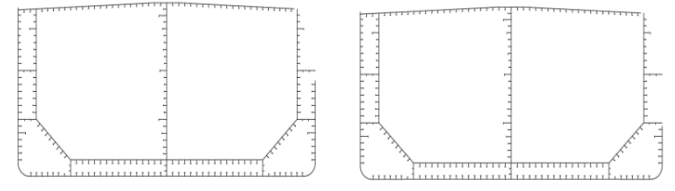


Fig. 2 Single hull bulk carrier (Ship B1)



(a) 10% damage

(b) 20% damage

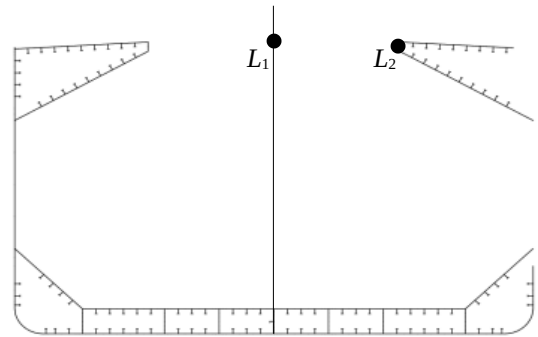


(c) 40% damage

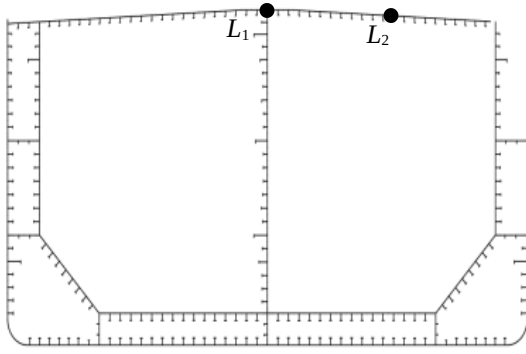
(d) 70% damage

Fig. 3 Double hull oil tanker (Ship T2)

The investigation of the residual hull girder strength under sagging condition is performed by taking two locations of the critical deck elements as shown in Fig. 4. For Single-hull bulk carriers (B1 and B2), the locations of the critical element are L_1 and L_2 . L_1 is located at the center line and L_2 at the hatch coaming on the damage side. For the case of double-hull oil tanker (T2), L_1 is located at the center line and L_2 at the distance of $B/4$ from the damaged side shell. As for the critical stress, the maximum stress of elements located at points L_1 and/or L is used.



(a) Single-hull bulk carrier



(b) Double-hull oil tanker

Fig. 4 Locations of the critical deck elements

RESULT AND DISCUSSION

In sagging condition, it is well recognized that the ultimate hull girder strength is almost attained when the primary deck members in longitudinal compression reached their ultimate strength. Also, because the damage takes place at the asymmetric position, in other word, collision damage is placed at the side shell through to the deck part (B/16) and there is no damage located at the bottom part, so that it is very important to investigate the critical member under sagging condition. In the present study, the ultimate strength is analyzed after damage has taken place. The water ingress is not considered in the analysis.

The results obtained by progressive collapse analysis under sagging condition for 20% and 70% damage are presented in Fig. 5 and Fig. 6, respectively. Case 1 considers the rotation of neutral axis and Case 2 does not. The resultant of bending moment versus curvature is plotted.

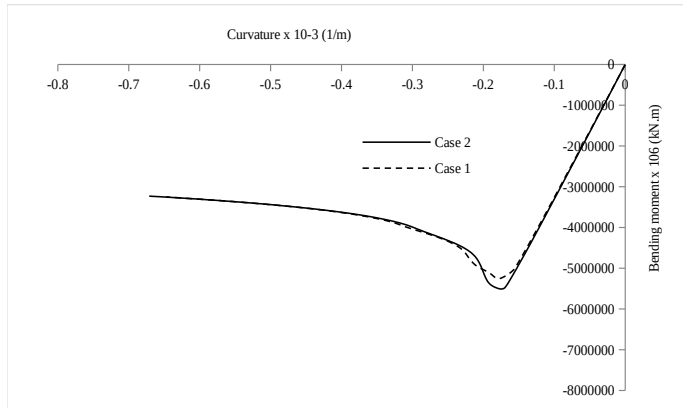


Fig. 5 Single-hull bulk carrier (Ship B1) with 20% damage

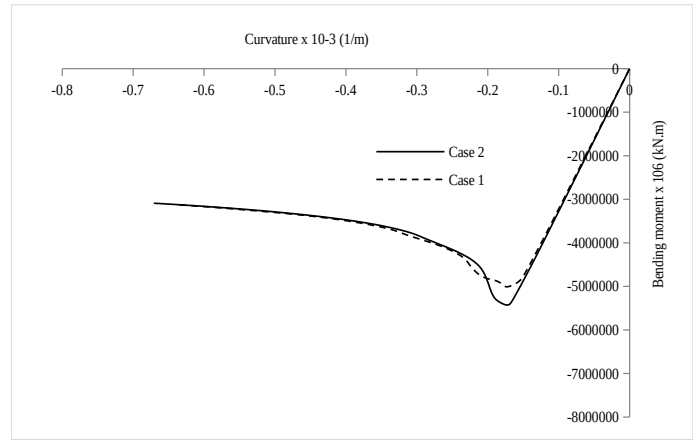


Fig. 6 Single-hull bulk carrier (Ship B1) with 70% damage

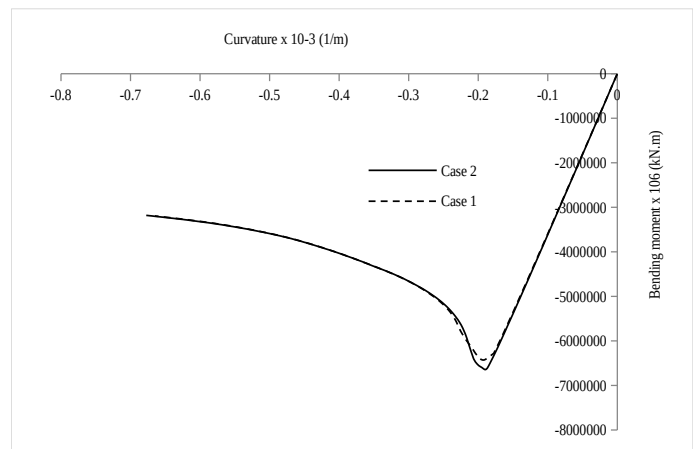


Fig. 7 Single-hull bulk carrier (Ship B2) with 20% damage

Similarly, the resultant bending moment and curvature curve for Ship B2 and Ship T2 with 20% and 70% damage are presented in Figs. 7 through 10.

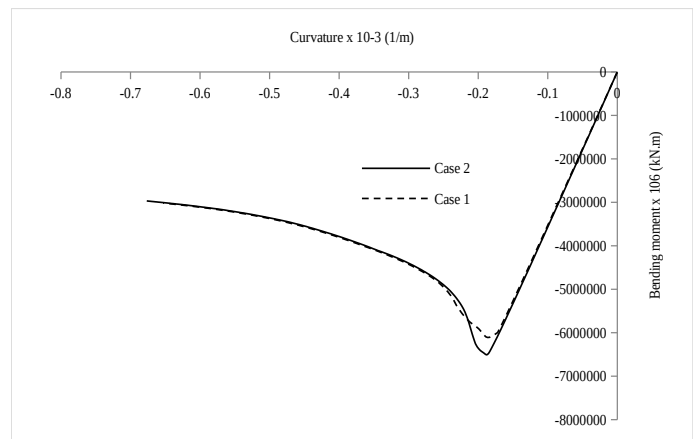


Fig. 8 Single-hull bulk carrier (Ship B2) with 70% damage

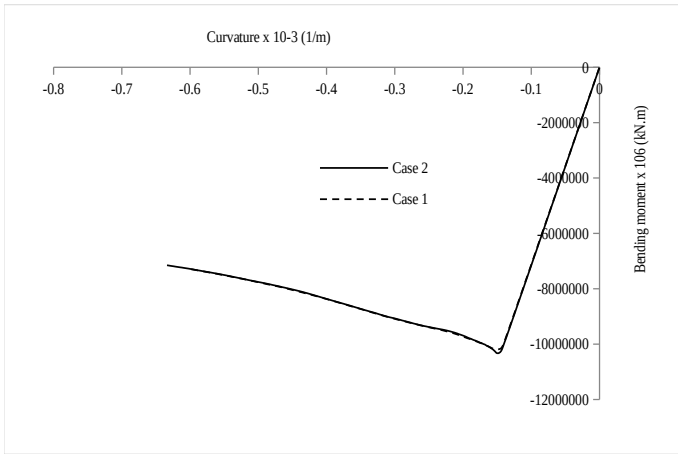


Fig. 9 Double-hull oil tanker (Ship T2) with 20% damage

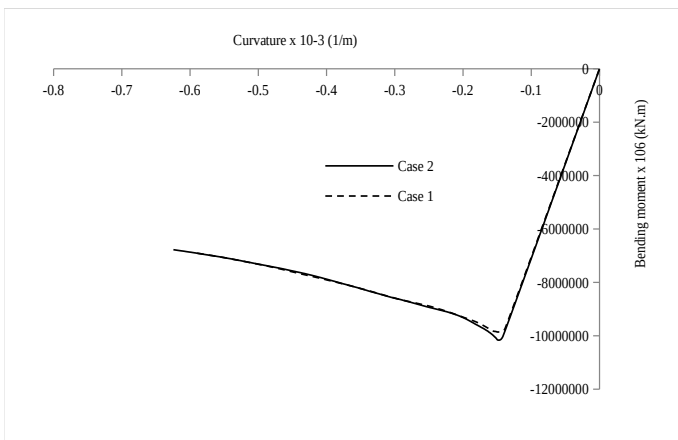
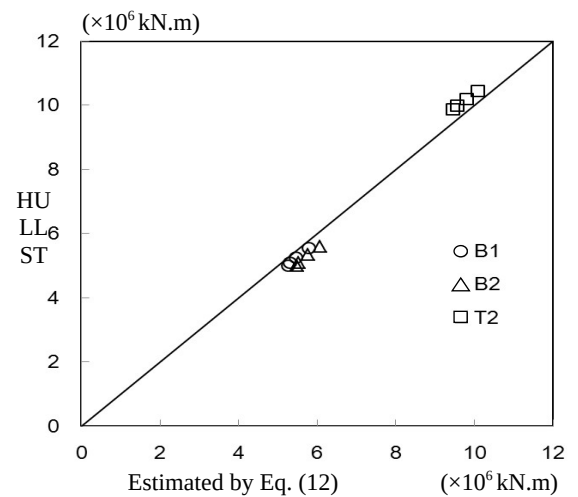
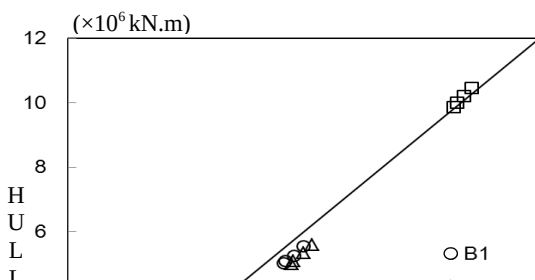


Fig. 10 Double-hull oil tanker (T2) with 70% damage

Figures 7 and 8 show the results of the moment-curvature relationship obtained by progressive collapse analysis for single-hull bulk carrier (B2). It is found that Case 2 generally gives higher ultimate strength than Case 1 because the horizontal curvature is constrained. The ultimate hull girder strength is attained even the horizontal curvature is constrained because of the horizontal bending moment is induced by the incremental equation for horizontal and vertical bending moments and this makes the ultimate hull girder strength becomes higher. The effect of constraint is the largest in Ship B1, and is smaller in Ship B2. For Ship B1, Case 1's strength is 7.3% smaller than Case 2's in the sagging condition. The difference between Ship B1 and Ship B2 may be attributed to that of the depth-to-breadth ratio, member scantlings etc. Figures 9 and 10 represent the moment-curvature relationship under the sagging condition for a double-hull oil tanker (T2) for 20% and 70% of damages, respectively. According to the result obtained by progressive collapse analysis of a double-hull oil tanker (Ship T2), the effect of rotation of the neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.



(b) Location L_2

Fig. 11 Comparison of residual hull girder strength M_V between The residual strengths of Ships B1, B2 and T2 obtained for the four different damage extents are summarized in Figures 11 and 12 (a) and (b). It is found that Eq. 11 gives an estimate of the residual strength that is in good agreement with the result of the progressive collapse analysis. For bulk carriers, the critical element at the location L_2 gives a better estimate of the residual strength. For the location L_1 bulk carriers, the ultimate strength of critical element is evaluated by using that of the element at L_2 . This is consistent with the observed collapse behavior in which the ultimate strength was attained when topside tank region of the damaged side almost fully failed. In the case of a double-hull tanker, location L_1 gives a better estimate of the residual strength than L_2 . This is also consistent with the failure behavior of T2 in which the ultimate strength was attained when the deck part almost fully failed.

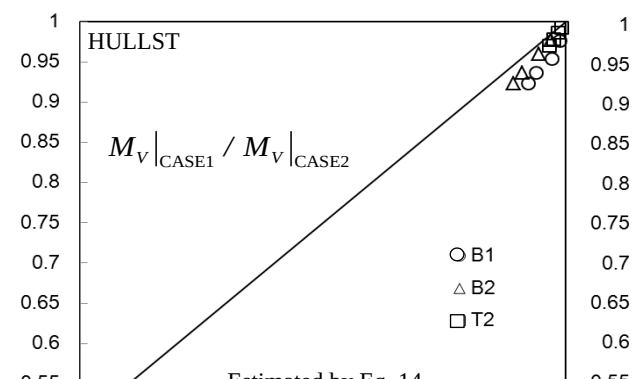


Fig. 12 Comparison of reduction ratio of residual hull girder due to rotation of neutral axis between the simplified method and the progressive collapse analysis (Case 1/Case 2)

CONCLUSIONS

Progressive collapse analysis was performed on two single-hull bulk carriers and a double-hull oil tanker with asymmetrically damaged cross section. Closed-form formulae of residual strength and that of the reduction ratio of the residual strength considering the rotation of neutral axis are proposed. It is found through a comparison with the results obtained by the progressive collapse analysis that the residual hull girder strength of asymmetrically damaged ships under the sagging bending moment can be predicted by the proposed formulae with reasonable accuracy. The ultimate strength obtained with the horizontal curvature constrained is larger than that without constraint. The effect of the rotation of the neutral axis is the largest for single-hull bulk carrier and almost negligible for the double-hull oil tanker. The difference characteristic for two single-hull bulk carriers may be related to that of the depth-to-breadth ratio, member scantlings etc.

The resultant of bending moment is induced by the accumulation of the horizontal and vertical bending moments based on the reference coordinate system. Figure 12 shows the comparison of the reduction rates of the residual strength due to rotation of the neutral axis obtained by Eq. 14 and progressive collapse analysis. The influence of the rotation of the neutral axis is larger for a larger damage extent in general. For the case of the subject ships and damages under consideration, the influence is larger in bulk carriers than in tankers. Equation 14 gives a relatively good estimate of the reduction rate. It can be a good basis of a rational expression of the influence of the rotation of the neutral axis on the reserve ultimate hull girder strength, as required in ship structures. More systematic analyses are definitely needed to develop the formula having a larger applicability in ship types and damaged cases.

According to the result obtained by progressive collapse analysis of double-hull oil tanker, the effect of rotation of neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

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It is necessary to revise the manuscript as suggested below for the publication of this paper in IJOPE.

- (1) Abstract; 2nd line: “Two kinds of ship” → “Two kinds of ships”
- (2) Introduction; left column; 4th – 5th lines: “safety ship” → “safety of ships”
- (3) Introduction; left column; 13th line: “damaged” → “damages”
- (4) Introduction; left column; 15th line: “grounded” → “grounding”
- (5) Introduction; right column; 6th line: “condition” → “conditions”
- (6) Introduction; right column; 9th line: “condition” → “conditions”
- (7) Introduction; right column; 11th line: “symmetrical” → “symmetrically”
- (8) Introduction; right column; 19th line: “work” → “works”
- (9) Introduction; right column; 25th line: “calculate” → “calculated”
- (10) Page 2; left column; 1st line: “influence” → “influential”
- (11) Page 2; right column; 1st line below Eq.(3): “Where” → “where”
- (12) Page 2; right column; 2nd line below Eq.(3): “stress-strain” → “stress-average strain”
- (13) Page 2; right column; 1st line below Fig. 1: “symmetrical” → “symmetrically”
- (14) Page 2; right column; 1st line below Eq.(5): “Where I and M is” → “where I and M are”
- (15) Page 3; left column; below Eq.(9): The following has to be inserted:
Therefore,
$$\phi_V = \frac{M_V}{EI_{VV}} \quad (10)$$
- (16) Page 3; left column; 1st line above Eq.(10): “Eq.(9) to Eq.(1)” → “Eq.(10) to Eq.(1)”
- (17) Page 3; left column; 1st line above Eq.(11): “($y_C - z_C$)” → “(y_C, z_C)”
- (18) Page 3; left column; equation number: (10) → (11)
- (19) Page 3; left column; equation number: (11) → (12)
- (20) Page 3; left column; equation number: (12) → (13)
- (21) Page 3; left column; equation number: (13) → (14)
- (22) Page 3; left column; 1st line above Eq.(13): “Eq.(11) to Eq.(12)” → “Eq.(12) to Eq.(13)”
- (23) Page 3; right column; Table 1: “Table 1” has to be placed above the table.
- (24) Page 3; right column; 3rd line below Table 1: “bulk carrier” → “bulk carriers”
- (25) Page 4; left column; 3rd line: “Single hull bulk carrier” → “For single hull bulk carriers”
- (26) Page 4; left column; 4th line: “and L_2, L_1 ” → “ L_2, L_1 ”
- (27) Page 4; left column; 7th line: “side shell.” → “side shell. As for the critical stress, the maximum stress of elements located at points L_1 and/or L_2 is used.”

- (28) In relation to the above (27), what average stress-average strain relationship is considered when L_1 is chosen as critical point in case of bulk carriers. The author has to describe concretely about this. As this reviewer's comment, L_1 should not be specified as a critical point in case of buck carrier because there is no element here. So, in case of such cross-sections, L_1 and L_2 should be hatch coaming and end of the deck (or top of the side shell plating).
- (29) Page 4; left column; 10th line from the bottom: "is place" → "is placed"
- (30) Page 4; left column; 6th line from the bottom: "takes place" → "has taken place"
- (31) Page 5; right column; 3rd line: "larger" → "higher"
- (32) Page 5; right column; 5th – 9th line: "The ultimate hull girder strength is attained even the horizontal curvature is constrained because of the horizontal bending moment is induced by the stiffened matrix interaction for horizontal and vertical and this makes the ultimate hull girder strength becomes higher." → This sentence is difficult to understand. First of all, use "even" is strange. The ultimate hull girder strength is definitely attained in any case. "stiffened matrix" may be "stiffness matrix". In conclusion, this part could be deleted.
- (33) Page 5; right column; 9th line: "The effect is largest in Ship B1, smaller in Ship B2," → "The effect of constraint is the largest in ship B1, and is smaller in Ship B2."
- (34) Page 5; right column; 9th – 10th lines: "and almost negligible in Ship T2." → This sentence has to be deleted since Figs. 10 and 11 are not yet referred here.
- (35) Page 5; right column; 12th line: "be related to" → "be attributed to"
- (36) Page 5; Fig. 11: "Estimate by Eq.(11)" → "Estimation by Eq.(12)" or "Estimated by Eq.(12)"
- (37) Page 6; left column; 8th – 10th lines: "The location L_1 by M_V ." → You have to describe what critical stress is used at Point L_1 , at which no element exists, see (28).
- (38) Page 6; left column; 11th line: "of tankers" → "of a double hull tanker"
- (39) Page 6; right column; 1st to 14th line: This paragraph has to come at the location presently "CONCLUSIONS" is placed. And "CONCLUSIONS" has to come after this paragraph. A part of "CONCLUSIONS" may come at the top of the right column of Page 6.
- (40) Page 6; right column; 3rd line: "comparison the reduction" → "comparison of the reduction"
- (41) Page 6; right column; 5th line: "Eq. (13)" → "Eq.(14)"
- (42) Page 6; right column; 9th line: "Eq. (13)" → "Eq.(14)"
- (43) Page 6; right column; 11th line: "reserve hull" → "reserve ultimate hull"

- (44) Page 6; Fig. 12: “**Estimate** by Eq.(13)” → “**Estimation** by Eq.(14)” or “**Estimated** by Eq.(14)”
- (45) Page 6; CONCLUSIONS; 6th line: “**due to**” → “**considering**”
- (46) Page 6; CONCLUSIONS; 13th - 17th line “The ultimate strength becomes higher.” → This sentence is recommended to delete with the same reason described in (32).
- (47) Page 6; CONCLUSIONS; 17th line: “The effect is largest” → “The effect **of the rotation of neutral axis** is **the** largest”

Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships

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ABSTRACT

The objective of the present study is to investigate the ultimate hull girder strength of an asymmetrically damaged ship under a sagging condition. Two kinds of ships are taken as the object of analysis. The cross section of the ship is considered and assumed to have remained plane. The simply supported boundary condition is applied to both sides of the cross section. The ultimate hull girder strength is attained when a plate and/or stiffened plate element at the specified location called the “critical element” reaches its ultimate strength. To investigate the ultimate hull girder strength, a simplified approach is proposed. The result obtained by the simplified approach is compared with the progressive collapse analysis for the effectiveness and validation.

KEY WORDS: Single-hull bulk carrier, double-hull oil tanker, cross section, neutral axis, asymmetrically damaged, ultimate strength, simplified approach.

INTRODUCTION

The ability to predict accurately the ultimate strength of a ship hull girder when subjected to longitudinal bending is one of the most important aspects of ship structural design. Collision and grounding damage may take place on a ship's hull, which may threaten the safety of ships and the surrounding environment. In this regard, to enhance the safety of the ship's structure and minimize risks, the International Maritime Organization (2009) has required in its goal-based new ship construction standards the consideration of the residual strength of the hull girder in specified damage conditions as one of the functional requirements for the structural rules for bulk carriers and tankers.

Many studies have been conducted on the analyses of the residual hull girder strength as a result of collision and grounding damages. Pedersen (1994) presented a mathematical model to estimate the contact pressure between the grounded ship and the sea bottom. The grounding contact force was compared with the force that would crush the forward bottom of the ship. The sectional bending moment due to grounding was determined and compared with the ultimate hull girder strengths. The model experiments and full-scale controlled grounding experiments were also performed to validate the mathematical model. Paik et al. (1998) developed a rapid procedure to identify the possibility of hull girder failure after collision and grounding damages based on the closed-form formulae of the ultimate hull girder strength and section modulus after the damages. Guedes Soares et al. (2008) evaluated the ability of simplified structural analysis methods based on Smith's formulation to predict the ultimate strength of a damaged ship's hull. Muis Alie et al. (2016) investigated the influence of the superstructure on the ultimate strength of a Ro-Ro ship under a vertical bending moment. The cross section was considered to be analyzed. The results obtained by beam theory with and without superstructure were compared with one another. The assessment of the ultimate hull girder strength was conducted by Muis Alie et al. (2017). The cross section of a Ro-Ro ship was taken to be analyzed. The

collision and grounding damages were assumed to be located on the side and bottom areas, respectively. The damages were created by removing the element from the side shell and bottom part. Ohtsubo et al. (1994) showed the experimental and numerical works on ship structural damages due to collision and grounding. This was one of the first attempts to apply the explicit finite element method codes, such as LS-DYNA and Dytran to the collision and grounding problems of ships. Özgüç et al. (2005) investigated the collision resistance and residual strength of single-skin and double-skin bulk carriers subjected to damages. Notaro et al. (2010) carried out full nonlinear finite element assessments of hull girder capacity in intact and damage conditions. The effects of several influential factors such as model extend and complexity, damage representations, and model imperfections were investigated on the different vessels. It was found that the effect of damage extent in a vertical direction is more critical than in a longitudinal direction, and the damage varies according to the location of the neutral axes, including higher stresses in proximity of the damage areas. The various probability levels were considered for the damage extent estimation.

When a hull-girder cross section is symmetric with respect to the centerline and subjected to pure vertical bending moment, the neutral axis for vertical bending is always horizontal and moves only vertically during the progressive collapse behavior. However, when the cross section is asymmetrically damaged, for example, because of a collision, the neutral axis rotates. Both rotation and translation need to be taken into account during the progressive collapse behavior even when only a vertical bending moment is applied, and the problem needs to be treated as a biaxial bending problem. Previous studies using Smith's method on the ultimate strength of hull girders under biaxial thrust (Özgüç and Barltrop, 2008) and the residual strength of damaged hulls (Fang and Das, 2004; Hussein and Guedes Soares, 2009; Choung et al., 2011) consider the rotation and translation of a neutral axis in a reasonable way. However, they employ a trial-and-error approach to detect the position of the neutral axis. An easier approach to detect the position of a neutral axis is demanded.

BASIC ASSUMPTION

1 The following assumption is made for the prediction of the residual hull girder strength under the sagging condition:

- (1) The ultimate sagging strength is attained when a stiffened panel element at the specified location (hereafter called the “critical element”) reaches the ultimate strength.
- (2) The hull girder cross section is elastic until the failure of the critical member.
- (3) The ultimate strength of the critical member is predicted from the average axial stress and average axial strain relationship calculated by HULLST (Yao and Nikolov, 1992).

EFFECT OF NEUTRAL AXIS ROTATION ON THE ESTIMATION OF THE ULTIMATE HULL GIRDER STRENGTH

In the elastic cross section, the bending stress at the i th element (see Fig. 1), σ_i , is expressed as

$$\sigma_i = E \left[(y_i - y_G) \phi_H + (z_i - z_G) \phi_V \right] \quad (1)$$

where E is Young's modulus, y_G and z_G the centroid coordinates, and ϕ_H and ϕ_V the horizontal and vertical curvatures, respectively. y_G and z_G are given by

$$y_G = \frac{\left(\sum_{i=1}^N y_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (2)$$

$$z_G = \frac{\left(\sum_{i=1}^N z_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)}, \quad (3)$$

where D_i , A_i , and (y_i, z_i) are the tangential stiffness obtained as a slope of the average stress-average strain curve, cross-sectional area, and the coordinates of the centroid of individual elements, respectively.

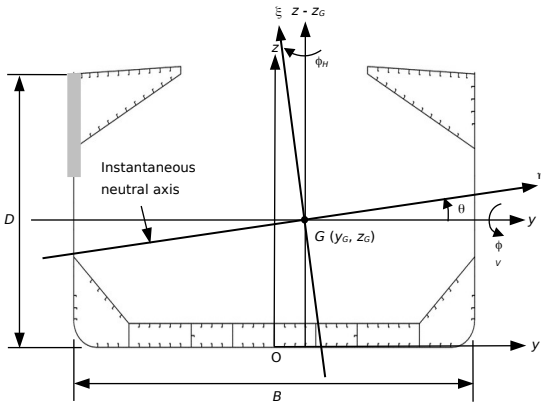


Fig. 1 Neutral axes of the elastic hull girder cross section with asymmetric damage

For the case of an asymmetrically damaged cross section, Eqs. 4 through 8 are used, and for the intact one, the expressions are given in Eqs. 9 and 10. The biaxial moment and curvature relationship is given in the form

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (4)$$

where

$$\begin{aligned} I_{HV} &= I_{VH} = \sum_{i=1}^N (y_i - y_G)(z_i - z_G) A_i \\ I_{HH} &= \sum_{i=1}^N (y_i - y_G)^2 A_i \\ I_{VV} &= \sum_{i=1}^N (z_i - z_G)^2 A_i \end{aligned} \quad (5)$$

where I and M are the moment of inertia and bending moment, respectively. When the vertical bending moment M_V is applied to the cross section with no constraint on the horizontal curvature (Case 1), the horizontal curvature as well as the vertical curvature is induced under the condition of horizontal bending moment $M_H = 0$. The incremental equation to be solved is

$$\begin{Bmatrix} 0 \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix}. \quad (6)$$

Therefore,

$$\begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} = \frac{1}{E(I_{HH} I_{VV} - I_{HV}^2)} \begin{Bmatrix} -I_{HV} M_V \\ I_{HH} M_V \end{Bmatrix}. \quad (7)$$

Substituting Eq. 7 into Eq. 1, the bending stress σ_i is given by

$$\sigma_i = \frac{-(y_i - y_G) I_{HV} + (z_i - z_G) I_{HH}}{(I_{HH} I_{VV} - I_{HV}^2)} M_V. \quad (8)$$

The terms including the moment of inertia, I_{HV} , represent the effect of the rotation of the neutral axis.

On the other hand, when the vertical bending moment is applied to the cross section with the horizontal curvature constrained (Case 2), the bending moment is induced under the condition of $\phi_H = 0$; that is,

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} 0 \\ \phi_V \end{Bmatrix}. \quad (9)$$

Therefore,

$$\phi_V = \frac{M_V}{EI_{VV}}. \quad (11)$$

Substituting Eq. 10 into Eq. 1, the bending stress σ_i is given by

$$\sigma_i = \frac{(z_i - z_G)}{I_{VV}} M_V \quad (12)$$

Here, it is assumed that the residual hull girder strength in the sagging condition, M_V^u , is attained when a critical member at the location of (y_C, z_C) reaches its ultimate strength, σ_C^u ; namely, for Case 1,

$$M_V^u|_{CASE\ 1} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \sigma_C^u \quad (13)$$

and for Case 2,

$$M_V^u|_{CASE\ 2} = \frac{I_{VV}}{(z_C - z_G)} \sigma_C^u \quad (14)$$

Therefore, the reduction rate of the residual strength due to the rotation of the neutral axis in the framework of the proposed approximate approach is given by the ratio of Eq. 12 to Eq. 13 as

$$\frac{M_V^u|_{CASE\ 1}}{M_V^u|_{CASE\ 2}} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \frac{(z_C - z_G)}{I_{VV}} \quad (13)$$

CASE STUDY

Two single-hull bulk carriers, B1 and B2, and one double-hull oil tanker, T2, are taken as the subject ships as shown in Table 1. Ship B1, built in 1987, was designed according to the International Association of Classification Studies (IACS) Pre-Unified Requirements (UR) rule and Ship B2 according to the Common Structural Rules for Bulk Carriers (CSR-BC), having larger cross-section and scantling sizes. Ship T2 was designed according to Common Structural Rules for Oil Tankers (CSR-OT).

Table 1 Subject ships

Ship	B1	B2	T2
L (mm)	217,000	219,000	234,000
B (mm)	32,236	32,240	44,000
D (mm)	18,300	19,900	21,200
Design criteria	Pre-IACS UR	IACS CSR-BC	IACS CSR-OT

The damage of the upper part of side shell due to collision is assumed. The vertical damage extent is taken as 10%, 20%, 40%, and 70% of the depth D for both bulk carriers and tanker. The horizontal damage extent is taken as $B/16$, and it is kept constant for all damaged cases. The damaged cross sections of Ship B1 are illustrated in Fig. 2 and those of Ship T2 in Fig. 3. The stiffness of the elements in the damaged area is completely removed. For the double-hull tanker, only the outer side shell is assumed to be damaged. The locations of the critical deck element are presented in Fig. 4 for both the single-hull bulk carrier and double-hull oil tanker.

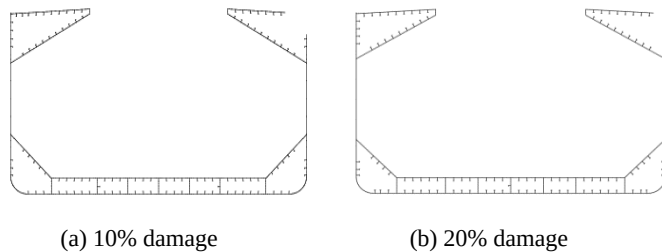


Fig. 2 Single-hull bulk carrier (Ship B1)

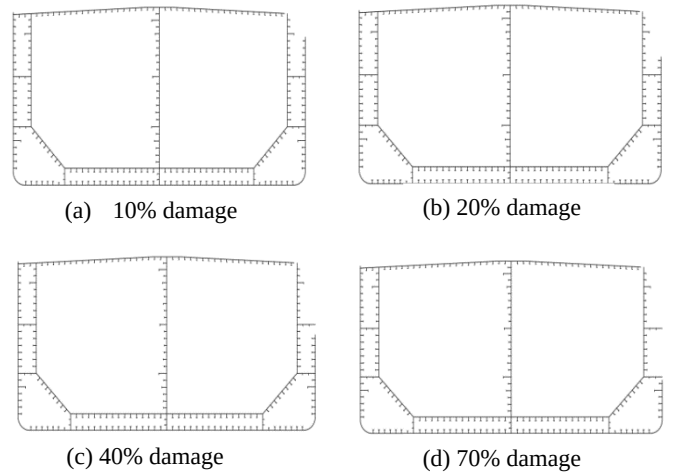
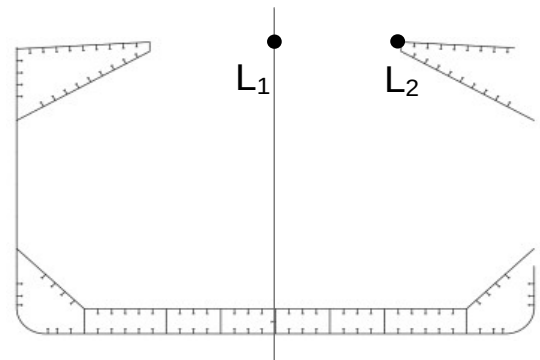
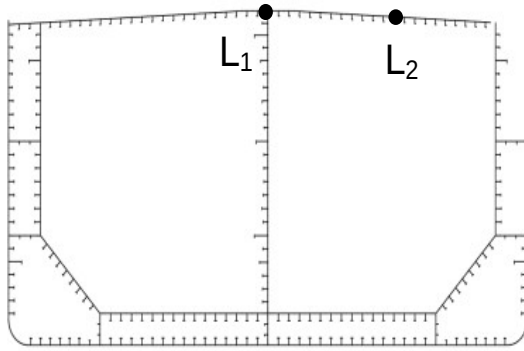


Fig. 3 Double-hull oil tanker (Ship T2)

The investigation of the residual hull girder strength under the sagging condition is performed by taking two locations of the critical deck elements as shown in Fig. 4. For single-hull bulk carriers (B1 and B2), the locations of the critical element are L_1 and L_2 . L_1 is located at the center line and L_2 at the hatch coaming on the damaged side. For the case of double-hull oil tanker (T2), L_1 is located at the center line and L_2 at the distance of $B/4$ from the damaged side shell. As for the critical stress, the maximum stress of elements located at point L_1 and/or point L is used.



(a) Single-hull bulk carrier



(b) Double-hull oil tanker

Fig. 4 Locations of the critical deck elements

RESULT AND DISCUSSION

In the sagging condition, it is well recognized that the ultimate hull girder strength is almost attained when the primary deck members in longitudinal compression reach their ultimate strength. Because the damage takes place at the asymmetric position, collision damage is placed at the side shell through to the deck part (*B/16*), and there is no damage located at the bottom part, so it is very important to investigate the critical member under a sagging condition. In the present study, the ultimate strength is analyzed after damage has taken place. The water ingress is not considered in the analysis. The results obtained by progressive collapse analysis under the sagging condition for 20% and 70% damage are presented in Fig. 5 and Fig. 6, respectively. Case 1 considers the rotation of a neutral axis and Case 2 does not. The resultant of a bending moment versus curvature is plotted.

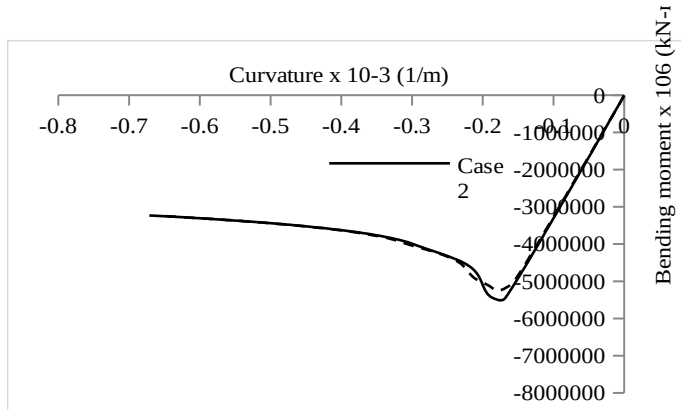


Fig. 5 Single-hull bulk carrier (Ship B1) with 20% damage

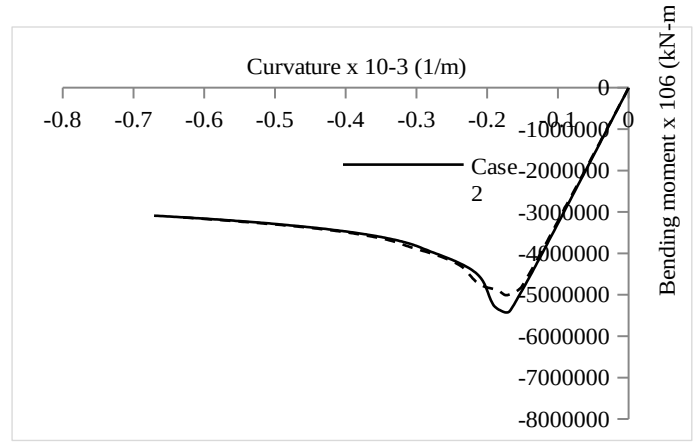


Fig. 6 Single-hull bulk carrier (Ship B1) with 70% damage

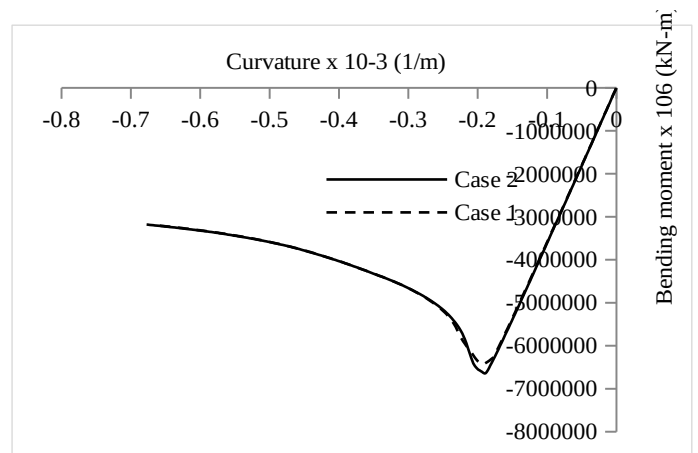


Fig. 7 Single-hull bulk carrier (Ship B2) with 20% damage

Similarly, the resultant bending moment and curvature curve for Ships B2 and T2 with 20% and 70% damage are presented in Figs. 7 through 10.

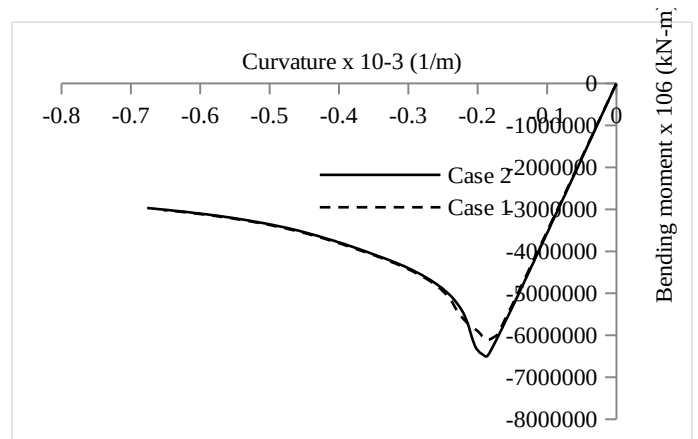


Fig. 8 Single-hull bulk carrier (Ship B2) with 70% damage

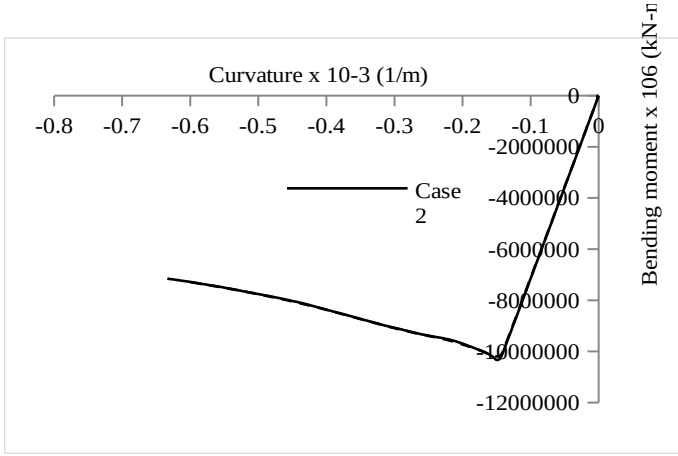


Fig. 9 Double-hull oil tanker (Ship T2) with 20% damage

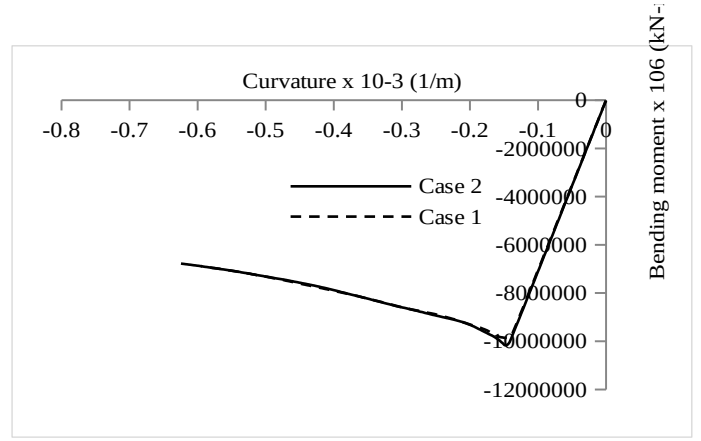
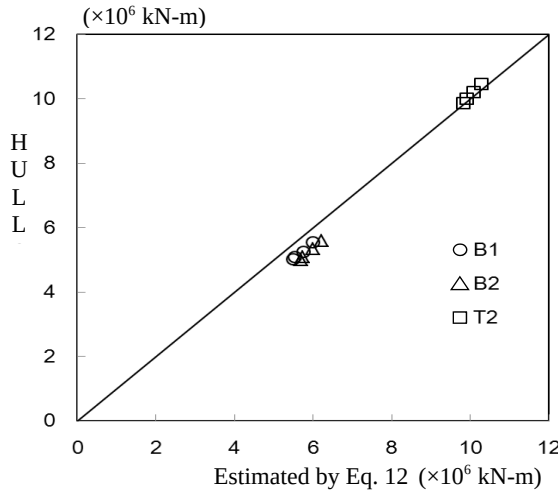
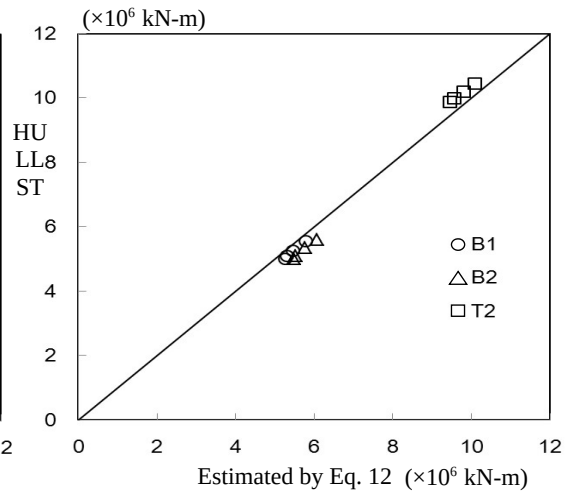


Fig. 10 Double-hull oil tanker (T2) with 70% damage



(a) Location L_1



(b) Location L_2

Fig. 11 Comparison of residual hull girder strength M_V between the simplified method and the progressive collapse analysis

Figures 7 and 8 show the results of the moment-curvature relationship obtained by progressive collapse analysis for a single-hull bulk carrier (B2). It is found that Case 2 generally gives higher ultimate strength than Case 1 because the horizontal curvature is constrained. The ultimate hull girder strength is attained even when the horizontal curvature is constrained because of the horizontal bending moment induced by the incremental equation for horizontal and vertical bending moments, causing the ultimate hull girder strength to increase. The effect of constraint is the largest in Ship B1 and is smaller in Ship B2. For Ship B1, Case 1's strength is 7.3% smaller than Case 2's in the sagging condition. The difference between Ship B1 and Ship B2 may be attributed to that of the depth-to-breadth ratio, member scantlings, etc. Figures 9 and 10 represent the moment-curvature relationship under the sagging condition for a double-hull oil tanker (T2) for 20% and 70% of damages, respectively. According to the result obtained by progressive collapse analysis of a double-hull oil tanker (Ship T2), the effect of rotation of the neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

The residual strengths of Ships B1, B2, and T2 obtained for the four different damage extents are summarized in Fig. 11. It is found that Eq. 11 gives an estimate of the residual strength that is in good agreement with the result of the progressive collapse analysis. For bulk carriers, the critical element at location L_2 gives a better estimate of the residual strength. For the location L_1 bulk carriers, the ultimate strength of the critical element is evaluated by using that of the element at L_2 . This is consistent with the observed collapse behavior in which the ultimate strength was attained when the topside tank region of the damaged side almost fully failed. In the case of a double-hull tanker, location L_1 gives a better estimate of the residual strength than L_2 . This is also consistent with the failure behavior of T2 in which the ultimate strength was attained when the deck part almost fully failed.

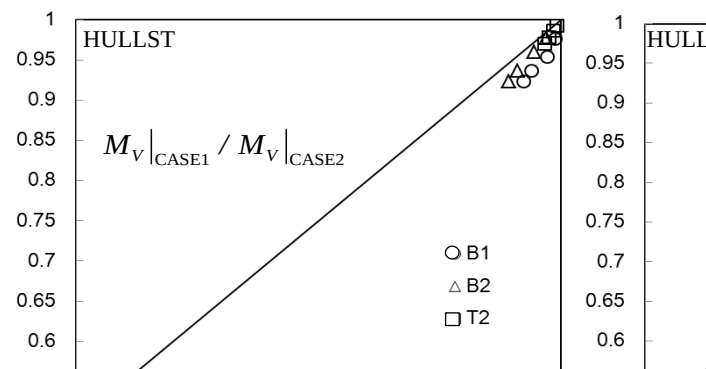


Fig. 12 Comparison of reduction ratio of residual hull girder due to rotation of neutral axis between the simplified method and the progressive collapse analysis (Case 1/Case 2)

CONCLUSIONS

Progressive collapse analysis applying Smith's method was performed on two single-hull bulk carriers and a double-hull oil tanker with asymmetrically damaged cross sections. Closed-form formulae of residual strength and that of the reduction ratio of the residual strength considering the rotation of the neutral axis are proposed. It is found through a comparison with the results obtained by the progressive collapse analysis that the residual hull girder strength of asymmetrically damaged ships under the sagging bending moment can be predicted by the proposed formulae with reasonable accuracy. The ultimate strength obtained with the horizontal curvature constrained is larger than that without constraint. The effect of the rotation of the neutral axis is the largest for the single-hull bulk carrier and almost negligible for the double-hull oil tanker. The difference characteristic for two single-hull bulk carriers may be related to that of the depth-to-breadth ratio, member scantlings, etc.

The resultant of bending moment is induced by the accumulation of the horizontal and vertical bending moments based on the reference coordinate system. Figure 12 shows the comparison of the reduction rates of the residual strength due to rotation of the neutral axis obtained by Eq. 14 and progressive collapse analysis. The influence of the rotation of the neutral axis is larger for a larger damage extent in general. For the case of the subject ships and damages under consideration, the influence is larger in bulk carriers than in tankers. Equation 14 gives a relatively good estimate of the reduction rate. It can be a good basis of a rational expression of the influence of the rotation of the neutral axis on the reserve ultimate hull girder strength, as required in ship structures. More systematic analyses are definitely needed to develop the formula having a larger applicability in ship types and damaged cases.

According to the result obtained by progressive collapse analysis of double-hull oil tanker, the effect of rotation of the neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

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Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships

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ABSTRACT

The objective of the present study is to investigate the ultimate hull girder strength of asymmetrically damaged ship under sagging condition. Two kinds of ship are taken as the object of the analysis. The cross section of the ship is considered and assumed to be remained plane. The simply supported of boundary condition is applied to both sides of the cross section. The ultimate hull girder strength is attained when a plate and/or stiffened plate element at the specified location called “critical element” reach their ultimate strength. To investigate the ultimate hull girder strength, a simplified approach is proposed. The result obtained by simplified approach is compared to the progressive collapse analysis for the effectiveness and validation.

KEY WORDS: Single hull bulk carrier, double hull oil tanker, cross section, neutral axis, asymmetrically damaged, ultimate strength, simplified approach.

INTRODUCTION

The ability to predict accurately the ultimate strength of ship hull girder when subjected to longitudinal bending is one of the most important aspects of ship structural design. A collision and grounding damages may takes place on ship's hull, which may threaten safety ship and surrounding environment. In this regard, to enhance the safety of ship's structure and minimize the risks, the International Maritime Organization (IMO, 2009) has required in Goal Based Standard for New Ship Construction (GBS) to consider the residual strength of the hull girder in specified damage conditions as one of the functional requirements for the structural rules for bulk carriers and tankers.

Many studies have been conducted on the analyses of the residual hull girder strength due to collision and grounding damaged. Pedersen (1994) presented a mathematical modeling to estimate the contact pressure between the grounded ship and the sea bottom. The grounded contact force was compared to the force which would crush the forward bottom of the ship. The sectional bending moment due to grounding was determined and compared to the ultimate hull girder strengths. The model experiments and full-scale controlled grounding experiments were also performed to validate the mathematical model. Paik et al. (1998) developed a rapid procedure to identify the possibility of hull girder failure after collision and grounding damages based on the closed-form formulae of the ultimate hull girder strength and section modulus after the damages. Soares et al. (2008) evaluated the ability of simplified structural analysis methods based on the Smith's formulation to predict the ultimate strength of damage ship's hull. Toh et al. (2012) developed simplified calculation program to calculate the ultimate strength in intact and damage condition and the reduction of hull girder ultimate strength is investigated. The calculation result of simplified method is compared to the FE result for both intact and damage condition. Muis Alie, M.Z et al. (2012) investigated the incidence of neutral axis rotation on residual hull

girder strength for asymmetrical damaged ships under longitudinal bending, applying the progressive collapse method and finding an explicit expression of neutral axis rotation. After performing a series of progressive collapse analyses on several bulk carriers and tanker, it was found that residual hull girder strength, considering the instantaneous neutral axis is generally lower than the relevant one, obtained by constraining the rotation, as it is commonly assumed in classical procedures. Ohtsubo et al. (1994) showed the experimental and numerical work on the ship structural damages due to collision and grounding. This was one of the first attempts to apply the explicit Finite Element Method codes, such as LS-DYNA and DYTRAN, to the collision and grounding problems of ships. Ozguc et al. (2005) investigated the collision resistance and residual strength of single skin and double skin bulk carriers subjected to damages. Lee et al. (2008) calculate the ultimate strength with collision damage using LS-DYNA and compared with the experiment results. It is found that the ultimate strength is reduced as a damage size increased as expected. Notaro et al. (2010) carried out full nonlinear FE assessments of hull girder capacity in intact and damage conditions. The effects of several influences factors such as model extend and complexity, damage representations and model imperfections are investigated on the different vessels. It was found that the effect of damage extent in vertical direction is more critical than in longitudinal direction, and the damage varies the location of the neutral axes including higher stresses in proximity of the damage areas. The various probability levels are considered for the damage extent estimation.

When a hull-girder cross section is symmetric with respect to the centerline and subjected to pure vertical bending moment, the neutral axis for vertical bending is always horizontal and moves only vertically during the progressive collapse behavior. However, when the cross section is asymmetrically damaged due, for example, to a collision, the neutral axis rotates. Both rotation and translation need to be taken into account during the progressive collapse behavior even when only a vertical bending moment is applied, and the problem needs to be treated as a biaxial bending problem. Previous studies using the Smith's method on the ultimate strength of hull girders under biaxial thrust (Ozguc and Barltrop, 2008) and the residual strength of damaged hulls (Fang and Das, 2004; Hussein and Guedes

Soares, 2009; Choung et al, 2011) consider the rotation and translation of neutral axis in a reasonable way. However, they employ a trial and error approach to detect the position of neutral axis. More easy approach to detect the position of neutral axis is demanded.

BASIC ASSUMPTION

1 The following assumption is made for the prediction of the residual hull girder strength under the sagging condition:

- (1) The ultimate sagging strength is attained when a stiffened panel element at the specified location (hereafter called 'critical element') reached the ultimate strength.
- (2) The hull girder cross section is elastic until the failure of the critical member.
- (3) The ultimate strength of the critical member is predicted from the average axial stress and average axial strain relationship calculated by HULLST (Yao and Nikolov).

ESTIMATION OF THE ULTIMATE HULL GIRDER STRENGTH NEUTRAL AXIS EFFECT

In the elastic cross section, the bending stress at the i -th element (see Fig.1), σ_i , is expressed as

$$\sigma_i = E \left[(y_i - y_G) \varphi_H + (z_i - z_G) \varphi_V \right] \quad (1)$$

where E is Young's modulus, y_G and z_G the centroid coordinates, and φ_H and φ_V the horizontal and vertical curvatures, respectively. y_G and z_G are given by

$$y_G = \frac{\left(\sum_{i=1}^N y_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (2)$$

$$z_G = \frac{\left(\sum_{i=1}^N z_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (3)$$

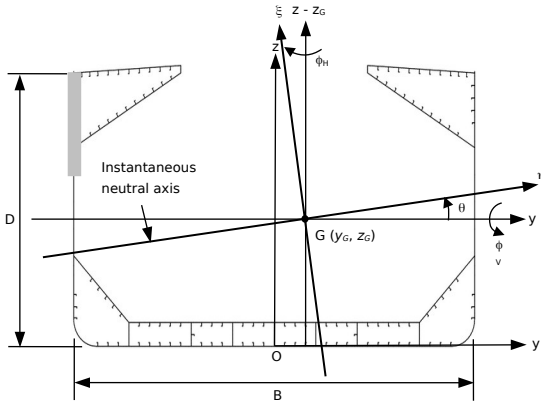


Fig. 1 Neutral axes of the elastic hull girder cross section with

asymmetric damage

The biaxial moment and curvature relationship is given in the form

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \varphi_H \\ \varphi_V \end{Bmatrix} \quad (4)$$

where

$$\begin{aligned} I_{HV} &= I_{VH} = \sum_{i=1}^N (y_i - y_G)(z_i - z_G) A_i \\ I_{HH} &= \sum_{i=1}^N (y_i - y_G)^2 A_i \\ I_{VV} &= \sum_{i=1}^N (z_i - z_G)^2 A_i \end{aligned} \quad (5)$$

When the vertical bending moment is applied to the cross section with no constraint on the horizontal curvature (Case 1), the horizontal curvature as well as the vertical curvature is induced under the condition of $M_H = 0$. The incremental equation to be solved is

$$\begin{Bmatrix} 0 \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \varphi_H \\ \varphi_V \end{Bmatrix} \quad (6)$$

Therefore,

$$\begin{Bmatrix} \varphi_H \\ \varphi_V \end{Bmatrix} = \frac{1}{E(I_{HH} I_{VV} - I_{HV}^2)} \begin{Bmatrix} -I_{HV} M_V \\ I_{HH} M_V \end{Bmatrix} \quad (7)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{-(y_i - y_G) I_{HV} + (z_i - z_G) I_{HH}}{(I_{HH} I_{VV} - I_{HV}^2)} M_V \quad (8)$$

The terms including the moment of inertia, I_{HV} , represent the effect of the rotation of the neutral axis.

On the other hand, when the vertical bending moment is applied to the cross section with the horizontal curvature constrained (Case 2), the bending moment are induced under the condition of $\varphi_H = 0$, that is,

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} 0 \\ \varphi_V \end{Bmatrix} \quad (9)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{(z_i - z_G)}{I_{VV}} M_V \quad (10)$$

Here, it is assumed that the residual hull girder strength in the sagging condition M_V^u is attained when a critical member at the location of $(y_C - z_C)$ reached its ultimate strength, σ_C^u , namely for Case 1

$$M_V^u|_{CASE\ 1} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \sigma_C^u \quad (11)$$

And for Case 2

$$M_V^u|_{CASE\ 2} = \frac{I_{VV}}{(z_C - z_G)} \sigma_C^u \quad (12)$$

Therefore, the reduction rate of the residual strength due to the rotation of the neutral axis in the framework of the proposed approximate approach is given by ratio of Eq. (12) to Eq. (13) as

$$\frac{M_V^u|_{CASE\ 1}}{M_V^u|_{CASE\ 2}} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \frac{(z_C - z_G)}{I_{VV}} \quad (13)$$

CASE STUDY

Two single-hull bulk carriers, B1 and B4, and one double-hull oil tanker, T2, are taken as the subject ships as shown in Table 1. Ship B1 is designed according to Pre-UR rule and built in 1987 and Ship B4 according to CSR-B having larger cross section and scantling sizes. Ship T2 is designed according to CSR-T.

Ship	B1	B4	T2
L (mm)	217,000	219,000	234,000
B (mm)	32,236	32,240	44,000
D (mm)	18,300	19,900	21,200
Design criteria	Pre-IACS UR	IACS CSR-B	IACS CSR-T

Table 1 Subject ships

The damage of the upper part of side shell due to collision is assumed. The vertical damage extent is taken as 10%, 20%, 40% and 70% of the depth D for both bulk carrier and tanker. The horizontal damage extent is taken as $B/16$, and it is kept constant for all damaged cases. The damaged cross sections of Ship B1 are illustrated in Fig. 2 and those of Ship T2 in Fig. 3. The stiffness of the elements in the damaged area is completely removed. For the double hull tanker, only outer side shell is assumed to be damaged. The locations of the critical deck element are presented in Fig. 4 for single hull bulk carrier and double hull oil tanker, respectively.

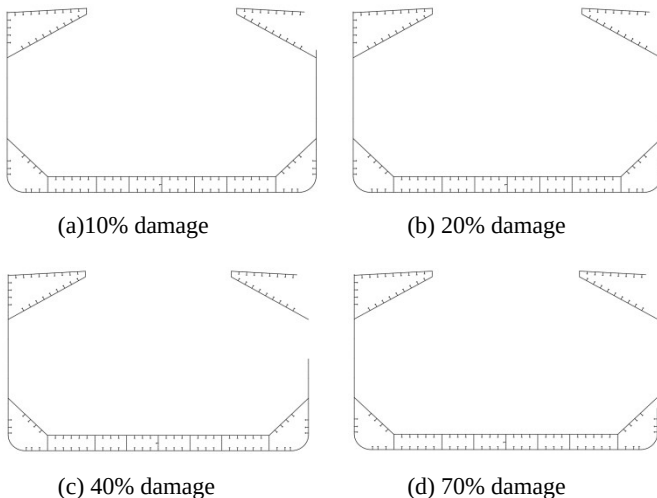


Fig. 2 Single hull bulk carrier (Ship B1)

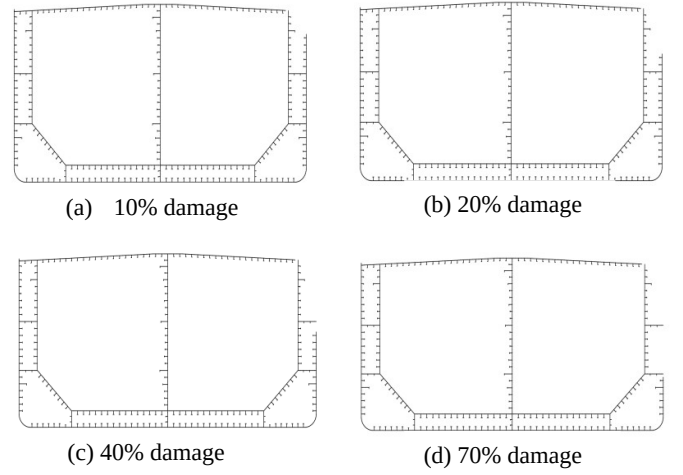
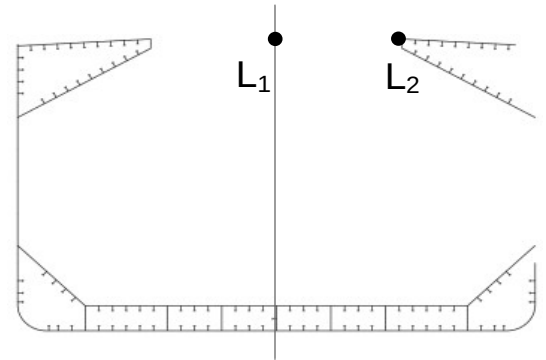
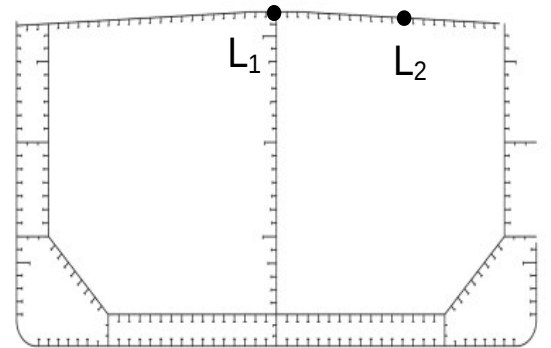


Fig. 3 Double hull oil tanker (Ship T2)



(a) Single hull bulk carrier



(b) Double hull oil tanker

Fig. 4 Locations of the critical deck elements

RESULT AND DISCUSSION

The results obtained by progressive collapse analysis under sagging condition for 20% and 70% damage are presented in Fig. 5 and Fig. 6, respectively. Case1 considers the rotation of neutral axis and Case 2 does not. The mome-curvature relationship is given as follow,

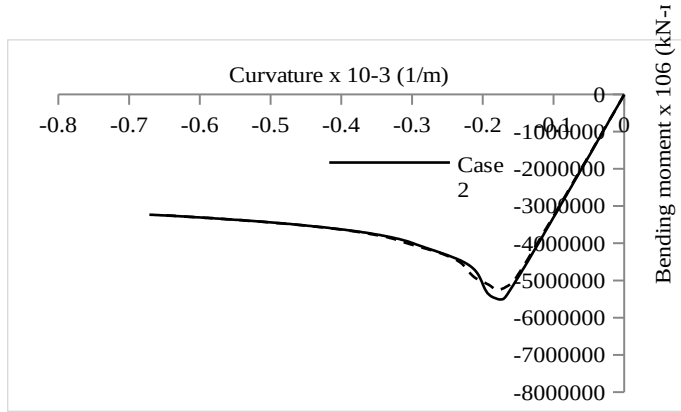


Fig. 5 Single hull bulk carrier (Ship B1) with 20% damage

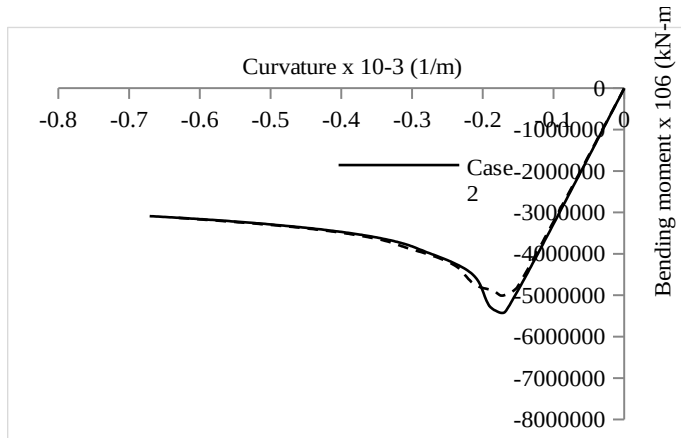


Fig. 6 Single hull bulk carrier (Ship B1) with 70% damage

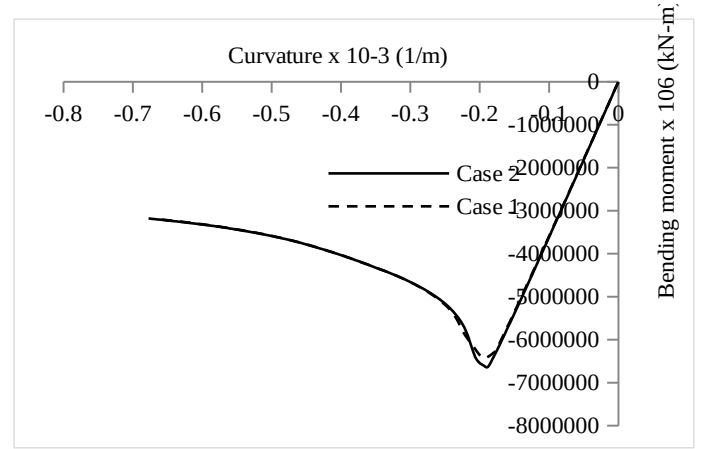


Fig. 7 Single hull bulk carrier (Ship B2) with 20% damage

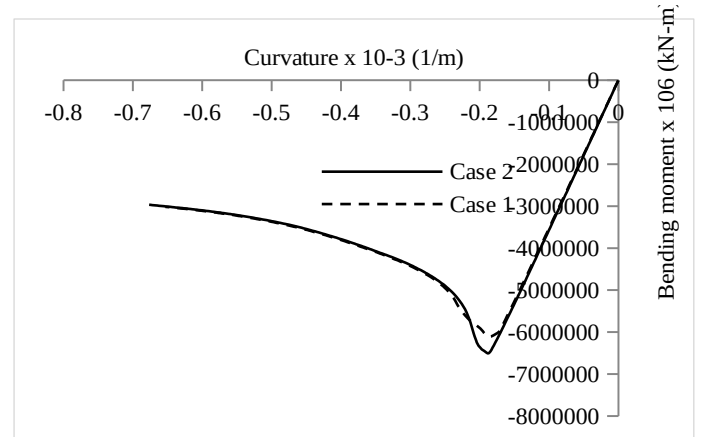


Fig. 8 Single hull bulk carrier (Ship B2) with 70% damage

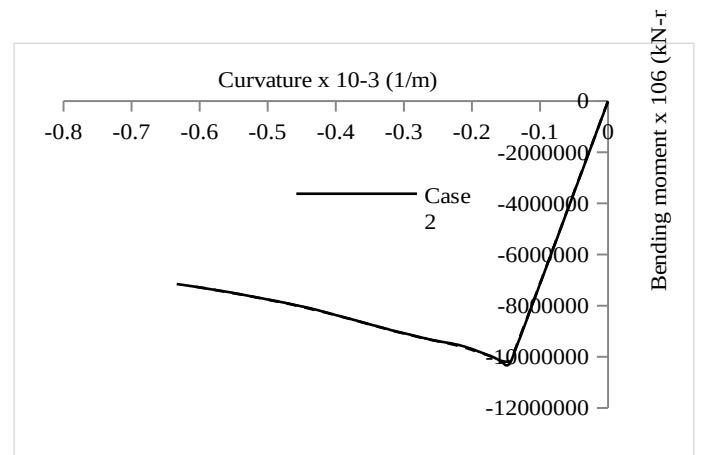


Fig. 9 Double hull oil tanker (Ship T2) with 20% damage

Fig. 7 and Fig. 8 shows the results of the mome-curvature relationship obtained by progressive collapse analysis for single hull bulk carrier (B2). It is found that Case 2 generally gives larger ultimate strength than Case 1 because the horizontal curvature is constrained. The effect is largest in Ship B1, smaller in Ship B4, and

almost negligible in Ship T2. For Ship B1, Case 1 strength is 7.3% smaller than Case 2 in sagging condition. The difference between Ship B1 and Ship B4 may be related to that of the depth to breadth ratio, member scantlings etc. Fig. 9 and Fig. 10 represent the moment-curvature relationship under sagging condition for double hull oil tanker (T2) for 20% and 70% of damaged, respectively. According to the result obtained by progressive collapse analysis of double hull oil tanker (Ship T2), the effect of rotation of neural axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

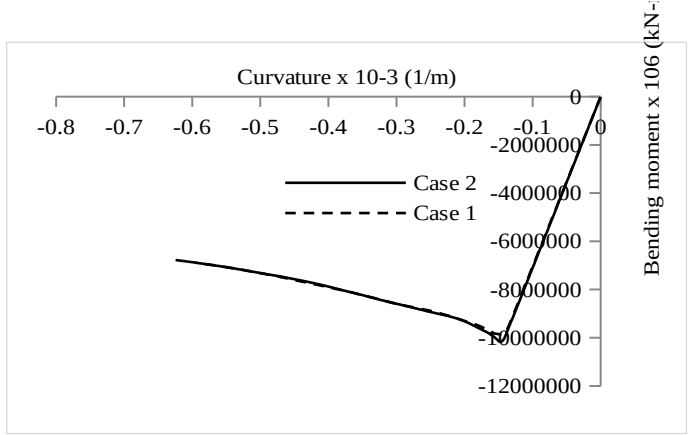


Fig. 10 Double hull oil tanker (T2) with 70% damage

The investigation of the residual hull girder strength under sagging condition is performed by taking two locations of the critical deck elements as shown in Fig. 4.

hatch coaming on the damage side. For the case of double hull oil tanker (T2), L_1 is located at the center line and L_2 at the distance of $B/4$ from the damage side shell.

The residual strengths of Ship B1, Ship B2 and Ship T2 obtained for the four different damage extents are summarized in Fig. 11. It is found that Eq. (11) gives an estimate of the residual strength which is in good agreement with the result of the progressive collapse analysis. For bulk carriers, the critical element at the location L_2 gives a better estimate of the residual strength. This is consistent with the observed collapse behavior in which the ultimate strength is attained when topside tank region of the damage side almost fully failed. The location L_1 cannot well take account of the effect of the horizontal curvature induce by M_V , resulting in the slight overestimate of the strength. In the case of tankers, the location L_1 gives better estimate of the residual strength than L_2 . This is also consistent with the failure behavior of T2 in which the ultimate strength is attained when the deck part almost fully failed.

Fig. 12 shows the comparison the reduction rates of the residual strength due to rotation of the neutral axis obtained by Eq. (13) and progressive collapse analysis. The influence of the rotation of the neutral axis is larger for a larger damage extent in general. For the case of the subject ships and damages under consideration, the influence is larger in bulk carriers than in tankers. Eq. (13) gives a relatively good estimate of the reduction rate. It can be a good basis of a rational expression of the influence of the rotation of the neutral axis on the reserved hull girder strength, as required in ship structural. More systematic analyses are definitely needed to develop the formula having larger applicability in ship types and damaged cases.

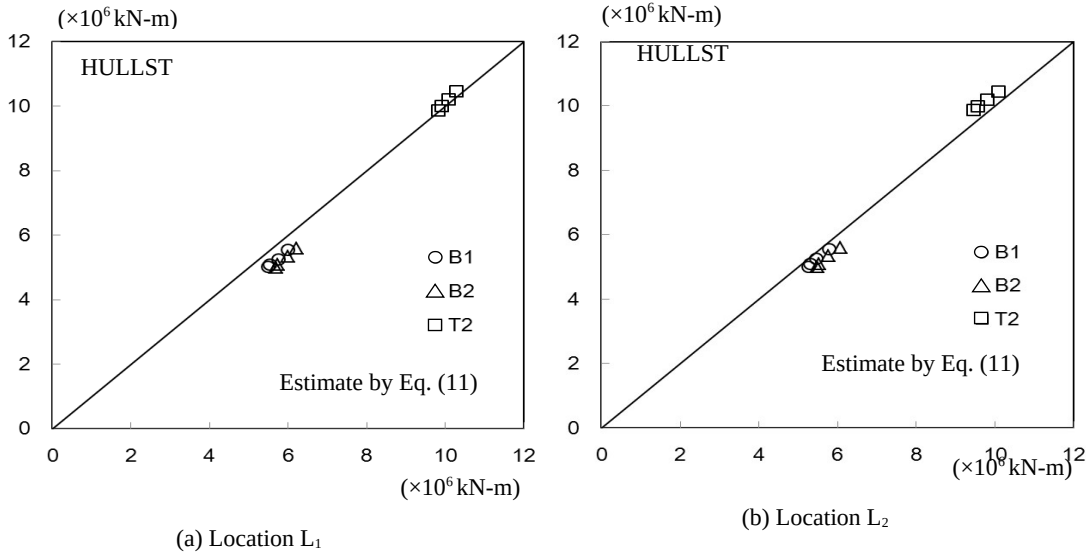


Fig. 11 Comparison of residual hull girder strength M_V between the simplified method and the progressive collapse analysis

Single hull bulk carrier (B1 and B2), the locations of the critical element are L_1 and L_2 , L_1 is located at the center line and L_2 at the

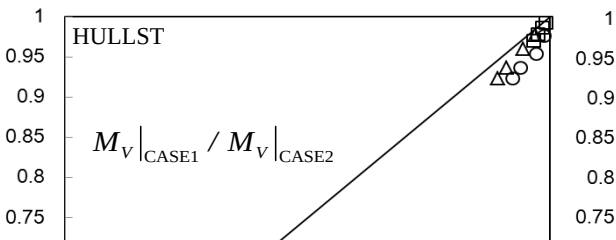


Fig. 12 Comparison of reduction ratio of residual hull girder due to rotation of neutral axis between the simplified method and the progressive collapse analysis (Case 1/Case 2)

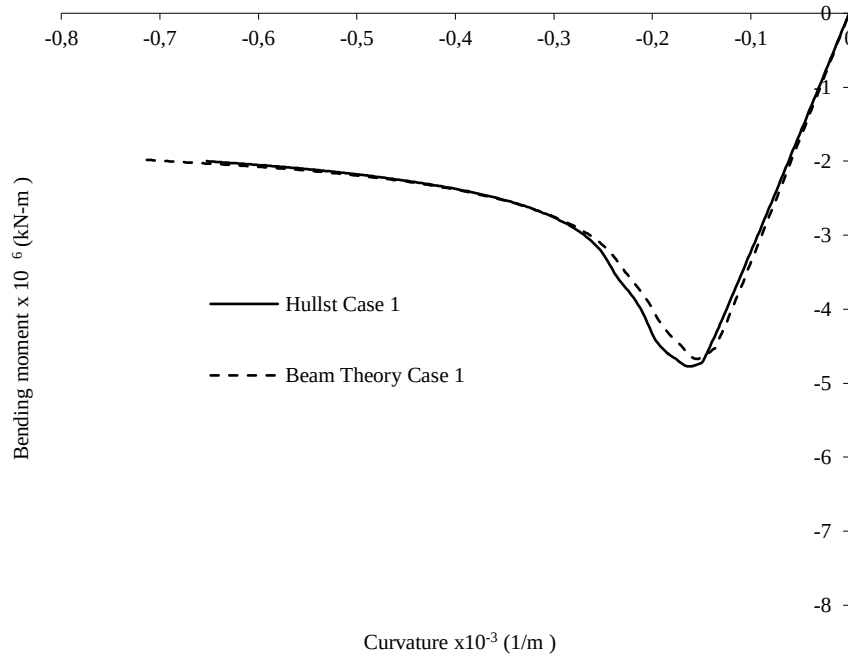
CONCLUSIONS

The ultimate hull girder strength analysis of single hull bulk carriers and a double hull oil tanker with asymmetrically damaged has been performed using the simplified approach under sagging condition by performing the elastic cross-sectional properties and critical member elements. A closed form formulae of residual strength and that of the reduction ratio of the residual strength due to the rotation of neutral axis are proposed. It is found through a comparison with the results obtained by the progressive collapse analysis that the residual hull girder strength of asymmetrically damaged ships under sagging bending moment can be predicted by the proposed formulae with a reasonable accuracy.

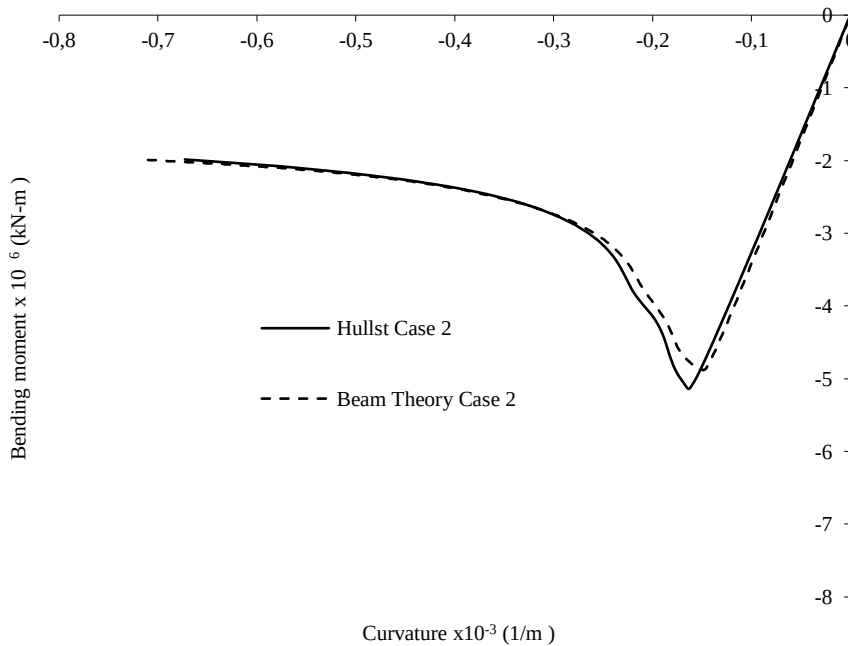
The ultimate strength obtained by Case 2 generally gives larger ultimate strength than Case 1 because the horizontal curvature is constrained. The effect is largest in Ship B1, smaller in Ship B4, and almost negligible in Ship T2. The difference between Ship B1 and Ship B4 may be related to that of the depth to breadth ratio, member scantlings etc. According to the result obtained by progressive collapse analysis of double hull oil tanker (Ship T2), the effect of rotation of neural axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

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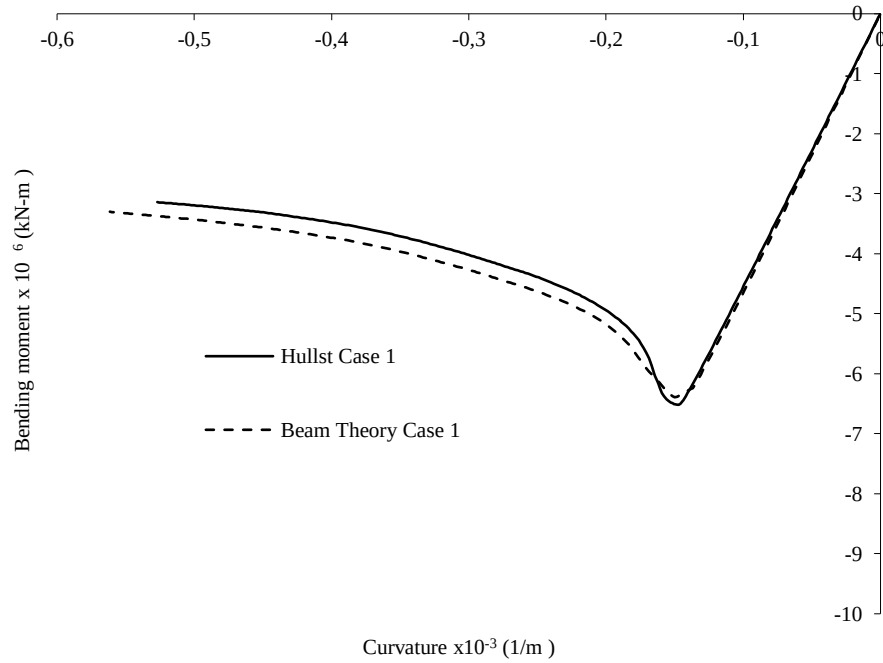
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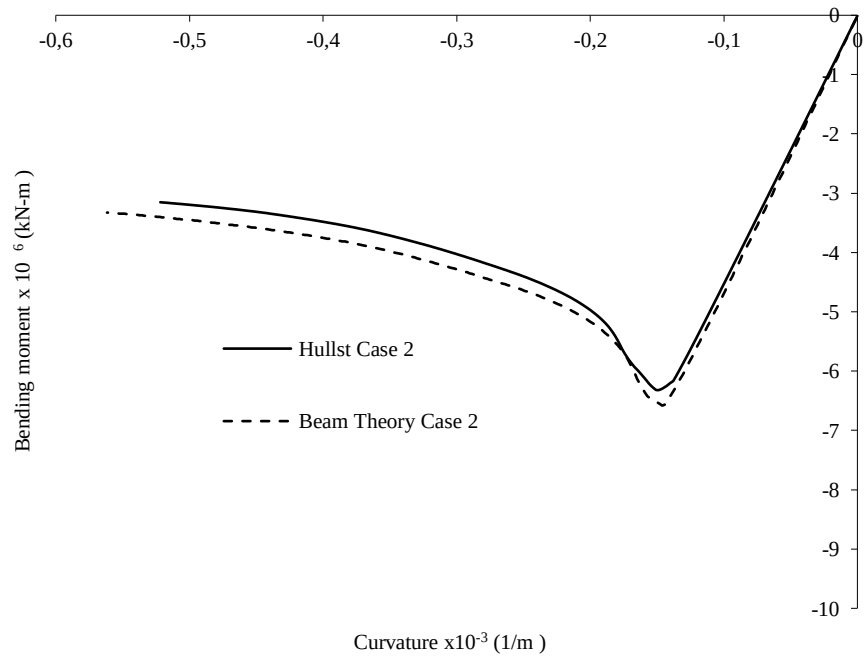
Validation of **HULLST** with **Beam Theory** for the ultimate strength in Sagging condition of single hull bulk carrier (Ship B1) with 20% damage for Case 1.



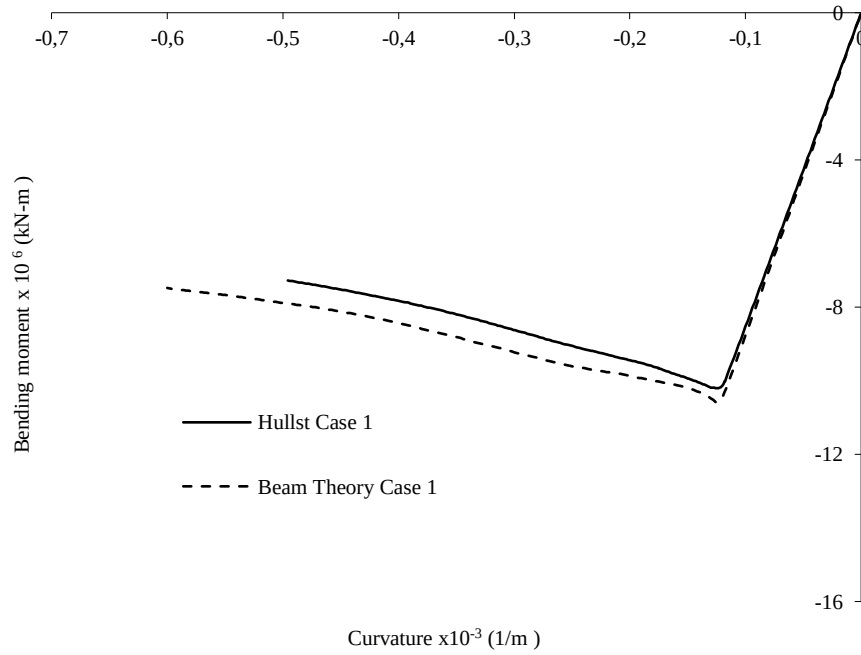
Validation of **HULLST** with **Beam Theory** for the ultimate strength in Sagging condition of single hull bulk carrier (Ship B1) with 20% damage for Case 2.



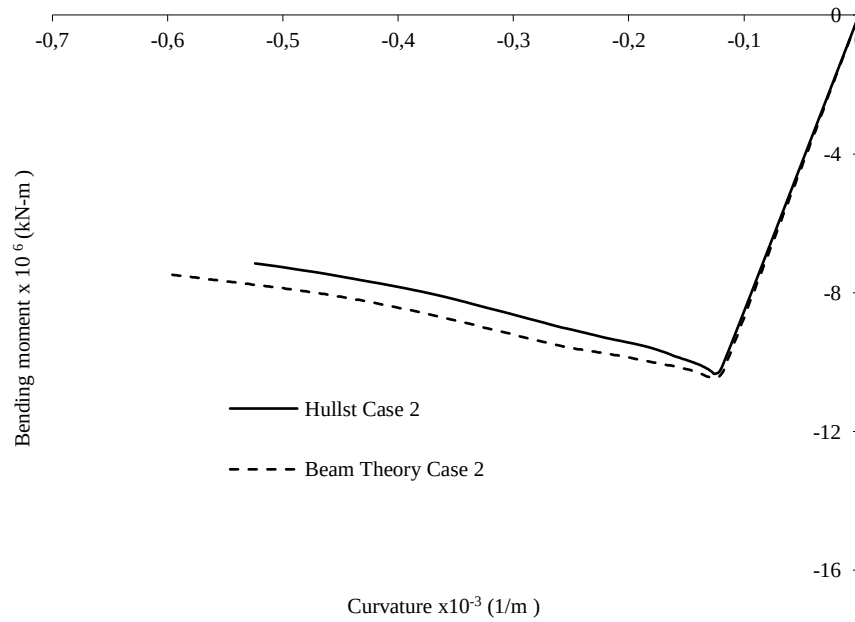
Validation of **HULLST** with **Beam Theory** for the ultimate strength in Sagging condition of single hull bulk carrier (Ship B2) with 20% damage for Case 1.



Validation of **HULLST** with **Beam Theory** for the ultimate strength in Sagging condition of single hull bulk carrier (Ship B2) with 20% damage for Case 2.



Validation of **HULLST** with **Beam Theory** for the ultimate strength in Sagging condition of double hull oil tanker (Ship T2) with 20% damage for Case 1.



Validation of **HULLST** with **Beam Theory** for the ultimate strength in Sagging condition of double hull oil tanker (Ship T2) with 20% damage for Case 2.

Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships

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Gowa, South Sulawesi, Indonesia

ABSTRACT

The objective of the present study is to investigate the ultimate hull girder strength of an asymmetrically damaged ship under a sagging condition. Two kinds of ships are taken as the object of analysis. The cross section of the ship is considered and assumed to have remained plane. The simply supported boundary condition is applied to both sides of the cross section. The ultimate hull girder strength is attained when a plate and/or stiffened plate element at the specified location called “critical element” reach its ultimate strength. To investigate the ultimate hull girder strength, a simplified approach is proposed. The result obtained by the simplified approach is compared with the progressive collapse analysis to determine effectiveness and for validation.

KEY WORDS: Single hull bulk carrier, double hull oil tanker, cross section, neutral axis, asymmetrically damaged, ultimate strength, simplified approach.

INTRODUCTION

The ability to predict accurately the ultimate strength of ship hull girder when subjected to longitudinal bending is one of the most important aspects of ship structural design. Collision and grounding damage may take place on ship's hull, which may threaten safety of ships and surrounding environment. In this regard, to enhance the safety of ship's structure and minimize the risks, the International Maritime Organization (IMO, 2009) has required in Goal Based Standard for New Ship Construction (GBS) to consider the residual strength of the hull girder in specified damage conditions as one of the functional requirements for the structural rules for bulk carriers and tankers.

Many studies have been conducted on the analyses of the residual hull girder strength as a result of collision and grounding damages. Pedersen (1994) presented a mathematical model to estimate the contact pressure between the grounded ship and the sea bottom. The grounding contact force was compared with the force that would crush the forward bottom of the ship. The sectional bending moment due to grounding was determined and compared with the ultimate hull girder strengths. The model experiments and full-scale controlled grounding experiments were also performed to validate the mathematical model. Paik et al. (1998) developed a rapid procedure to identify the possibility of hull girder failure after collision and grounding damages based on the closed-form formulae of the ultimate hull girder strength and section modulus after the damages. Guedes Soares et al. (2008) evaluated the ability of simplified structural analysis methods based on Smith's formulation to predict the ultimate strength of damaged ship's hull. Muis Alie, M.Z et al. (2016) investigated the influence of the superstructure on the ultimate strength of Ro-Ro ship under a vertical bending moment. The cross section was considered to be analyzed. The results obtained by beam theory with and without superstructure were compared with one another. The assessment of the ultimate hull girder strength was conducted by Muis Alie, M.Z et al.

(2017). The cross section of Ro-Ro ship was taken to be analyzed. The collision and grounding damages were assumed to be located on the side and bottom areas, respectively. The damages were created by removing the element from the side shell and bottom part. Ohtsubo et al. (1994) showed the experimental and numerical works on the ship structural damages due to collision and grounding. This was one of the first attempts to apply the explicit finite element method codes, such as LS-DYNA and MSC Dytran, to the collision and grounding problems of ships. Ozguc et al. (2005) investigated the collision resistance and residual strength of single skin and double skin bulk carriers subjected to damages. Notaro et al. (2010) carried out full nonlinear finite element assessments of hull girder capacity in intact and damage conditions. The effects of several influential factors such as model extend and complexity, damage representations and model imperfections were investigated on the different vessels. It was found that the effect of damage extent in a vertical direction is more critical than in a longitudinal direction, and the damage varies according to the location of the neutral axes including higher stresses in proximity of the damage areas. The various probability levels were considered for the damage extent estimation.

When a hull-girder cross section is symmetric with respect to the centerline and subjected to pure vertical bending moment, the neutral axis for vertical bending is always horizontal and moves only vertically during the progressive collapse behavior. However, when the cross section is asymmetrically damaged, for example, because of a collision, the neutral axis rotates. Both rotation and translation need to be taken into account during the progressive collapse behavior even when only a vertical bending moment is applied, and the problem needs to be treated as a biaxial bending problem. Previous studies using the Smith's method on the ultimate strength of hull girders under biaxial thrust (Ozguc and Barltrop, 2008) and the residual strength of damaged hulls (Fang and Das, 2004; Hussein and Guedes Soares, 2009; Choung et al, 2011) consider the rotation and translation of neutral axis in a reasonable way. However, they employ a trial and error approach to detect the position of neutral axis. More easy approach to detect the position of neutral axis is suggested.

BASIC ASSUMPTION

1 The following assumption is made for the prediction of the residual hull girder strength under the sagging condition:

- (1) The ultimate sagging strength is attained when a stiffened panel element at the specified location (hereafter called ‘critical element’) reached the ultimate strength.
- (2) The hull girder cross section is elastic until the failure of the critical member.
- (3) The ultimate strength of the critical member is predicted from the average axial stress and average axial strain relationship calculated by HULLST (Yao and Nikolov, 1992).

EFFECT OF NEUTRAL AXIS ROTATION ON THE ESTIMATION OF THE ULTIMATE HULL GIRDER STRENGTH

In the elastic cross section, the bending stress at the i -th element (see Fig.1), σ_i , is expressed as

$$\sigma_i = E \left[(y_i - y_G) \phi_H + (z_i - z_G) \phi_V \right] \quad (1)$$

where E is Young’s modulus, y_G and z_G the centroid coordinates, and ϕ_H and ϕ_V the horizontal and vertical curvatures, respectively. y_G and z_G are given by

$$y_G = \frac{\left(\sum_{i=1}^N y_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (2)$$

$$z_G = \frac{\left(\sum_{i=1}^N z_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (3)$$

where D_i , A_i , and (y_i, z_i) are the tangential stiffness obtained as a slope of the average stress-average strain curve, cross sectional area and the coordinates of the centroid of individual elements, respectively.

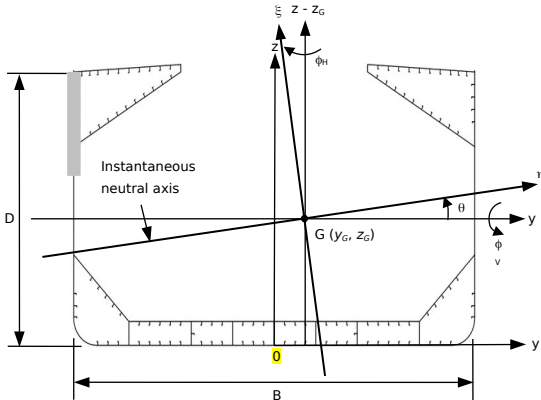


Fig. 1 Neutral axes of the elastic hull girder cross section with asymmetric damage

For the case of an asymmetrically damaged cross section, Eqs (4) through (8) are used, and for the intact one, the expressions are given in Eqs (9) and (10). The biaxial moment and curvature relationship is given in the form

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (4)$$

where

$$\begin{aligned} I_{HV} &= I_{VH} = \sum_{i=1}^N (y_i - y_G)(z_i - z_G) A_i \\ I_{HH} &= \sum_{i=1}^N (y_i - y_G)^2 A_i \\ I_{VV} &= \sum_{i=1}^N (z_i - z_G)^2 A_i \end{aligned} \quad (5)$$

where I and M are the moment of inertia and bending moment, respectively. When the vertical bending moment M_V is applied to the cross section with no constraint on the horizontal curvature (Case 1), the horizontal curvature as well as the vertical curvature is induced under the condition of horizontal bending moment $M_H = 0$. The incremental equation to be solved is

$$\begin{Bmatrix} 0 \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (6)$$

Therefore,

$$\begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} = \frac{1}{E(I_{HH} I_{VV} - I_{HV}^2)} \begin{Bmatrix} -I_{HV} M_V \\ I_{HH} M_V \end{Bmatrix} \quad (7)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{-(y_i - y_G) I_{HV} + (z_i - z_G) I_{HH}}{(I_{HH} I_{VV} - I_{HV}^2)} M_V \quad (8)$$

The terms including the moment of inertia, I_{HV} , represent the effect of the rotation of the neutral axis.

On the other hand, when the vertical bending moment is applied to the cross section with the horizontal curvature constrained (Case 2), the bending moment is induced under the condition of $\phi_H = 0$, that is,

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} 0 \\ \phi_V \end{Bmatrix} \quad (9)$$

Therefore,

$$\phi_V = \frac{M_V}{EI_{VV}} \quad (10)$$

Substituting Eq. (10) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{(z_i - z_G)}{I_{VV}} M_V \quad (11)$$

Here, it is assumed that the residual hull girder strength in the sagging condition M_V^u is attained when a critical member at the location of (y_C, z_C) reached its ultimate strength, σ_C^u , namely for Case 1

$$M_V^u|_{CASE\ 1} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \sigma_C^u \quad (12)$$

And for Case 2

$$M_V^u|_{CASE\ 2} = \frac{I_{VV}}{(z_C - z_G)} \sigma_C^u \quad (13)$$

Therefore, the reduction rate of the residual strength due to the rotation of the neutral axis in the framework of the proposed approximate approach is given by ratio of Eq. (12) to Eq. (13) as

$$\frac{M_V^u|_{CASE\ 1}}{M_V^u|_{CASE\ 2}} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \frac{(z_C - z_G)}{I_{VV}} \quad (14)$$

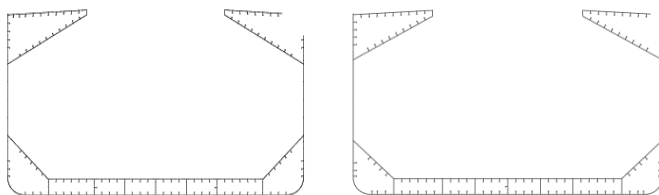
CASE STUDY

Two single-hull bulk carriers, B1 and B2, and one double-hull oil tanker, T2, are taken as the subject ships as shown in Table 1. Ship B1 is designed according to Pre-UR rule and built in 1987 and Ship B2 according to CSR-B having larger cross section and scantling sizes. Ship T2 is designed according to CSR-T.

Table 1 Subject ships

Ship	B1	B2	T2
L (mm)	217,000	219,000	234,000
B (mm)	32,236	32,240	44,000
D (mm)	18,300	19,900	21,200
Design criteria	Pre-IACS UR	IACS CSR-B	IACS CSR-T

The damage of the upper part of side shell due to collision is assumed. The vertical damage extent is taken as 10%, 20%, 40% and 70% of the depth D for both bulk carriers and tanker. The horizontal damage extent is taken as $B/16$, and it is kept constant for all damaged cases. The damaged cross sections of Ship B1 are illustrated in Fig. 2 and those of Ship T2 in Fig. 3. The stiffness of the elements in the damaged area is completely removed. For the double-hull tanker, only outer side shell is assumed to be damaged. The locations of the critical deck element are presented in Fig. 4 for single-hull bulk carrier and double-hull oil tanker, respectively.



(a) 10% damage

(b) 20% damage

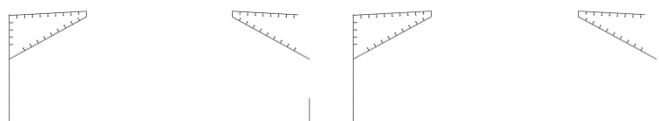
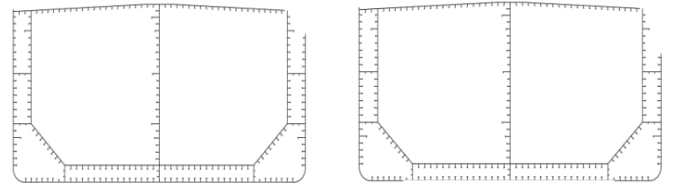
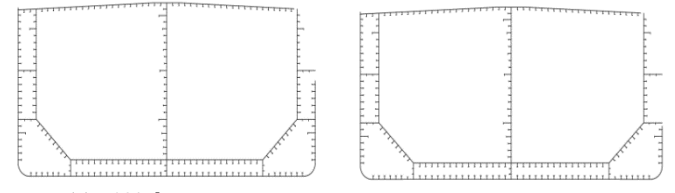


Fig. 2 Single hull bulk carrier (Ship B1)



(a) 10% damage

(b) 20% damage

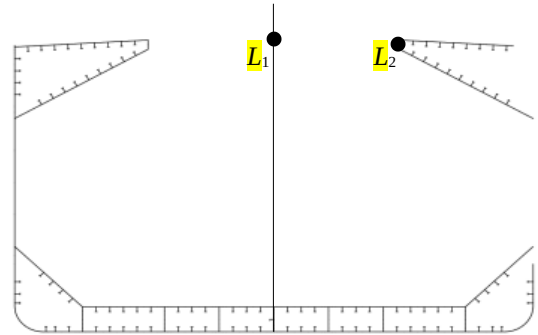


(c) 40% damage

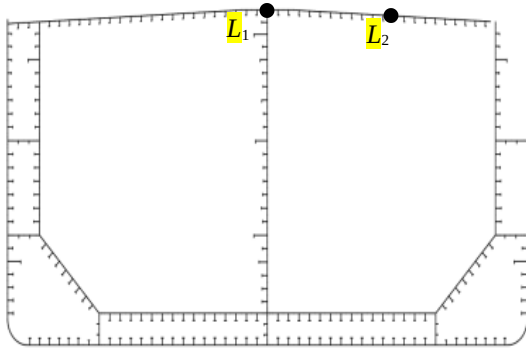
(d) 70% damage

Fig. 3 Double hull oil tanker (Ship T2)

The investigation of the residual hull girder strength under sagging condition is performed by taking two locations of the critical deck elements as shown in Fig. 4. For Single-hull bulk carriers (B1 and B2), the locations of the critical element are L_1 and L_2 . L_1 is located at the center line and L_2 at the hatch coaming on the damage side. For the case of double-hull oil tanker (T2), L_1 is located at the center line and L_2 at the distance of $B/4$ from the damaged side shell. As for the critical stress, the maximum stress of elements located at points L_1 and/or L is used.



(a) Single-hull bulk carrier



(b) Double-hull oil tanker

Fig. 4 Locations of the critical deck elements

RESULT AND DISCUSSION

In sagging condition, it is well recognized that the ultimate hull girder strength is almost attained when the primary deck members in longitudinal compression reached their ultimate strength. Also, because the damage takes place at the asymmetric position, in other word, collision damage is placed at the side shell through to the deck part (B/16) and there is no damage located at the bottom part, so that it is very important to investigate the critical member under sagging condition. In the present study, the ultimate strength is analyzed after damage has taken place. The water ingress is not considered in the analysis.

The results obtained by progressive collapse analysis under sagging condition for 20% and 70% damage are presented in Fig. 5 and Fig. 6, respectively. Case 1 considers the rotation of neutral axis and Case 2 does not. The resultant of bending moment versus curvature is plotted.

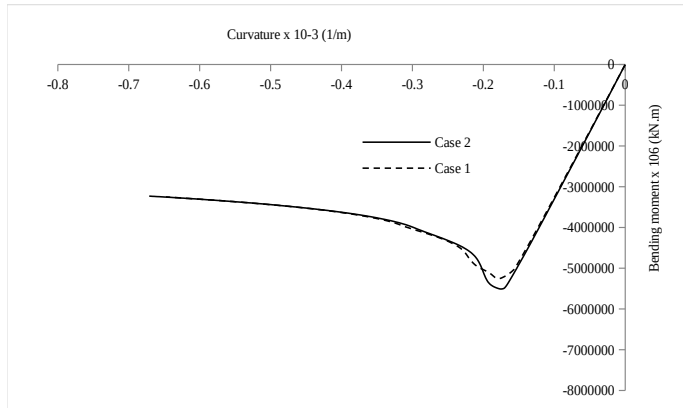


Fig. 5 Single-hull bulk carrier (Ship B1) with 20% damage

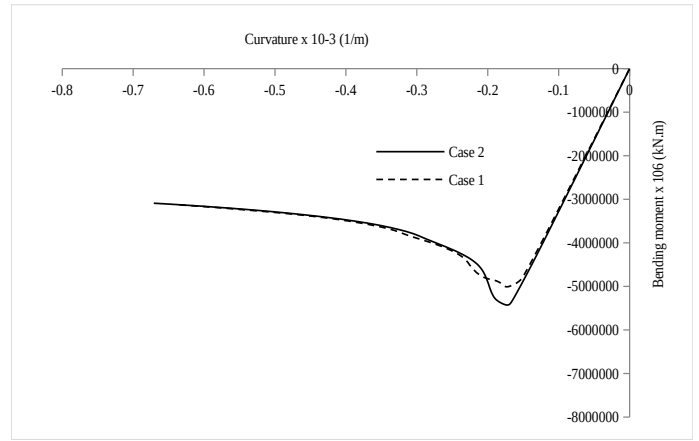


Fig. 6 Single-hull bulk carrier (Ship B1) with 70% damage

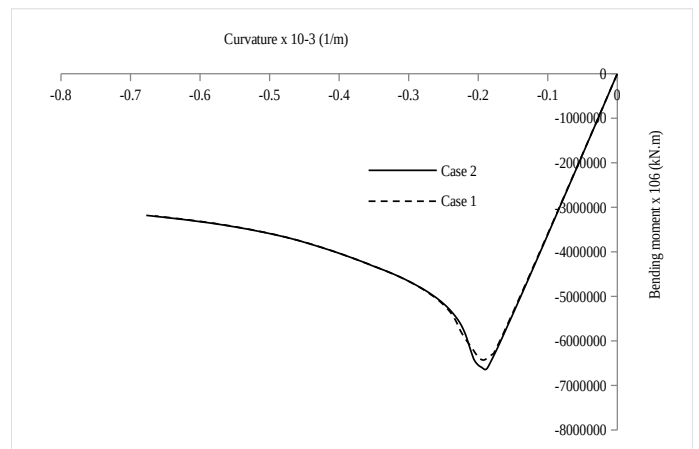


Fig. 7 Single-hull bulk carrier (Ship B2) with 20% damage

Similarly, the resultant bending moment and curvature curve for Ship B2 and Ship T2 with 20% and 70% damage are presented in Figs. 7 through 10.

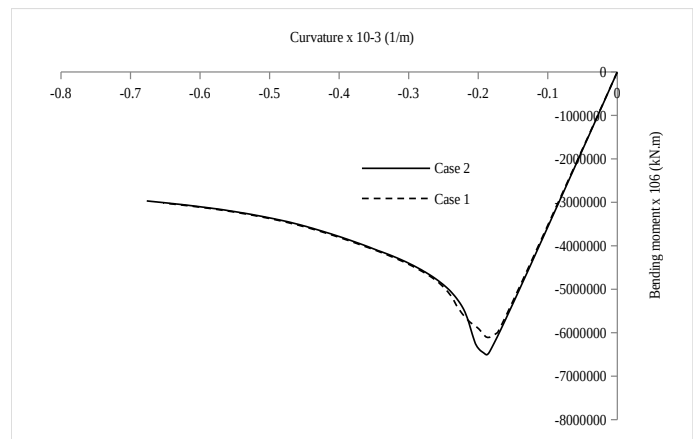


Fig. 8 Single-hull bulk carrier (Ship B2) with 70% damage

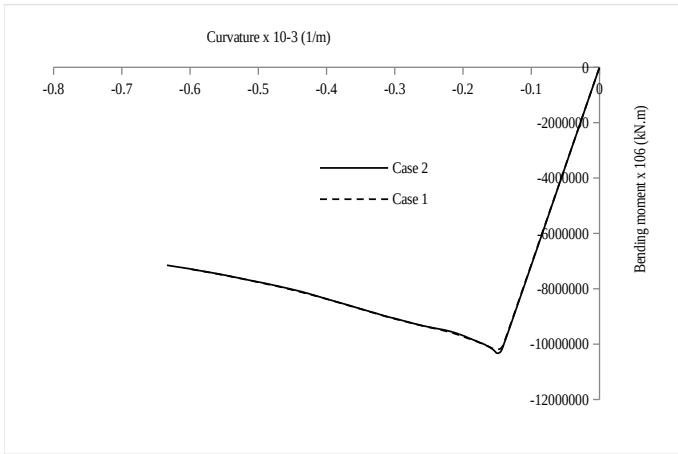


Fig. 9 Double-hull oil tanker (Ship T2) with 20% damage

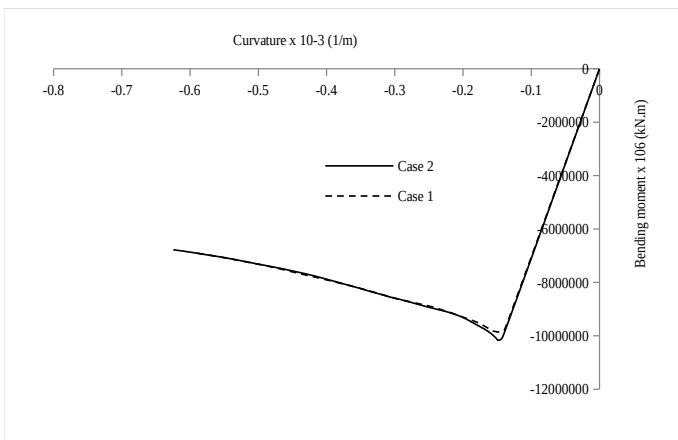
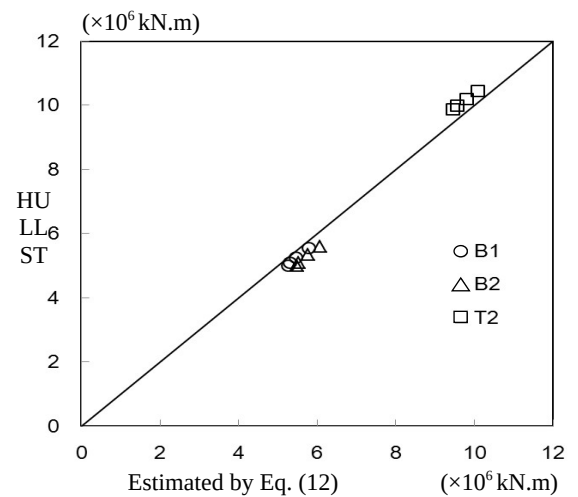
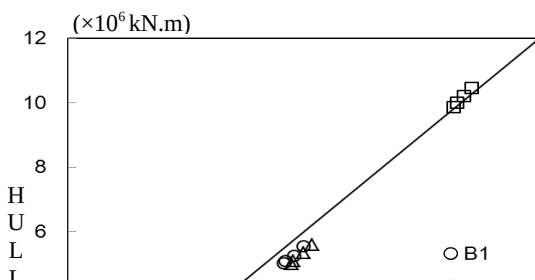


Fig. 10 Double-hull oil tanker (T2) with 70% damage

Figures 7 and 8 show the results of the moment-curvature relationship obtained by progressive collapse analysis for single-hull bulk carrier (B2). It is found that Case 2 generally gives higher ultimate strength than Case 1 because the horizontal curvature is constrained. The ultimate hull girder strength is attained even the horizontal curvature is constrained because of the horizontal bending moment is induced by the incremental equation for horizontal and vertical bending moments and this makes the ultimate hull girder strength becomes higher. The effect of constraint is the largest in Ship B1, and is smaller in Ship B2. For Ship B1, Case 1's strength is 7.3% smaller than Case 2's in the sagging condition. The difference between Ship B1 and Ship B2 may be attributed to that of the depth-to-breadth ratio, member scantlings etc. Figures 9 and 10 represent the moment-curvature relationship under the sagging condition for a double-hull oil tanker (T2) for 20% and 70% of damages, respectively. According to the result obtained by progressive collapse analysis of a double-hull oil tanker (Ship T2), the effect of rotation of the neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.



(b) Location L_2

Fig. 11 Comparison of residual hull girder strength M_v between HU, LL6, and ST. The residual strengths of Ships B1, B2 and T2 obtained for the four different damage extents are summarized in Figures 11 and 12 (a) and (b). It is found that Eq. 11 gives an estimate of the residual strength that is in good agreement with the result of the progressive collapse analysis. For bulk carriers, the critical element at the location L_2 gives a better estimate of the residual strength. For the location L_1 bulk carriers, the ultimate strength of critical element is evaluated by using that of the element at L_2 . This is consistent with the observed collapse behavior in which the ultimate strength was attained when topside tank region of the damaged side almost fully failed. In the case of a double-hull tanker, location L_1 gives a better estimate of the residual strength than L_2 . This is also consistent with the failure behavior of T2 in which the ultimate strength was attained when the deck part almost fully failed.

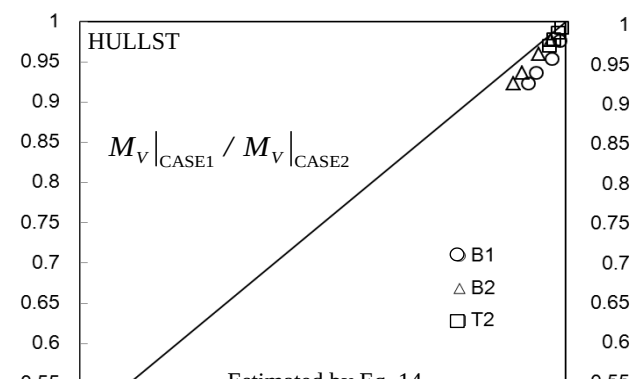


Fig. 12 Comparison of reduction ratio of residual hull girder due to rotation of neutral axis between the simplified method and the progressive collapse analysis (Case 1/Case 2)

CONCLUSIONS

Progressive collapse analysis was performed on two single-hull bulk carriers and a double-hull oil tanker with asymmetrically damaged cross section. Closed-form formulae of residual strength and that of the reduction ratio of the residual strength considering the rotation of neutral axis are proposed. It is found through a comparison with the results obtained by the progressive collapse analysis that the residual hull girder strength of asymmetrically damaged ships under the sagging bending moment can be predicted by the proposed formulae with reasonable accuracy. The ultimate strength obtained with the horizontal curvature constrained is larger than that without constraint. The effect of the rotation of the neutral axis is the largest for single-hull bulk carrier and almost negligible for the double-hull oil tanker. The difference characteristic for two single-hull bulk carriers may be related to that of the depth-to-breadth ratio, member scantlings etc.

The resultant of bending moment is induced by the accumulation of the horizontal and vertical bending moments based on the reference coordinate system. Figure 12 shows the comparison of the reduction rates of the residual strength due to rotation of the neutral axis obtained by Eq. 14 and progressive collapse analysis. The influence of the rotation of the neutral axis is larger for a larger damage extent in general. For the case of the subject ships and damages under consideration, the influence is larger in bulk carriers than in tankers. Equation 14 gives a relatively good estimate of the reduction rate. It can be a good basis of a rational expression of the influence of the rotation of the neutral axis on the reserve ultimate hull girder strength, as required in ship structures. More systematic analyses are definitely needed to develop the formula having a larger applicability in ship types and damaged cases.

According to the result obtained by progressive collapse analysis of double-hull oil tanker, the effect of rotation of **neutral** axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

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Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships

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ABSTRACT

The objective of the present study is to investigate the ultimate hull girder strength of asymmetrically damaged ship under sagging condition. Two kinds of ship are taken as the object of the analysis. The cross section of the ship is considered and assumed to be remained plane. The simply supported of boundary condition is applied to both sides of the cross section. The ultimate hull girder strength is attained when a plate and/or stiffened plate element at the specified location called “critical element” reach their ultimate strength. To investigate the ultimate hull girder strength, a simplified approach is proposed. The result obtained by simplified approach is compared to the progressive collapse analysis for the effectiveness and validation.

KEY WORDS: Single hull bulk carrier, double hull oil tanker, cross section, neutral axis, asymmetrically damaged, ultimate strength, simplified approach.

INTRODUCTION

The ability to predict accurately the ultimate strength of ship hull girder when subjected to longitudinal bending is one of the most important aspects of ship structural design. A collision and grounding damages may takes place on ship's hull, which may threaten safety ship and surrounding environment. In this regard, to enhance the safety of ship's structure and minimize the risks, the International Maritime Organization (IMO, 2009) has required in Goal Based Standard for New Ship Construction (GBS) to consider the residual strength of the hull girder in specified damage conditions as one of the functional requirements for the structural rules for bulk carriers and tankers.

Many studies have been conducted on the analyses of the residual hull girder strength due to collision and grounding damaged. Pedersen (1994) presented a mathematical modeling to estimate the contact pressure between the grounded ship and the sea bottom. The grounded contact force was compared to the force which would crush the forward bottom of the ship. The sectional bending moment due to grounding was determined and compared to the ultimate hull girder strengths. The model experiments and full-scale controlled grounding experiments were also performed to validate the mathematical model. Paik et al. (1998) developed a rapid procedure to identify the possibility of hull girder failure after collision and grounding damages based on the closed-form formulae of the ultimate hull girder strength and section modulus after the damages. Soares et al. (2008) evaluated the ability of simplified structural analysis methods based on the Smith's formulation to predict the ultimate strength of damage ship's hull. Toh et al. (2012) developed simplified calculation program to calculate the ultimate strength in intact and damage condition and the reduction of hull girder ultimate strength is investigated. The calculation result of simplified method is compared to the FE result for both intact and damage condition. Muis Alie, M.Z et al. (2012) investigated the incidence of neutral axis rotation on residual hull

girder strength for asymmetrical damaged ships under longitudinal bending, applying the progressive collapse method and finding an explicit expression of neutral axis rotation. After performing a series of progressive collapse analyses on several bulk carriers and tanker, it was found that residual hull girder strength, considering the instantaneous neutral axis is generally lower than the relevant one, obtained by constraining the rotation, as it is commonly assumed in classical procedures. Ohtsubo et al. (1994) showed the experimental and numerical work on the ship structural damages due to collision and grounding. This was one of the first attempts to apply the explicit Finite Element Method codes, such as LS-DYNA and DYTRAN, to the collision and grounding problems of ships. Ozguc et al. (2005) investigated the collision resistance and residual strength of single skin and double skin bulk carriers subjected to damages. Lee et al. (2008) calculate the ultimate strength with collision damage using LS-DYNA and compared with the experiment results. It is found that the ultimate strength is reduced as a damage size increased as expected. Notaro et al. (2010) carried out full nonlinear FE assessments of hull girder capacity in intact and damage conditions. The effects of several influences factors such as model extend and complexity, damage representations and model imperfections are investigated on the different vessels. It was found that the effect of damage extent in vertical direction is more critical than in longitudinal direction, and the damage varies the location of the neutral axes including higher stresses in proximity of the damage areas. The various probability levels are considered for the damage extent estimation.

When a hull-girder cross section is symmetric with respect to the centerline and subjected to pure vertical bending moment, the neutral axis for vertical bending is always horizontal and moves only vertically during the progressive collapse behavior. However, when the cross section is asymmetrically damaged due, for example, to a collision, the neutral axis rotates. Both rotation and translation need to be taken into account during the progressive collapse behavior even when only a vertical bending moment is applied, and the problem needs to be treated as a biaxial bending problem. Previous studies using the Smith's method on the ultimate strength of hull girders under biaxial thrust (Ozguc and Barltrop, 2008) and the residual strength of damaged hulls (Fang and Das, 2004; Hussein and Guedes

Soares, 2009; Choung et al, 2011) consider the rotation and translation of neutral axis in a reasonable way. However, they employ a trial and error approach to detect the position of neutral axis. More easy approach to detect the position of neutral axis is demanded.

BASIC ASSUMPTION

1) The following assumption is made for the prediction of the residual hull girder strength under the sagging condition:

(1) The ultimate sagging strength is attained when a stiffened panel element at the specified location (hereafter called ‘critical element’) reached the ultimate strength.

(2) The hull girder cross section is elastic until the failure of the critical member.

(3) The ultimate strength of the critical member is predicted from the average axial stress and average axial strain relationship calculated by HULLST (Yao and Nikolov).

EFFECT OF NEUTRAL AXIS ROTATION ON ESTIMATION OF THE ULTIMATE HULL GIRDER STRENGTH

In the elastic cross section, the bending stress at the i -th element (see Fig.1), σ_i , is expressed as

$$\sigma_i = E \left[(y_i - y_G) \varphi_H + (z_i - z_G) \varphi_V \right] \quad (1)$$

where E is Young's modulus, y_G and z_G the centroid coordinates, and φ_H and φ_V the horizontal and vertical curvatures, respectively. y_G and z_G are given by

$$y_G = \frac{\left(\sum_{i=1}^N y_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (2)$$

$$z_G = \frac{\left(\sum_{i=1}^N z_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (3)$$

Where D_i , A_i , y_i and z_i are the tangential stiffeners obtained as a slope of the average stress-strain relationship, cross section and the coordinate position of the individual elements, respectively.

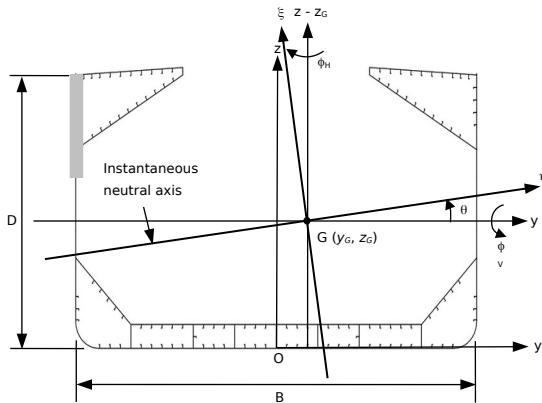


Fig. 1 Neutral axes of the elastic hull girder cross section with asymmetric damage

For the case of asymmetric damage cross section, the equations are used from Eqs. (4) to (8), and for the intact one, the expressions are given in Eqs. 9 and (10). The biaxial moment and curvature relationship is given in the form

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \varphi_H \\ \varphi_V \end{Bmatrix} \quad (4)$$

where

$$\begin{aligned} I_{HV} &= I_{VH} = \sum_{i=1}^N (y_i - y_G)(z_i - z_G) A_i \\ I_{HH} &= \sum_{i=1}^N (y_i - y_G)^2 A_i \\ I_{VV} &= \sum_{i=1}^N (z_i - z_G)^2 A_i \end{aligned} \quad (5)$$

Where I and M is the moment of inertia and bending moment, respectively. When the vertical bending moment M_V is applied to the cross section with no constraint on the horizontal curvature (Case 1), the horizontal curvature as well as the vertical curvature is induced under the condition of horizontal bending moment $M_H = 0$. The incremental equation to be solved is

$$\begin{Bmatrix} 0 \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \varphi_H \\ \varphi_V \end{Bmatrix} \quad (6)$$

Therefore,

$$\begin{Bmatrix} \varphi_H \\ \varphi_V \end{Bmatrix} = \frac{1}{E(I_{HH} I_{VV} - I_{HV}^2)} \begin{Bmatrix} -I_{HV} M_V \\ I_{HH} M_V \end{Bmatrix} \quad (7)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{-(y_i - y_G) I_{HV} + (z_i - z_G) I_{HH}}{(I_{HH} I_{VV} - I_{HV}^2)} M_V \quad (8)$$

The terms including the moment of inertia, I_{HV} , represent the effect of the rotation of the neutral axis.

On the other hand, when the vertical bending moment is applied to the cross section with the horizontal curvature constrained (Case 2), the bending moment are induced under the condition of $\varphi_H = 0$, that is,

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} 0 \\ \varphi_V \end{Bmatrix} \quad (9)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{(z_i - z_G)}{I_{VV}} M_V \quad (10)$$

Here, it is assumed that the residual hull girder strength in the sagging condition M_V^u is attained when a critical member at the location of $(y_C - z_C)$ reached its ultimate strength, σ_C^u , namely for Case 1

$$M_V^u|_{CASE\ 1} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \sigma_C^u \quad (11)$$

And for Case 2

$$M_V^u|_{CASE\ 2} = \frac{I_{VV}}{(z_C - z_G)} \sigma_C^u \quad (12)$$

Therefore, the reduction rate of the residual strength due to the rotation of the neutral axis in the framework of the proposed approximate approach is given by ratio of Eq. (11) to Eq. (12) as

$$\frac{M_V^u|_{CASE\ 1}}{M_V^u|_{CASE\ 2}} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \frac{(z_C - z_G)}{I_{VV}} \quad (13)$$

CASE STUDY

Two single-hull bulk carriers, B1 and B2, and one double-hull oil tanker, T2, are taken as the subject ships as shown in Table 1. Ship B1 is designed according to Pre-UR rule and built in 1987 and Ship B2 according to CSR-B having larger cross section and scantling sizes. Ship T2 is designed according to CSR-T.

Ship	B1	B2	T2
L (mm)	217,000	219,000	234,000
B (mm)	32,236	32,240	44,000
D (mm)	18,300	19,900	21,200
Design criteria	Pre-IACS UR	IACS CSR-B	IACS CSR-T

Table 1 Subject ships

The damage of the upper part of side shell due to collision is assumed. The vertical damage extent is taken as 10%, 20%, 40% and 70% of the depth D for both bulk carrier and tanker. The horizontal damage extent is taken as $B/16$, and it is kept constant for all damaged cases. The damaged cross sections of Ship B1 are illustrated in Fig. 2 and those of Ship T2 in Fig. 3. The stiffness of the elements in the damaged area is completely removed. For the double hull tanker, only outer side shell is assumed to be damaged. The locations of the critical deck element are presented in Fig. 4 for single hull bulk carrier and double hull oil tanker, respectively.

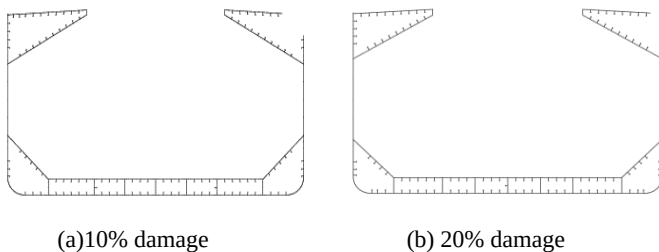


Fig. 2 Single hull bulk carrier (Ship B1)

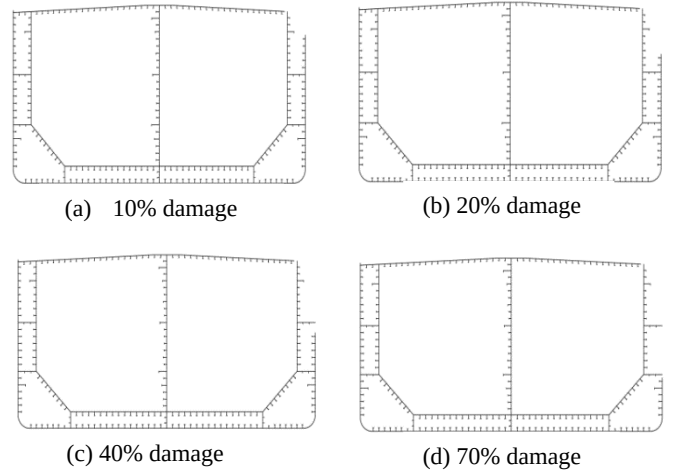
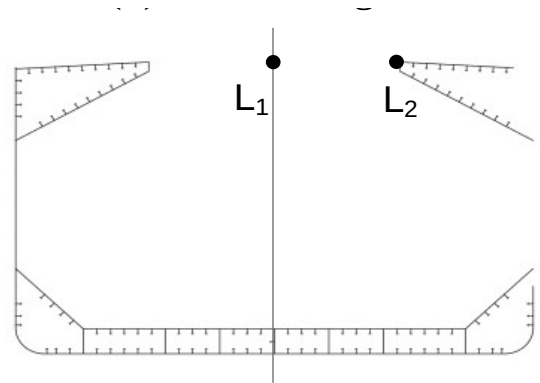
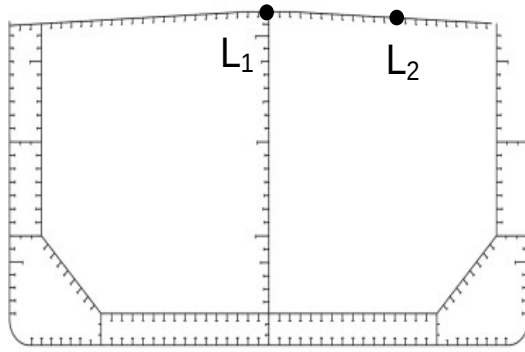


Fig. 3 Double hull oil tanker (Ship T2)

The investigation of the residual hull girder strength under sagging condition is performed by taking two locations of the critical deck elements as shown in Fig. 4. Single hull bulk carrier (B1 and B2), the locations of the critical element are L_1 and L_2 , L_1 is located at the center line and L_2 at the hatch coaming on the damage side. For the case of double hull oil tanker (T2), L_1 is located at the center line and L_2 at the distance of $B/4$ from the damage side shell.



(a) Single hull bulk carrier



(b) Double hull oil tanker

Fig. 4 Locations of the critical deck elements

RESULT AND DISCUSSION

In sagging condition, it is well recognized that the ultimate hull girder strength is almost attained when the primary deck members in longitudinal compression reached their ultimate strength. Also, because the damage takes place at the asymmetric position, in other word, collision damage is place at the side shell through to the deck part (B/16) and there is no damage located at the bottom part, so that it is very important to investigate the critical member under sagging condition. In the present study, the ultimate strength is analyzed after damaged takes place. The water ingress is not considered in the analysis.

The results obtained by progressive collapse analysis under sagging condition for 20% and 70% damage are presented in Fig. 5 and Fig. 6, respectively. Case 1 considers the rotation of neutral axis and Case 2 does not. The moment-curvature relationship is given by

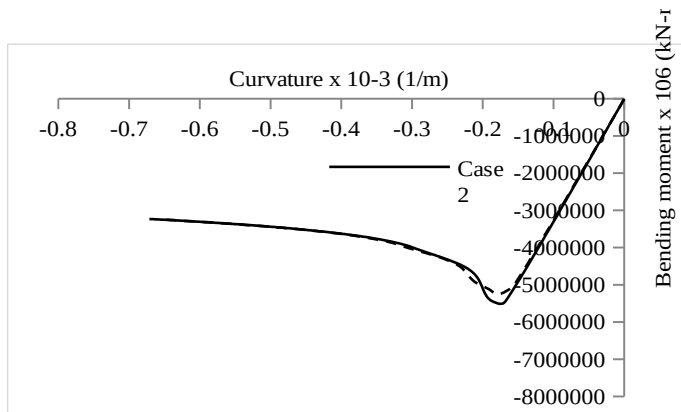


Fig. 5 Single hull bulk carrier (Ship B1) with 20% damage

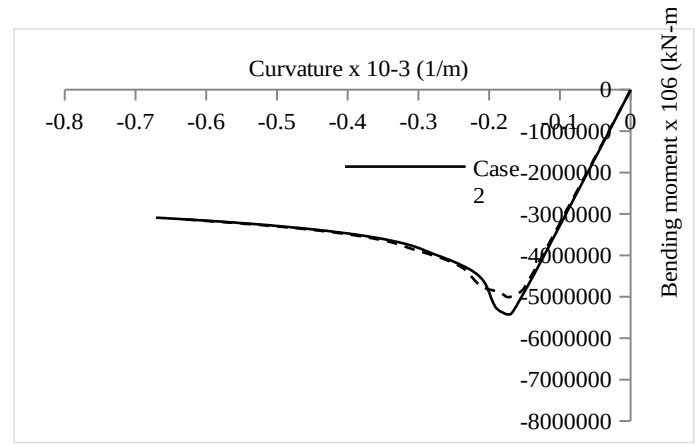


Fig. 6 Single hull bulk carrier (Ship B1) with 70% damage

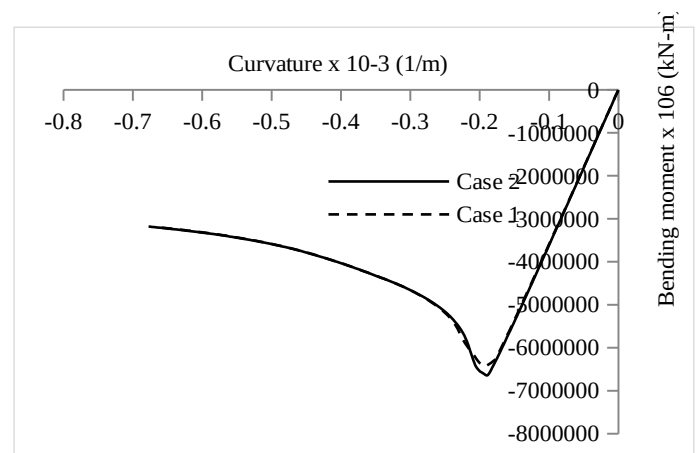


Fig. 7 Single hull bulk carrier (Ship B2) with 20% damage

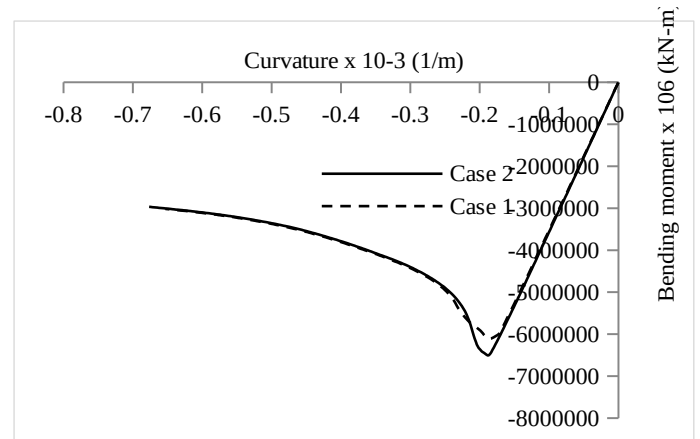


Fig. 8 Single hull bulk carrier (Ship B2) with 70% damage

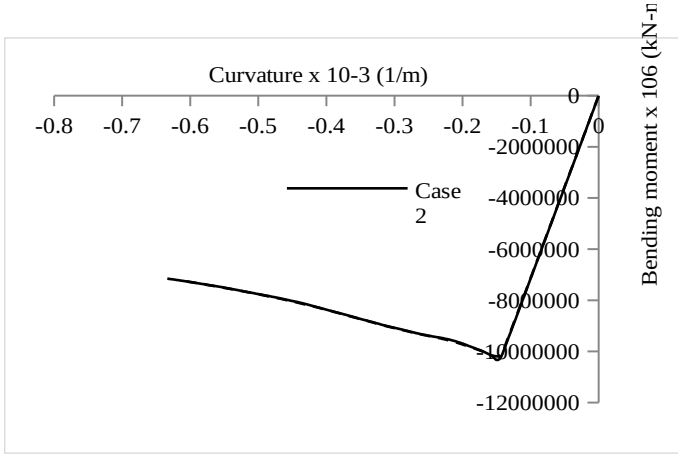


Fig. 9 Double hull oil tanker (Ship T2) with 20% damage

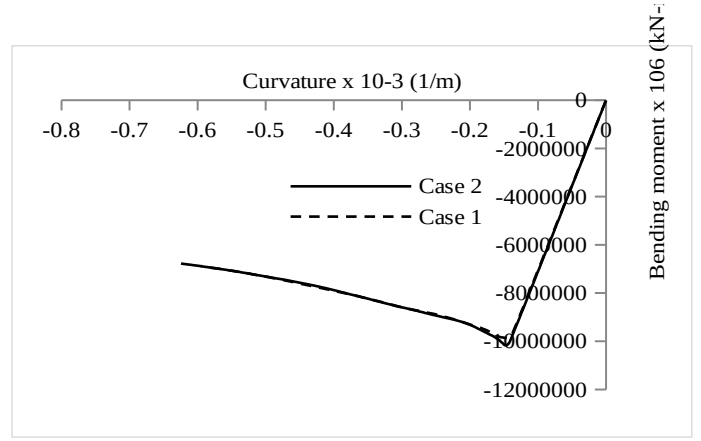


Fig. 10 Double hull oil tanker (T2) with 70% damage

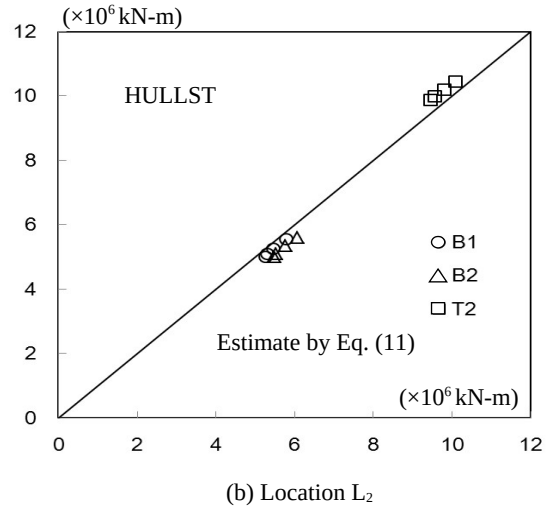
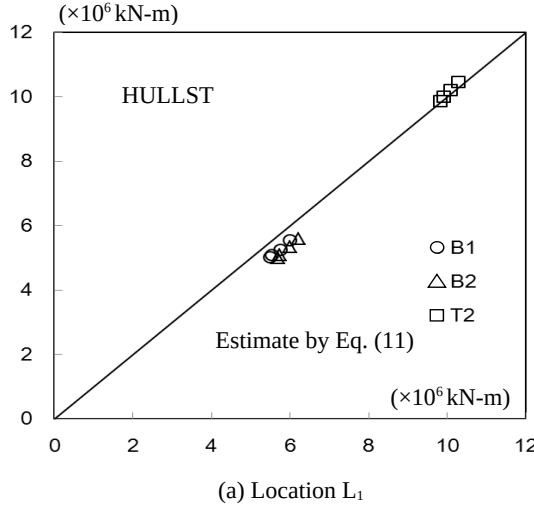


Fig. 11 Comparison of residual hull girder strength M_V between the simplified method and the progressive collapse analysis. Fig. 7 and Fig. 8 shows the results of the moment-curvature relationship obtained by progressive collapse analysis for single hull bulk carrier (B2). It is found that Case 2 generally gives larger ultimate strength than Case 1 because the horizontal curvature is constrained. The ultimate hull girder strength is attained even the horizontal curvature is constrained because of the horizontal bending moment is induced by the stiffened matrix interaction for horizontal and vertical and this makes the ultimate hull girder strength becomes higher. The effect is largest in Ship B1, smaller in Ship B2, and almost negligible in Ship T2. For Ship B1, Case 1 strength is 7.3% smaller than Case 2 in sagging condition. The difference between Ship B1 and Ship B2 may be related to that of the depth to breadth ratio, member scantlings etc. Fig. 9 and Fig. 10 represent the moment-curvature relationship under sagging condition for double hull oil tanker (T2) for 20% and 70% of damaged, respectively. According to the result obtained by progressive collapse analysis of double hull oil tanker (Ship T2), the effect of rotation of neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

The residual strengths of Ship B1, Ship B2 and Ship T2 obtained for the four different damage extents are summarized in Fig. 11. It is found that Eq. (11) gives an estimate of the residual strength which is in good agreement with the result of the progressive collapse analysis.

For bulk carriers, the critical element at the location L_2 gives a better estimate of the residual strength. This is consistent with the observed collapse behavior in which the ultimate strength is attained when topside tank region of the damage side almost fully failed. The location L_1 cannot well take account of the effect of the horizontal curvature induced by M_V , resulting in the slight overestimate of the strength. In the case of tankers, the location L_1 gives better estimate of the residual strength than L_2 . This is also consistent with the failure behavior of T2 in which the ultimate strength is attained when the deck part almost fully failed.

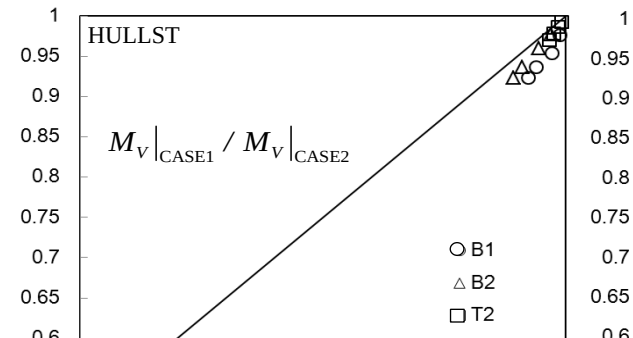


Fig. 12 Comparison of reduction ratio of residual hull girder due to rotation of neutral axis between the simplified method and the progressive collapse analysis (Case 1/Case 2)

CONCLUSIONS

The ultimate hull girder strength analysis of single hull bulk carriers and a double hull oil tanker with asymmetrically damaged cross section has been performed using the simplified approach under sagging condition by performing the elastic cross-sectional properties and critical member elements. A closed form formulae of residual strength and that of the reduction ratio of the residual strength due to the rotation of neutral axis are proposed. It is found through a comparison with the results obtained by the progressive collapse analysis that the residual hull girder strength of asymmetrically damaged ships under sagging bending moment can be predicted by the proposed formulae with a reasonable accuracy. The ultimate strength obtained with the horizontal curvature constrained is larger than without constrained one. The ultimate hull girder strength is attained even the horizontal curvature is constrained because of the horizontal bending moment is induced by the stiffened matrix interaction for horizontal and vertical and this makes the ultimate hull girder strength becomes higher. The effect is largest for single hull bulk carrier and almost negligible for double hull oil tanker. The difference characteristic for two single hull bulk carrier may be related to that of the depth to breadth ratio, member scantlings etc.

The resultant of bending moment is induced by the accumulation of the horizontal and vertical bending moment based on the reference coordinate system. Fig. 12 shows the comparison the reduction rates of the residual strength due to rotation of the neutral axis obtained by Eq. (13) and progressive collapse analysis. The influence of the rotation of the neutral axis is larger for a larger damage extent in general. For the case of the subject ships and damages under consideration, the influence is larger in bulk carriers than in tankers. Eq. (13) gives a relatively good estimate of the reduction rate. It can be a good basis of a rational expression of the influence of the rotation of the neutral axis on the reserved hull girder strength, as required in ship structures. More systematic analyses are definitely needed to develop the formula having larger applicability in ship types and damaged cases.

According to the result obtained by progressive collapse analysis of double hull oil tanker, the effect of rotation of neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

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Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships

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ABSTRACT

The objective of the present study is to investigate the ultimate hull girder strength of asymmetrically damaged ship under sagging condition. Two kinds of ship are taken as the object of the analysis. The cross section of the ship is considered and assumed to be remained plane. The [simply supported boundary condition](#) is applied to both sides of the cross section. The ultimate hull girder strength is attained when a plate and/or stiffened plate element at the specified location called “critical element” reach their ultimate strength. To investigate the ultimate hull girder strength, a simplified approach is proposed. The result obtained by simplified approach is compared to the progressive collapse analysis for the effectiveness and validation.

KEY WORDS: Single hull bulk carrier, double hull oil tanker, cross section, neutral axis, asymmetrically damaged, ultimate strength, simplified approach.

INTRODUCTION

The ability to predict accurately the ultimate strength of ship hull girder when subjected to longitudinal bending is one of the most important aspects of ship structural design. A collision and grounding damages may takes place on ship's hull, which may threaten [safety of ship](#) and surrounding environment. In this regard, to enhance the safety of ship's structure and minimize the risks, the International Maritime Organization (IMO, 2009) has required in Goal Based Standard for New Ship Construction (GBS) to consider the residual strength of the hull girder in specified damage conditions as one of the functional requirements for the structural rules for bulk carriers and tankers.

Many studies have been conducted on the analyses of the residual hull girder strength due to collision and grounding damaged. Pedersen (1994) presented a mathematical modeling to estimate the contact pressure between the grounded ship and the sea bottom. The grounded contact force was compared to the force which would crush the forward bottom of the ship. The sectional bending moment due to grounding was determined and compared to the ultimate hull girder strengths. The model experiments and full-scale controlled grounding experiments were also performed to validate the mathematical model. Paik et al. (1998) developed a rapid procedure to identify the possibility of hull girder failure after collision and grounding damages based on the closed-form formulae of the ultimate hull girder strength and section modulus after the damages. Soares et al. (2008) evaluated the ability of simplified structural analysis methods [based on](#) the Smith's formulation to predict the ultimate strength of damage ship's hull. Toh et al. (2012) developed simplified calculation program to calculate the ultimate strength in intact and damage condition and the reduction of hull girder ultimate strength is investigated. The calculation result of simplified method is compared to the FE result for both intact and damage condition. Muis Alie, M.Z et al. (2012) investigated the incidence of neutral axis rotation on residual hull

girder strength for asymmetrical damaged ships under longitudinal bending, [applying the progressive collapse calculation method and found an](#) explicit expression of neutral axis rotation. After performing a series of progressive collapse analyses on several bulk carriers and tanker, it was found that residual hull girder strength, considering the instantaneous neutral axis is generally lower than the relevant one, obtained by constraining the rotation, as it is commonly assumed in classical procedures. Ohtsubo et al. (1994) showed the experimental and numerical work on the ship structural damages due to collision and grounding. This was one of the first attempts to apply the explicit Finite Element Method codes, such as LS-DYNA and DYTRAN, to the collision and grounding problems of ships. Ozguc et al. (2005) investigated the collision resistance and residual strength of single skin and double skin bulk carriers subjected to damages. Lee et al. (2008) calculate the ultimate strength with collision damage using LS-DYNA and [compared the calculated results with](#) the experiment results. It is found that the ultimate strength is reduced as a damage size increased as expected. Notaro et al. (2010) carried out full nonlinear FE assessments of hull girder capacity in intact and damage conditions. The effects of several [influential factor](#) such as model extend and complexity, damage representations and model imperfections are investigated on the different vessels. It was found that the effect of damage extent in vertical direction is more critical than in longitudinal direction, and the damage varies the location of the neutral axes including higher stresses in proximity of the damage areas. The various probability levels are considered for the damage extent estimation.

When a hull-girder cross section is symmetric with respect to the centerline and subjected to pure vertical bending moment, the neutral axis for vertical bending is always horizontal and moves only vertically during the progressive collapse behavior. However, when the cross section is asymmetrically [damaged, for example, due to](#) a collision, the neutral axis rotates. Both rotation and translation need to be taken into account during the progressive collapse behavior even when only a vertical bending moment is applied, and the problem needs to be treated as a biaxial bending problem. Previous studies using the Smith's method on the ultimate strength of hull girders under biaxial thrust (Ozguc and Barltrop, 2008) and the residual

strength of damaged hulls (Fang and Das, 2004; Hussein and Guedes Soares, 2009; Choung et al, 2011) consider the rotation and translation of neutral axis in a reasonable way. However, they employ a trial and error approach to detect the position of neutral axis. More easy approach to detect the position of neutral axis is demanded.

BASIC ASSUMPTION

1 The following assumption is made for the prediction of the residual hull girder strength under the sagging condition:

- (1) The ultimate sagging strength is attained when a stiffened panel element at the specified location (hereafter called 'critical element') reached the ultimate strength.
- (2) The hull girder cross section is elastic until the failure of the critical member.
- (3) The ultimate strength of the critical member is predicted from the average axial stress and average axial strain relationship calculated by HULLST (Yao and Nikolov).

EFFECT OF NEUTRAL AXIS ROTATION ON ESTIMATION OF THE ULTIMATE HULL GIRDER STRENGTH

In the elastic cross section, the bending stress at the i -th element (see Fig.1), σ_i , is expressed as

$$\sigma_i = E \left[(y_i - y_G) \phi_H + (z_i - z_G) \phi_V \right] \quad (1)$$

where E is Young's modulus, y_G and z_G the centroid coordinates, and ϕ_H and ϕ_V the horizontal and vertical curvatures, respectively. y_G and z_G are given by

$$y_G = \frac{\left(\sum_{i=1}^N y_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (2)$$

$$z_G = \frac{\left(\sum_{i=1}^N z_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (3)$$

where D_i , A_i , and (y_i, z_i) are the tangential stiffness obtained as a slope of the average stress-average strain curve, cross sectional area and the coordinates of the centroid of individual elements, respectively.

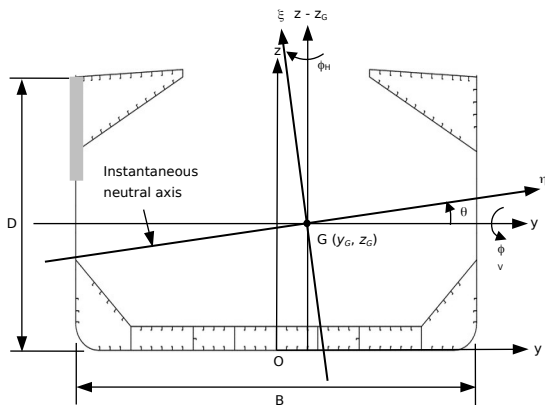


Fig. 1 Neutral axes of the elastic hull girder cross section with asymmetric damage

For the case of [asymmetrically damaged cross section, Eqs \(4\) through \(8\) are used](#), and for the intact one, the expressions are given in Eqs (9) and (10). The biaxial moment and curvature relationship is given in the form

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (4)$$

where

$$\begin{aligned} I_{HV} &= I_{VH} = \sum_{i=1}^N (y_i - y_G)(z_i - z_G) A_i \\ I_{HH} &= \sum_{i=1}^N (y_i - y_G)^2 A_i \\ I_{VV} &= \sum_{i=1}^N (z_i - z_G)^2 A_i \end{aligned} \quad (5)$$

where I and M are the moment of inertia and bending moment, respectively. When the vertical bending moment M_V is applied to the cross section with no constraint on the horizontal curvature (Case 1), the horizontal curvature as well as the vertical curvature is induced under the condition of horizontal bending moment $M_H = 0$. The incremental equation to be solved is

$$\begin{Bmatrix} 0 \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (6)$$

Therefore,

$$\begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} = \frac{1}{E(I_{HH} I_{VV} - I_{HV}^2)} \begin{Bmatrix} -I_{HV} M_V \\ I_{HH} M_V \end{Bmatrix} \quad (7)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{-(y_i - y_G) I_{HV} + (z_i - z_G) I_{HH}}{(I_{HH} I_{VV} - I_{HV}^2)} M_V \quad (8)$$

The terms including the moment of inertia, I_{HV} , represent the effect of the rotation of the neutral axis.

On the other hand, when the vertical bending moment is applied to the cross section with the horizontal curvature constrained (Case 2), the bending moment are induced under the condition of $\phi_H = 0$, that is,

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} 0 \\ \phi_V \end{Bmatrix} \quad (9)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{(z_i - z_G)}{I_{VV}} M_V \quad (10)$$

Here, it is assumed that the residual hull girder strength in the sagging condition M_V^u is attained when a critical member at the location of $(y_C - z_C)$ reached its ultimate strength, σ_C^u , namely for Case 1

$$M_V^u|_{CASE\ 1} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \sigma_C^u \quad (11)$$

And for Case 2

$$M_V^u|_{CASE\ 2} = \frac{I_{VV}}{(z_C - z_G)} \sigma_C^u \quad (12)$$

Therefore, the reduction rate of the residual strength due to the rotation of the neutral axis in the framework of the proposed approximate approach is given by ratio of Eq. (11) to Eq. (12) as

$$\frac{M_V^u|_{CASE\ 1}}{M_V^u|_{CASE\ 2}} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \frac{(z_C - z_G)}{I_{VV}} \quad (13)$$

CASE STUDY

Two single-hull bulk carriers, B1 and B2, and one double-hull oil tanker, T2, are taken as the subject ships as shown in Table 1. Ship B1 is designed according to Pre-UR rule and built in 1987 and Ship B2 according to CSR-B having larger cross section and scantling sizes. Ship T2 is designed according to CSR-T.

Ship	B1	B2	T2
L (mm)	217,000	219,000	234,000
B (mm)	32,236	32,240	44,000
D (mm)	18,300	19,900	21,200
Design criteria	Pre-IACS UR	IACS CSR-B	IACS CSR-T

Table 1 Subject ships

The damage of the upper part of side shell due to collision is assumed. The vertical damage extent is taken as 10%, 20%, 40% and 70% of the depth D for both bulk carrier and tanker. The horizontal damage extent is taken as $B/16$, and it is kept constant for all damaged cases. The damaged cross sections of Ship B1 are illustrated in Fig. 2 and those of Ship T2 in Fig. 3. The stiffness of the elements in the damaged area is completely removed. For the double hull tanker, only outer side shell is assumed to be damaged. The locations of the critical deck element are presented in Fig. 4 for single hull bulk carrier and double hull oil tanker, respectively.

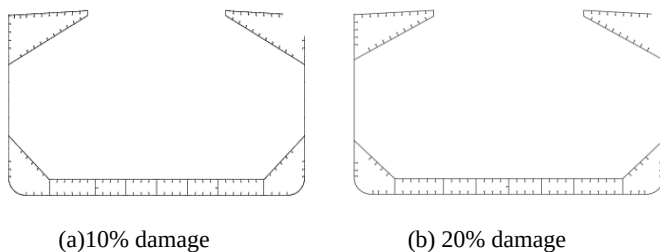


Fig. 2 Single hull bulk carrier (Ship B1)

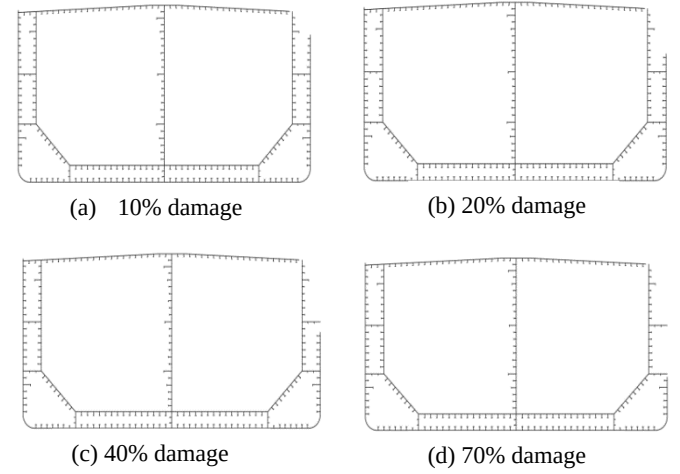
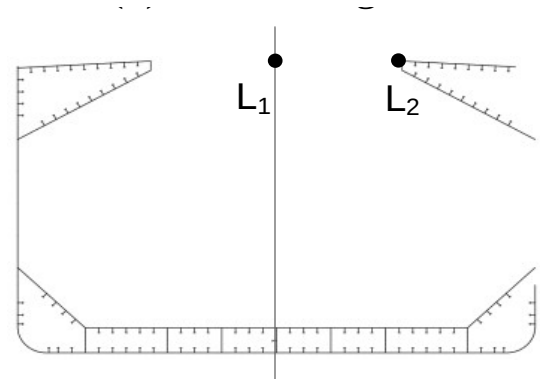
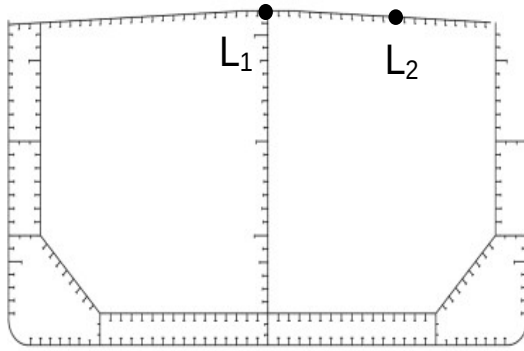


Fig. 3 Double hull oil tanker (Ship T2)

The investigation of the residual hull girder strength under sagging condition is performed by taking two locations of the critical deck elements as shown in Fig. 4. Single hull bulk carrier (B1 and B2), the locations of the critical element are L_1 and L_2 , L_1 is located at the center line and L_2 at the hatch coaming on the damage side. For the case of double hull oil tanker (T2), L_1 is located at the center line and L_2 at the distance of $B/4$ from the damaged side shell.



(a) Single hull bulk carrier



(b) Double hull oil tanker

Fig. 4 Locations of the critical deck elements

RESULT AND DISCUSSION

In sagging condition, it is well recognized that the ultimate hull girder strength is almost attained when the primary deck members in longitudinal compression reached their ultimate strength. Also, because the damage takes place at the asymmetric position, in other word, collision damage is placed at the side shell through to the deck part (B/16) and there is no damage located at the bottom part, so that it is very important to investigate the critical member under sagging condition. In the present study, the ultimate strength is analyzed after damage has taken place. The water ingress is not considered in the analysis.

The results obtained by progressive collapse analysis under sagging condition for 20% and 70% damage are presented in Fig. 5 and Fig. 6, respectively. Case 1 considers the rotation of neutral axis and Case 2 does not. The resultant of bending moment versus curvature is plotted.

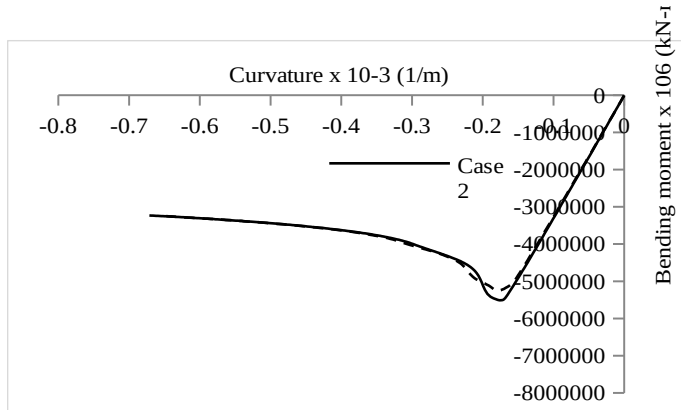


Fig. 5 Single hull bulk carrier (Ship B1) with 20% damage

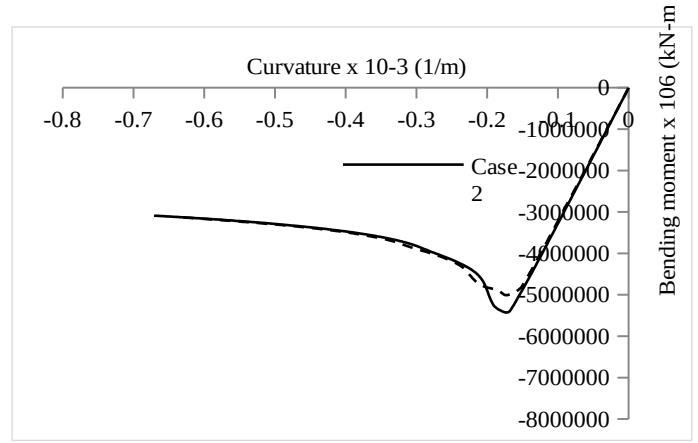


Fig. 6 Single hull bulk carrier (Ship B1) with 70% damage

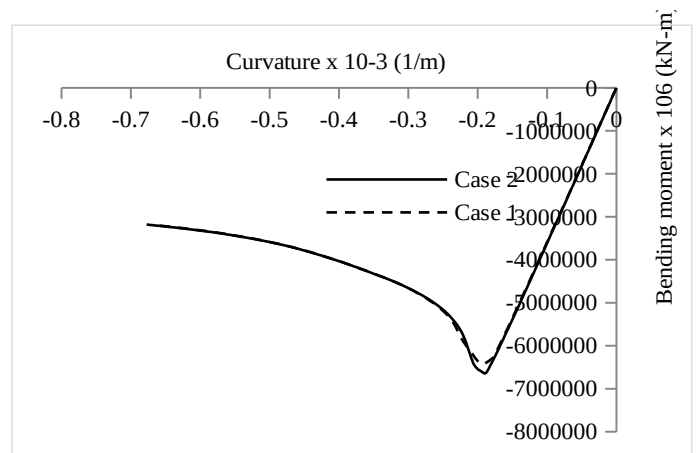


Fig. 7 Single hull bulk carrier (Ship B2) with 20% damage

Similarly, the resultant bending moment and curvature curve for Ship B2 and Ship T2 with 20% and 70% damage are presented in Figs. 7 through 10.

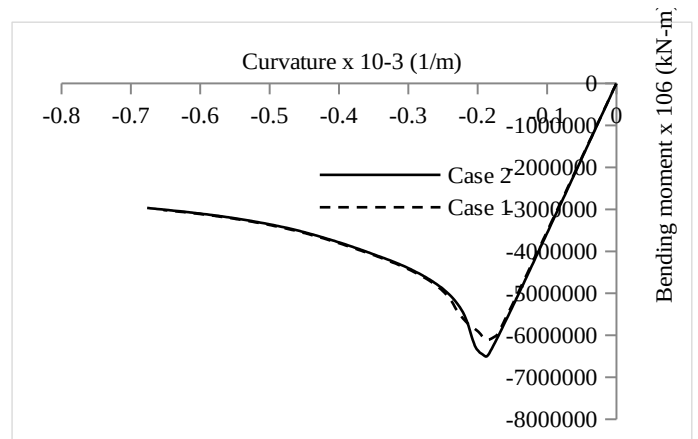


Fig. 8 Single hull bulk carrier (Ship B2) with 70% damage

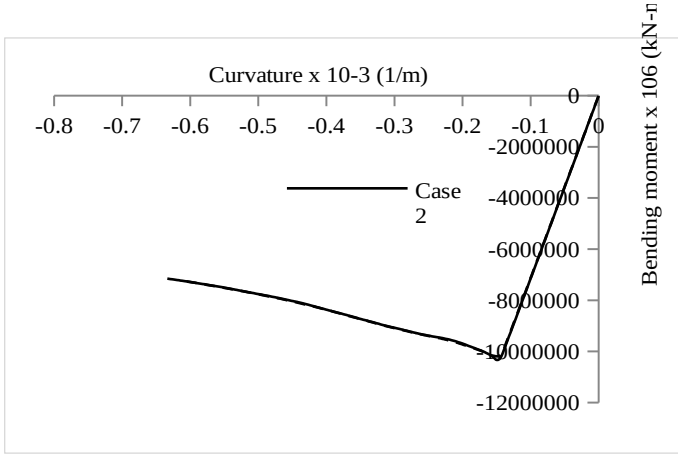


Fig. 9 Double hull oil tanker (Ship T2) with 20% damage

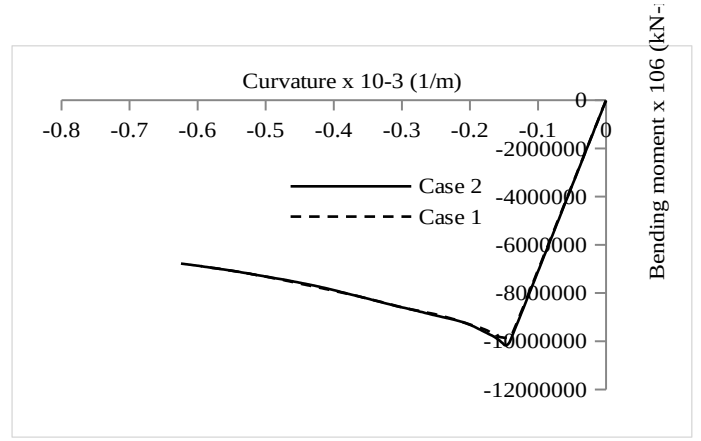
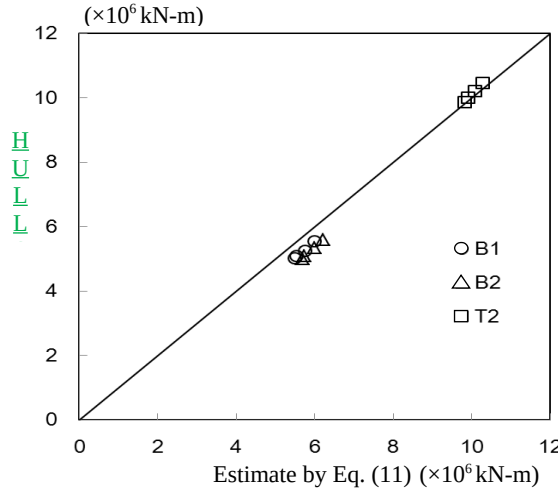
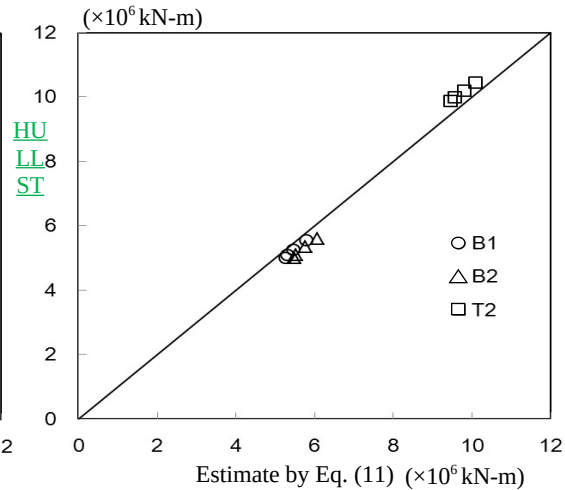


Fig. 10 Double hull oil tanker (T2) with 70% damage



(a) Location L_1



(b) Location L_2

Fig. 11 Comparison of residual hull girder strength M_V between the simplified method and the progressive collapse analysis. Fig. 7 and Fig. 8 shows the results of the moment-curvature relationship obtained by progressive collapse analysis for single hull bulk carrier (B2). It is found that Case 2 generally gives larger ultimate strength than Case 1 because the horizontal curvature is constrained. The ultimate hull girder strength is attained even the horizontal curvature is constrained because of the horizontal bending moment is induced by the incremental equation for horizontal and vertical bending moments and this makes the ultimate hull girder strength becomes higher. The effect is largest in Ship B1, smaller in Ship B2, and almost negligible in Ship T2. For Ship B1, Case 1 strength is 7.3% smaller than Case 2 in sagging condition. The difference between Ship B1 and Ship B2 may be related to that of the depth to breadth ratio, member scantlings etc. Fig. 9 and Fig. 10 represent the moment-curvature relationship under sagging condition for double hull oil tanker (T2) for 20% and 70% of damages, respectively. According to the result obtained by progressive collapse analysis of double hull oil tanker (Ship T2), the effect of rotation of neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

The residual strengths of Ship B1, Ship B2 and Ship T2 obtained for the four different damage extents are summarized in Fig. 11. It is found that Eq. (11) gives an estimate of the residual strength which is in good agreement with the result of the progressive collapse analysis. For bulk carriers, the critical element at the location L_2 gives a better estimate of the residual strength. This is consistent with the observed collapse behavior in which the ultimate strength is attained when topside tank region of the damaged side almost fully failed. In the case of tankers, the location L_1 gives better estimate of the residual strength than L_2 . This is also consistent with the failure behavior of T2 in which the ultimate strength is attained when the deck part almost fully failed.

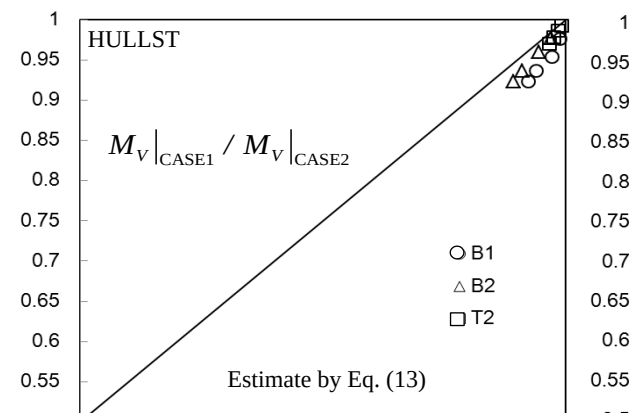


Fig. 12 Comparison of reduction ratio of residual hull girder due to rotation of neutral axis between the simplified method and the progressive collapse analysis (Case 1/Case 2)

CONCLUSIONS

Progressive collapse analysis was performed on two single hull bulk carriers and a double hull oil tanker with asymmetrically damaged cross section applying Smith's method. A closed form formulae of residual strength and that of the reduction ratio of the residual strength due to the rotation of neutral axis are proposed. It is found through a comparison with the results obtained by the progressive collapse analysis that the residual hull girder strength of asymmetrically damaged ships under sagging bending moment can be predicted by the proposed formulae with a reasonable accuracy. The ultimate strength obtained with the horizontal curvature constrained is larger than that without constraint one. The ultimate hull girder strength is attained under condition the horizontal curvature constrained because the horizontal bending moment is induced by the incremental equation for horizontal and vertical bending moments and this makes the ultimate hull girder strength higher. The effect is largest for single hull bulk carrier and almost negligible for double hull oil tanker. The difference characteristic for two single hull bulk carrier may be related to that of the depth to breadth ratio, member scantlings etc.

The resultant of bending moment is induced by the accumulation of the horizontal and vertical bending moment based on the reference coordinate system. Fig. 12 shows the comparison the reduction rates of the residual strength due to rotation of the neutral axis obtained by Eq. (13) and progressive collapse analysis. The influence of the rotation of the neutral axis is larger for a larger damage extent in general. For the case of the subject ships and damages under consideration, the influence is larger in bulk carriers than in tankers. Eq. (13) gives a relatively good estimate of the reduction rate. It can be a good basis of a rational expression of the influence of the rotation of the neutral axis on the reserved hull girder strength, as required in ship structures. More systematic analyses are definitely needed to develop the formula having larger applicability in ship types and damaged cases.

According to the result obtained by progressive collapse analysis of double hull oil tanker, the effect of rotation of neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

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Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships

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ABSTRACT

The objective of the present study is to investigate the ultimate hull girder strength of asymmetrically damaged ship under sagging condition. Two kinds of ships are taken as the object of the analysis. The cross section of the ship is considered and assumed to be remained plane. The simply supported boundary condition is applied to both sides of the cross section. The ultimate hull girder strength is attained when a plate and/or stiffened plate element at the specified location called “critical element” reach their ultimate strength. To investigate the ultimate hull girder strength, a simplified approach is proposed. The result obtained by simplified approach is compared to the progressive collapse analysis for the effectiveness and validation.

KEY WORDS: Single hull bulk carrier, double hull oil tanker, cross section, neutral axis, asymmetrically damaged, ultimate strength, simplified approach.

INTRODUCTION

The ability to predict accurately the ultimate strength of ship hull girder when subjected to longitudinal bending is one of the most important aspects of ship structural design. A collision and grounding damages may takes place on ship's hull, which may threaten safety of ships and surrounding environment. In this regard, to enhance the safety of ship's structure and minimize the risks, the International Maritime Organization (IMO, 2009) has required in Goal Based Standard for New Ship Construction (GBS) to consider the residual strength of the hull girder in specified damage conditions as one of the functional requirements for the structural rules for bulk carriers and tankers.

Many studies have been conducted on the analyses of the residual hull girder strength due to collision and grounding damages. Pedersen (1994) presented a mathematical modeling to estimate the contact pressure between the grounded ship and the sea bottom. The grounding contact force was compared to the force which would crush the forward bottom of the ship. The sectional bending moment due to grounding was determined and compared to the ultimate hull girder strengths. The model experiments and full-scale controlled grounding experiments were also performed to validate the mathematical model. Paik et al. (1998) developed a rapid procedure to identify the possibility of hull girder failure after collision and grounding damages based on the closed-form formulae of the ultimate hull girder strength and section modulus after the damages. Soares et al. (2008) evaluated the ability of simplified structural analysis methods based on the Smith's formulation to predict the ultimate strength of damage ship's hull. Toh et al. (2012) developed simplified calculation program to calculate the ultimate strength in intact and damage conditions and the reduction of hull girder ultimate strength is investigated. The calculation result of simplified method is compared to the FE result for both intact and damage conditions. Muis Alie, M.Z et al. (2012) investigated the incidence of neutral axis rotation on residual hull

girder strength for asymmetrically damaged ships under longitudinal bending, applying the progressive collapse calculation method and found an explicit expression of neutral axis rotation. After performing a series of progressive collapse analyses on several bulk carriers and tanker, it was found that residual hull girder strength, considering the instantaneous neutral axis is generally lower than the relevant one, obtained by constraining the rotation, as it is commonly assumed in classical procedures. Ohtsubo et al. (1994) showed the experimental and numerical works on the ship structural damages due to collision and grounding. This was one of the first attempts to apply the explicit Finite Element Method codes, such as LS-DYNA and DYTRAN, to the collision and grounding problems of ships. Ozguc et al. (2005) investigated the collision resistance and residual strength of single skin and double skin bulk carriers subjected to damages. Lee et al. (2008) calculated the ultimate strength with collision damage using LS-DYNA and compared the calculated results with the experiment results. It is found that the ultimate strength is reduced as a damage size increased as expected. Notaro et al. (2010) carried out full nonlinear FE assessments of hull girder capacity in intact and damage conditions. The effects of several influential factor such as model extend and complexity, damage representations and model imperfections are investigated on the different vessels. It was found that the effect of damage extent in vertical direction is more critical than in longitudinal direction, and the damage varies the location of the neutral axes including higher stresses in proximity of the damage areas. The various probability levels are considered for the damage extent estimation.

When a hull-girder cross section is symmetric with respect to the centerline and subjected to pure vertical bending moment, the neutral axis for vertical bending is always horizontal and moves only vertically during the progressive collapse behavior. However, when the cross section is asymmetrically damaged, for example, due to a collision, the neutral axis rotates. Both rotation and translation need to be taken into account during the progressive collapse behavior even when only a vertical bending moment is applied, and the problem needs to be treated as a biaxial bending problem. Previous studies using the Smith's method on the ultimate strength of hull girders under biaxial thrust (Ozguc and Barltrop, 2008) and the residual

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BASIC ASSUMPTION

1 The following assumption is made for the prediction of the residual hull girder strength under the sagging condition:

- (1) The ultimate sagging strength is attained when a stiffened panel element at the specified location (hereafter called 'critical element') reached the ultimate strength.
- (2) The hull girder cross section is elastic until the failure of the critical member.
- (3) The ultimate strength of the critical member is predicted from the average axial stress and average axial strain relationship calculated by HULLST (Yao and Nikolov).

EFFECT OF NEUTRAL AXIS ROTATION ON ESTIMATION OF THE ULTIMATE HULL GIRDER STRENGTH

In the elastic cross section, the bending stress at the i -th element (see Fig.1), σ_i , is expressed as

$$\sigma_i = E \left[(y_i - y_G) \phi_H + (z_i - z_G) \phi_V \right] \quad (1)$$

where E is Young's modulus, y_G and z_G the centroid coordinates, and ϕ_H and ϕ_V the horizontal and vertical curvatures, respectively. y_G and z_G are given by

$$y_G = \frac{\left(\sum_{i=1}^N y_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (2)$$

$$z_G = \frac{\left(\sum_{i=1}^N z_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (3)$$

where D_i , A_i , and (y_i, z_i) are the tangential stiffness obtained as a slope of the average stress-average strain curve, cross sectional area and the coordinates of the centroid of individual elements, respectively.

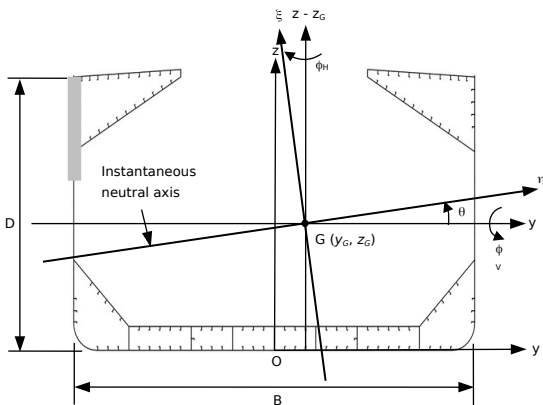


Fig. 1 Neutral axes of the elastic hull girder cross section with asymmetric damage

For the case of asymmetrically damaged cross section, Eqs (4) through (8) are used, and for the intact one, the expressions are given in Eqs (9) and (10). The biaxial moment and curvature relationship is given in the form

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (4)$$

where

$$\begin{aligned} I_{HV} &= I_{VH} = \sum_{i=1}^N (y_i - y_G)(z_i - z_G) A_i \\ I_{HH} &= \sum_{i=1}^N (y_i - y_G)^2 A_i \\ I_{VV} &= \sum_{i=1}^N (z_i - z_G)^2 A_i \end{aligned} \quad (5)$$

where I and M are the moment of inertia and bending moment, respectively. When the vertical bending moment M_V is applied to the cross section with no constraint on the horizontal curvature (Case 1), the horizontal curvature as well as the vertical curvature is induced under the condition of horizontal bending moment $M_H = 0$. The incremental equation to be solved is

$$\begin{Bmatrix} 0 \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (6)$$

Therefore,

$$\begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} = \frac{1}{E(I_{HH} I_{VV} - I_{HV}^2)} \begin{Bmatrix} -I_{HV} M_V \\ I_{HH} M_V \end{Bmatrix} \quad (7)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{-(y_i - y_G) I_{HV} + (z_i - z_G) I_{HH}}{(I_{HH} I_{VV} - I_{HV}^2)} M_V \quad (8)$$

The terms including the moment of inertia, I_{HV} , represent the effect of the rotation of the neutral axis.

On the other hand, when the vertical bending moment is applied to the cross section with the horizontal curvature constrained (Case 2), the bending moment are induced under the condition of $\phi_H = 0$, that is,

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} 0 \\ \phi_V \end{Bmatrix} \quad (9)$$

Therefore,

$$\phi_v = \frac{M_v}{EI_{VV}} \quad (10)$$

Substituting Eq. (10) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{(z_i - z_G)}{I_{VV}} M_v \quad (11)$$

Here, it is assumed that the residual hull girder strength in the sagging condition M_v^u is attained when a critical member at the location of (y_C, z_C) reached its ultimate strength, σ_C^u , namely for Case 1

$$M_v^u|_{CASE\ 1} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \sigma_C^u \quad (12)$$

And for Case 2

$$M_v^u|_{CASE\ 2} = \frac{I_{VV}}{(z_C - z_G)} \sigma_C^u \quad (13)$$

Therefore, the reduction rate of the residual strength due to the rotation of the neutral axis in the framework of the proposed approximate approach is given by ratio of Eq. (12) to Eq. (13) as

$$\frac{M_v^u|_{CASE\ 1}}{M_v^u|_{CASE\ 2}} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \frac{(z_C - z_G)}{I_{VV}} \quad (14)$$

CASE STUDY

Two single-hull bulk carriers, B1 and B2, and one double-hull oil tanker, T2, are taken as the subject ships as shown in Table 1. Ship B1 is designed according to Pre-UR rule and built in 1987 and Ship B2 according to CSR-B having larger cross section and scantling sizes. Ship T2 is designed according to CSR-T.

Table 1 Subject ships

Ship	B1	B2	T2
L (mm)	217,000	219,000	234,000
B (mm)	32,236	32,240	44,000
D (mm)	18,300	19,900	21,200
Design criteria	Pre-IACS UR	IACS CSR-B	IACS CSR-T

The damage of the upper part of side shell due to collision is assumed. The vertical damage extent is taken as 10%, 20%, 40% and 70% of the depth D for both bulk carriers and tanker. The horizontal damage extent is taken as $B/16$, and it is kept constant for all damaged cases. The damaged cross sections of Ship B1 are illustrated in Fig. 2 and those of Ship T2 in Fig. 3. The stiffness of the elements in the damaged area is completely removed. For the double hull tanker, only outer side shell is assumed to be damaged. The locations of the critical

deck element are presented in Fig. 4 for single hull bulk carrier and double hull oil tanker, respectively.

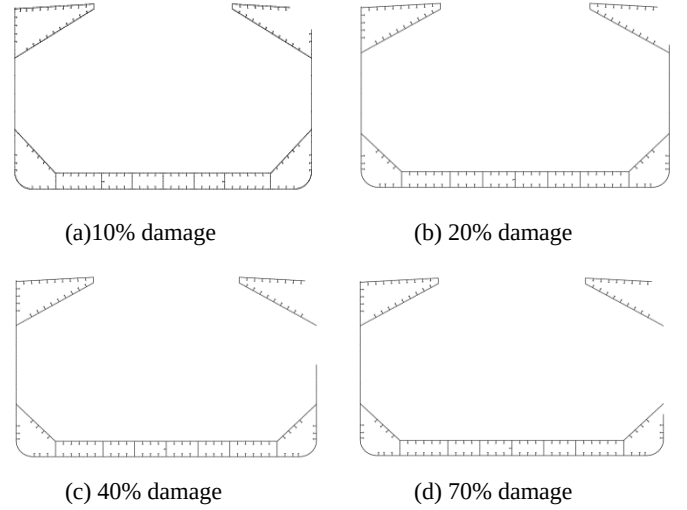


Fig. 2 Single hull bulk carrier (Ship B1)

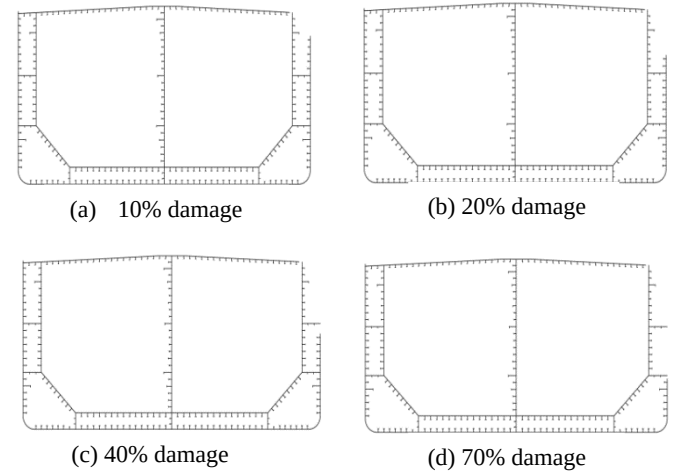
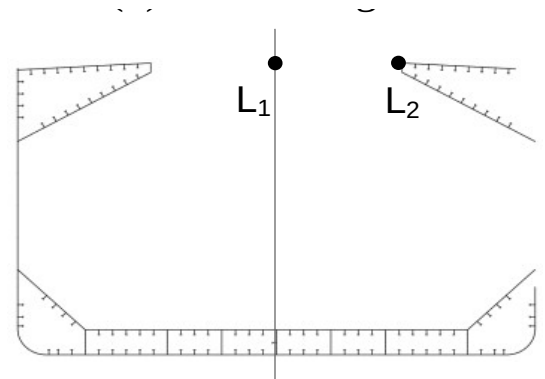
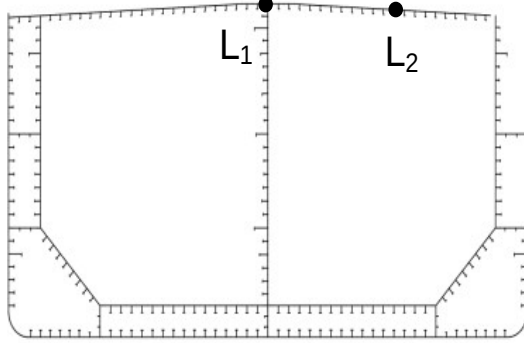


Fig. 3 Double hull oil tanker (Ship T2)

The investigation of the residual hull girder strength under sagging condition is performed by taking two locations of the critical deck elements as shown in Fig. 4. For single hull bulk carriers (B1 and B2), the locations of the critical element are L_1 and L_2 . L_1 is located at the center line and L_2 at the hatch coaming on the damage side. For the case of double hull oil tanker (T2), L_1 is located at the center line and L_2 at the distance of $B/4$ from the damaged side shell. As for the critical stress, the maximum stress of elements located at points L_1 and/or L_2 is used.



(a) Single hull bulk carrier



(b) Double hull oil tanker

Fig. 4 Locations of the critical deck elements

RESULT AND DISCUSSION

In sagging condition, it is well recognized that the ultimate hull girder strength is almost attained when the primary deck members in longitudinal compression reached their ultimate strength. Also, because the damage takes place at the asymmetric position, in other word, collision damage **is placed** at the side shell through to the deck part (B/16) and there is no damage located at the bottom part, so that it is very important to investigate the critical member under sagging condition. In the present study, the ultimate strength is analyzed after damage **has taken place**. The water ingress is not considered in the analysis.

The results obtained by progressive collapse analysis under sagging condition for 20% and 70% damage are presented in Fig. 5 and Fig. 6, respectively. Case 1 considers the rotation of neutral axis and Case 2 does not. The resultant of bending moment versus curvature is plotted.

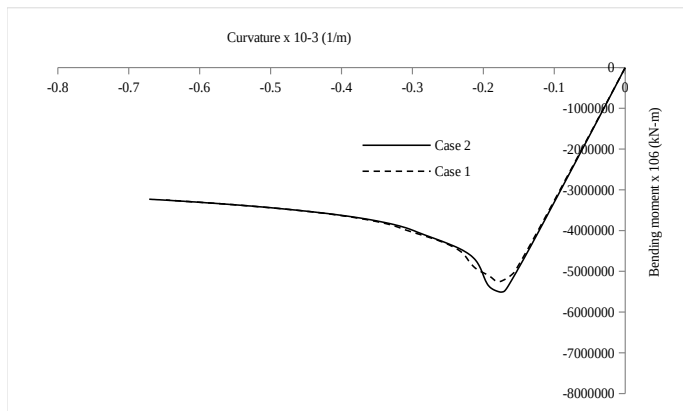


Fig. 5 Single hull bulk carrier (Ship B1) with 20% damage

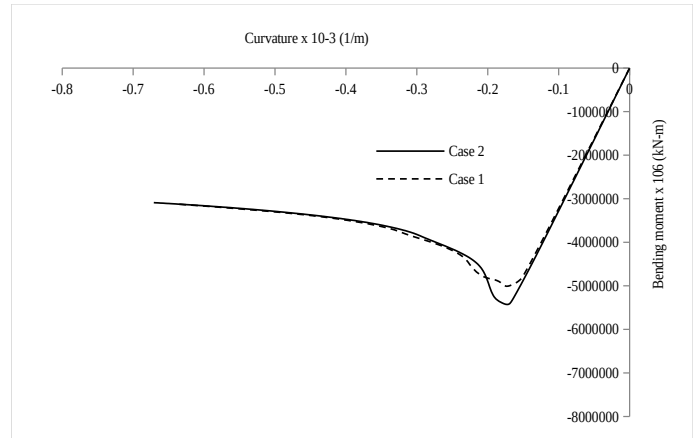


Fig. 6 Single hull bulk carrier (Ship B1) with 70% damage

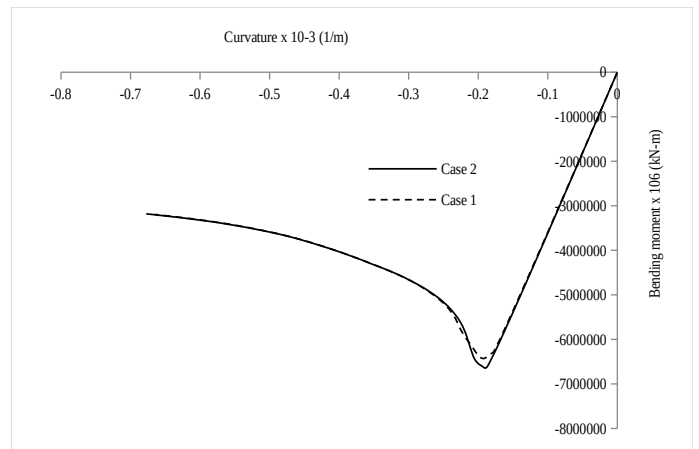


Fig. 7 Single hull bulk carrier (Ship B2) with 20% damage

Similarly, the resultant bending moment and curvature curve for Ship B2 and Ship T2 with 20% and 70% damage are presented in Figs. 7 through 10.

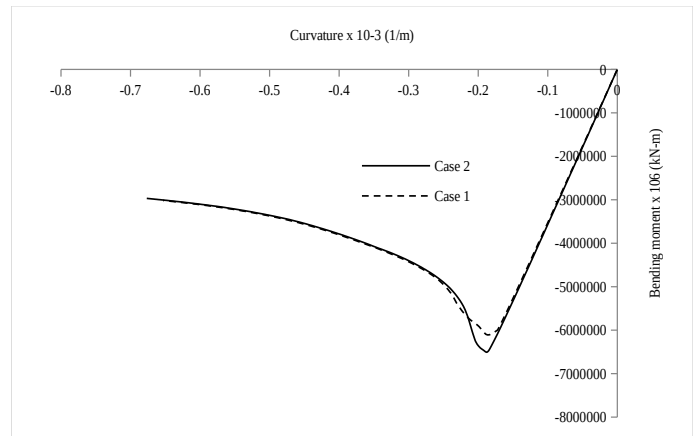


Fig. 8 Single hull bulk carrier (Ship B2) with 70% damage

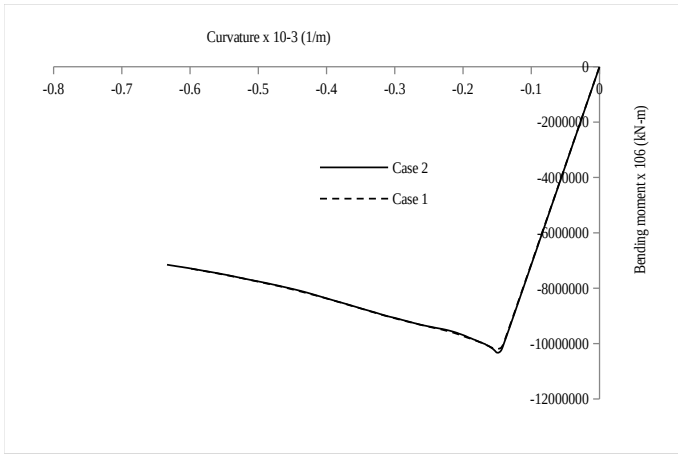


Fig. 9 Double hull oil tanker (Ship T2) with 20% damage

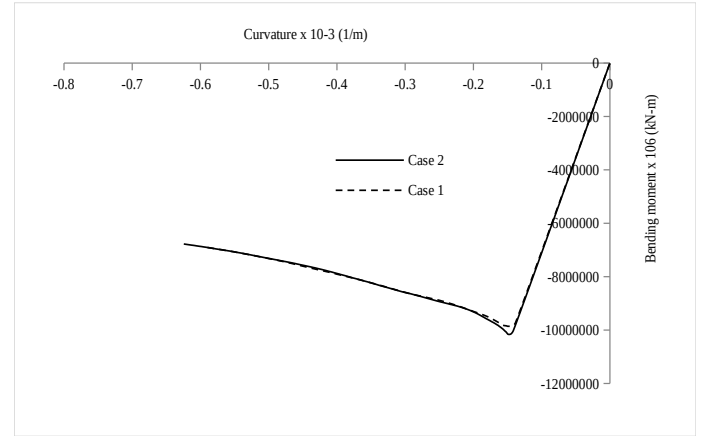


Fig. 10 Double hull oil tanker (T2) with 70% damage

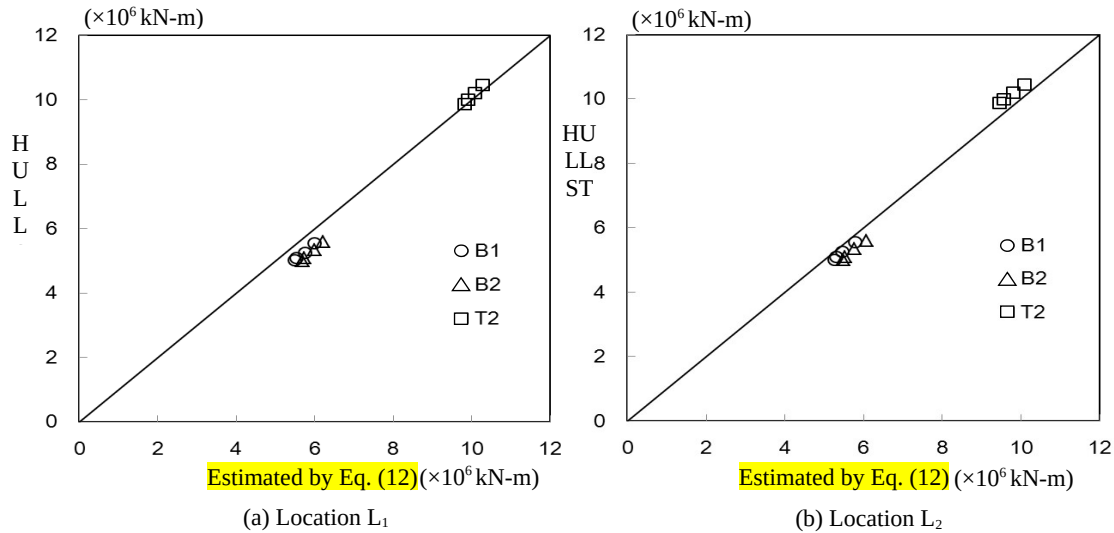


Fig. 11 Comparison of residual hull girder strength M_V between the simplified method and the progressive collapse. The results of the moment-curvature relationship obtained by progressive collapse analysis for single hull bulk carrier (B2). It is found that Case 2 generally gives higher ultimate strength than Case 1 because the horizontal curvature is constrained. The ultimate hull girder strength is attained even the horizontal curvature is constrained because of the horizontal bending moment is induced by the incremental equation for horizontal and vertical bending moments and this makes the ultimate hull girder strength becomes higher. The effect of constraint is the largest in Ship B1, and is smaller in Ship B2. For Ship B1, Case 1 strength is 7.3% smaller than Case 2 in sagging condition. The difference between Ship B1 and Ship B2 may be attributed to that of the depth to breadth ratio, member scantlings etc. Fig. 9 and Fig. 10 represent the moment-curvature relationship under sagging condition for double hull oil tanker (T2) for 20% and 70% of damages, respectively. According to the result obtained by progressive collapse analysis of double hull oil tanker (Ship T2), the effect of rotation of neural axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

The residual strengths of Ship B1, Ship B2 and Ship T2 obtained for the four different damage extents are summarized in Fig. 11. It is found that Eq. (11) gives an estimate of the residual strength which is in good agreement with the result of the progressive collapse analysis. For bulk carriers, the critical element at the location L_2 gives a better estimate of the residual strength. For the location of L_1 of bulk carriers, the ultimate strength of critical element is evaluated by using that of the element at L_2 . This is consistent with the observed collapse behavior in which the ultimate strength is attained when topside tank region of the damaged side almost fully failed. In the case of a double hull tanker, the location L_1 gives better estimate of the residual strength than L_2 . This is also consistent with the failure behavior of T2 in which the ultimate strength is attained when the deck part almost fully failed.

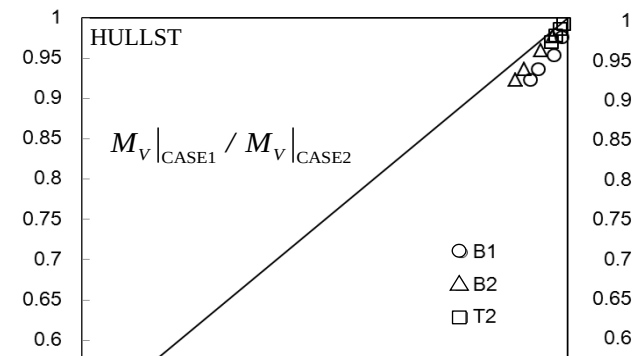


Fig. 12 Comparison of reduction ratio of residual hull girder due to rotation of neutral axis between the simplified method and the progressive collapse analysis (Case 1/Case 2)

CONCLUSIONS

Progressive collapse analysis was performed on two single hull bulk carriers and a double hull oil tanker with asymmetrically damaged cross section applying Smith's method. A closed form formulae of residual strength and that of the reduction ratio of the residual strength considering the rotation of neutral axis are proposed. It is found through a comparison with the results obtained by the progressive collapse analysis that the residual hull girder strength of asymmetrically damaged ships under sagging bending moment can be predicted by the proposed formulae with a reasonable accuracy. The ultimate strength obtained with the horizontal curvature constrained is larger than that without constraint one. The effect of the rotation of neutral axis is the largest for single hull bulk carrier and almost negligible for double hull oil tanker. The difference characteristic for two single hull bulk carrier may be related to that of the depth to breadth ratio, member scantlings etc.

The resultant of bending moment is induced by the accumulation of the horizontal and vertical bending moment based on the reference coordinate system. Fig. 12 shows the comparison of the reduction rates of the residual strength due to rotation of the neutral axis obtained by Eq. (14) and progressive collapse analysis. The influence of the rotation of the neutral axis is larger for a larger damage extent in general. For the case of the subject ships and damages under consideration, the influence is larger in bulk carriers than in tankers. Eq. (14) gives a relatively good estimate of the reduction rate. It can be a good basis of a rational expression of the influence of the rotation of the neutral axis on the reserve ultimate hull girder strength, as required in ship structures. More systematic analyses are definitely needed to develop the formula having larger applicability in ship types and damaged cases.

According to the result obtained by progressive collapse analysis of double hull oil tanker, the effect of rotation of neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

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INTRODUCTION

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BASIC ASSUMPTION

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where E is Young's modulus, y_G and z_G the centroid coordinates, and ϕ_H and ϕ_V the horizontal and vertical curvatures, respectively. y_G and z_G are given by

$$y_G = \frac{\left(\sum_{i=1}^N y_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (2)$$

$$z_G = \frac{\left(\sum_{i=1}^N z_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (3)$$

where D_i , A_i , and (y_i, z_i) are the tangential stiffness obtained as a slope of the average stress-average strain curve, cross sectional area and the coordinates of the centroid of individual elements, respectively.

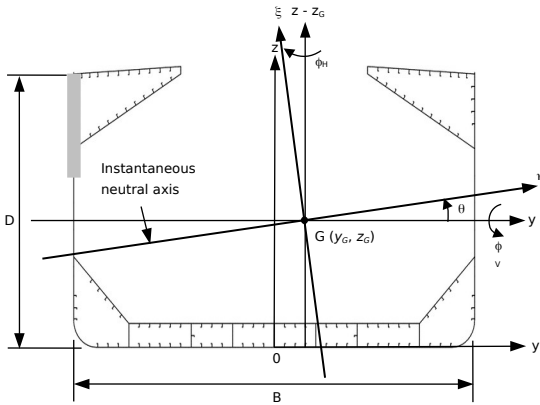


Fig. 1 Neutral axes of the elastic hull girder cross section with asymmetric damage

For the case of asymmetrically damaged cross section, Eqs (4) through (8) are used, and for the intact one, the expressions are given in Eqs (9) and (10). The biaxial moment and curvature relationship is given in the form

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (4)$$

where

$$\begin{aligned} I_{HV} &= I_{VH} = \sum_{i=1}^N (y_i - y_G)(z_i - z_G) A_i \\ I_{HH} &= \sum_{i=1}^N (y_i - y_G)^2 A_i \\ I_{VV} &= \sum_{i=1}^N (z_i - z_G)^2 A_i \end{aligned} \quad (5)$$

where I and M are the moment of inertia and bending moment, respectively. When the vertical bending moment M_V is applied to the cross section with no constraint on the horizontal curvature (Case 1), the horizontal curvature as well as the vertical curvature is induced under the condition of horizontal bending moment $M_H = 0$. The incremental equation to be solved is

$$\begin{Bmatrix} 0 \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (6)$$

Therefore,

$$\begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} = \frac{1}{E(I_{HH} I_{VV} - I_{HV}^2)} \begin{Bmatrix} -I_{HV} M_V \\ I_{HH} M_V \end{Bmatrix} \quad (7)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{-(y_i - y_G) I_{HV} + (z_i - z_G) I_{HH}}{(I_{HH} I_{VV} - I_{HV}^2)} M_V \quad (8)$$

The terms including the moment of inertia, I_{HV} , represent the effect of the rotation of the neutral axis.

On the other hand, when the vertical bending moment is applied to the cross section with the horizontal curvature constrained (Case 2), the bending moment are induced under the condition of $\phi_H = 0$, that is,

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} 0 \\ \phi_V \end{Bmatrix} \quad (9)$$

Therefore,

$$\phi_V = \frac{M_V}{EI_{VV}} \quad (10)$$

Substituting Eq. (10) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{(z_i - z_G)}{I_{VV}} M_V \quad (11)$$

Here, it is assumed that the residual hull girder strength in the sagging condition M_V^u is attained when a critical member at the location of (y_C, z_C) reached its ultimate strength, σ_C^u , namely for Case 1

$$M_V^u|_{CASE\ 1} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \sigma_C^u \quad (12)$$

And for Case 2

$$M_V^u|_{CASE\ 2} = \frac{I_{VV}}{(z_C - z_G)} \sigma_C^u \quad (13)$$

Therefore, the reduction rate of the residual strength due to the rotation of the neutral axis in the framework of the proposed approximate approach is given by ratio of Eq. (12) to Eq. (13) as

$$\frac{M_V^u|_{CASE\ 1}}{M_V^u|_{CASE\ 2}} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \frac{(z_C - z_G)}{I_{VV}} \quad (14)$$

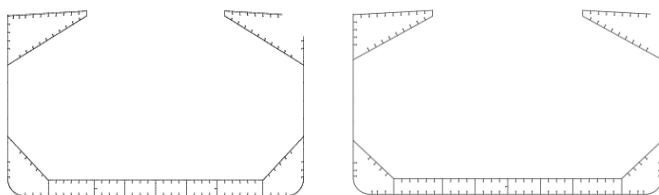
CASE STUDY

Two single-hull bulk carriers, B1 and B2, and one double-hull oil tanker, T2, are taken as the subject ships as shown in Table 1. Ship B1 is designed according to Pre-UR rule and built in 1987 and Ship B2 according to CSR-B having larger cross section and scantling sizes. Ship T2 is designed according to CSR-T.

Table 1 Subject ships

Ship	B1	B2	T2
L (mm)	217,000	219,000	234,000
B (mm)	32,236	32,240	44,000
D (mm)	18,300	19,900	21,200
Design criteria	Pre-IACS UR	IACS CSR-B	IACS CSR-T

The damage of the upper part of side shell due to collision is assumed. The vertical damage extent is taken as 10%, 20%, 40% and 70% of the depth D for both bulk carriers and tanker. The horizontal damage extent is taken as $B/16$, and it is kept constant for all damaged cases. The damaged cross sections of Ship B1 are illustrated in Fig. 2 and those of Ship T2 in Fig. 3. The stiffness of the elements in the damaged area is completely removed. For the double hull tanker, only outer side shell is assumed to be damaged. The locations of the critical deck element are presented in Fig. 4 for single hull bulk carrier and double hull oil tanker, respectively.



(a) 10% damage

(b) 20% damage

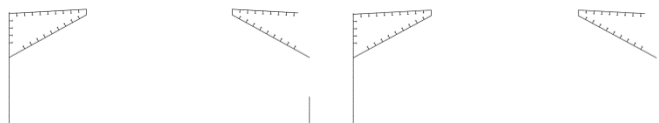
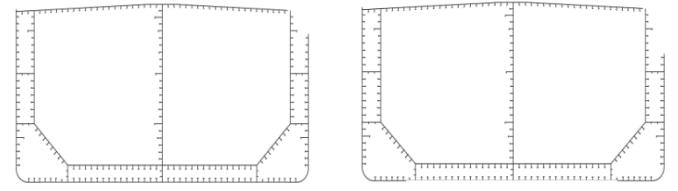
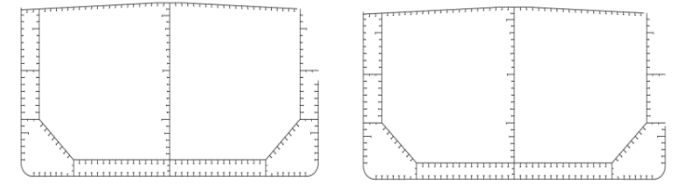


Fig. 2 Single hull bulk carrier (Ship B1)



(a) 10% damage

(b) 20% damage

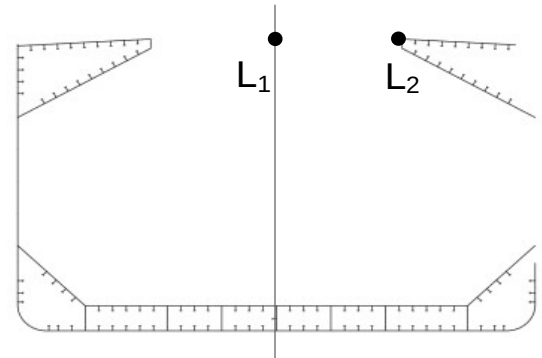


(c) 40% damage

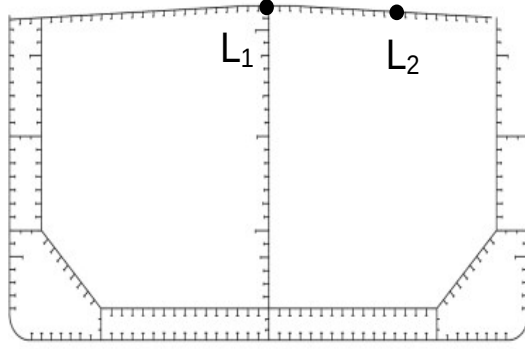
(d) 70% damage

Fig. 3 Double hull oil tanker (Ship T2)

The investigation of the residual hull girder strength under sagging condition is performed by taking two locations of the critical deck elements as shown in Fig. 4. For Single hull bulk carriers (B1 and B2), the locations of the critical element are L_1 and L_2 . L_1 is located at the center line and L_2 at the hatch coaming on the damage side. For the case of double hull oil tanker (T2), L_1 is located at the center line and L_2 at the distance of $B/4$ from the damaged side shell. As for the critical stress, the maximum stress of elements located at points L_1 and/or L is used.



(a) Single hull bulk carrier



(b) Double hull oil tanker

Fig. 4 Locations of the critical deck elements

RESULT AND DISCUSSION

In sagging condition, it is well recognized that the ultimate hull girder strength is almost attained when the primary deck members in longitudinal compression reached their ultimate strength. Also, because the damage takes place at the asymmetric position, in other word, collision damage is placed at the side shell through to the deck part (B/16) and there is no damage located at the bottom part, so that it is very important to investigate the critical member under sagging condition. In the present study, the ultimate strength is analyzed after damage has taken place. The water ingress is not considered in the analysis.

The results obtained by progressive collapse analysis under sagging condition for 20% and 70% damage are presented in Fig. 5 and Fig. 6, respectively. Case 1 considers the rotation of neutral axis and Case 2 does not. The resultant of bending moment versus curvature is plotted.

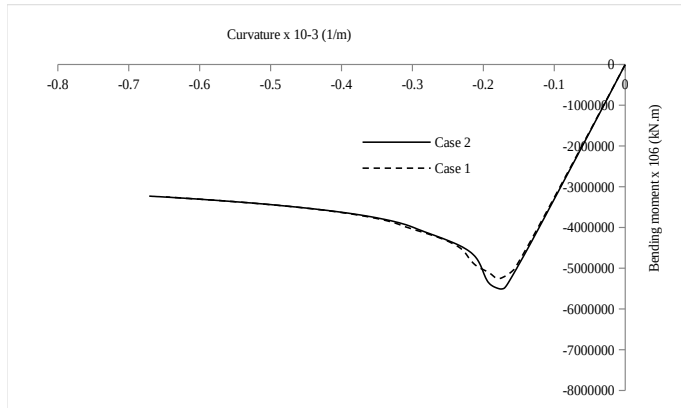


Fig. 5 Single hull bulk carrier (Ship B1) with 20% damage

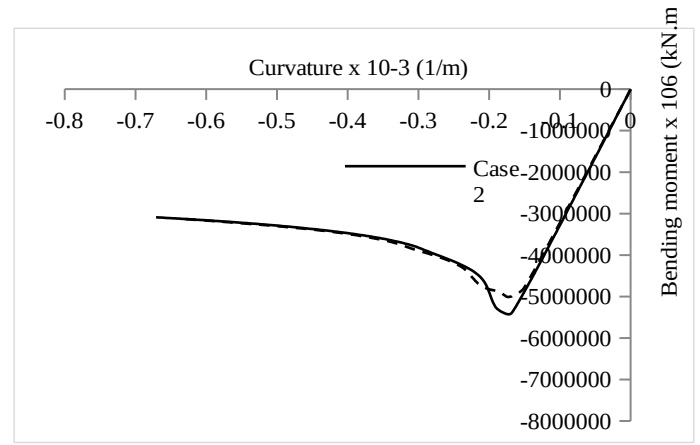


Fig. 6 Single hull bulk carrier (Ship B1) with 70% damage

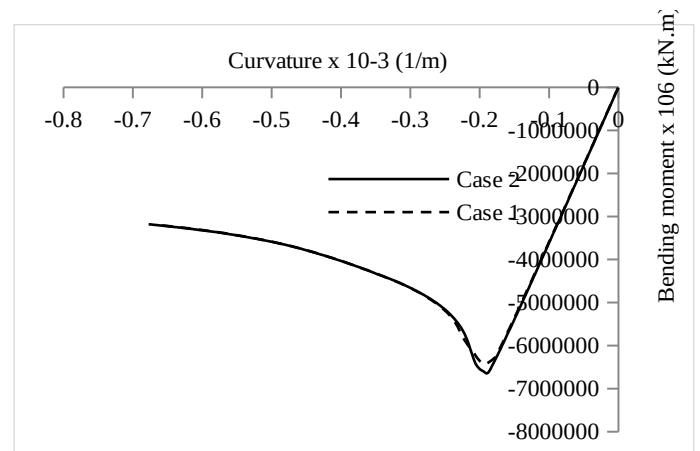


Fig. 7 Single hull bulk carrier (Ship B2) with 20% damage

Similarly, the resultant bending moment and curvature curve for Ship B2 and Ship T2 with 20% and 70% damage are presented in Figs. 7 through 10.

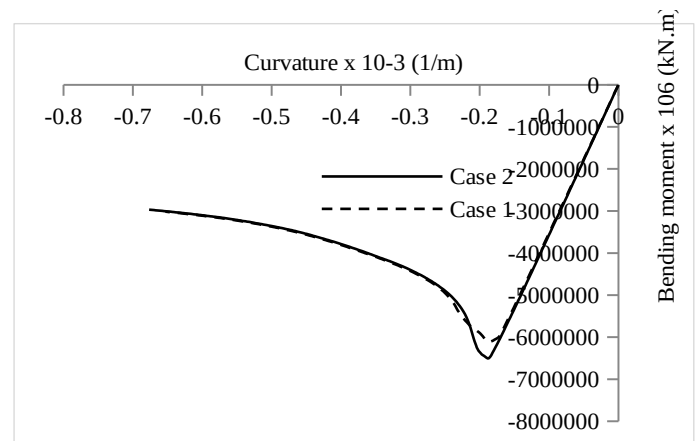


Fig. 8 Single hull bulk carrier (Ship B2) with 70% damage

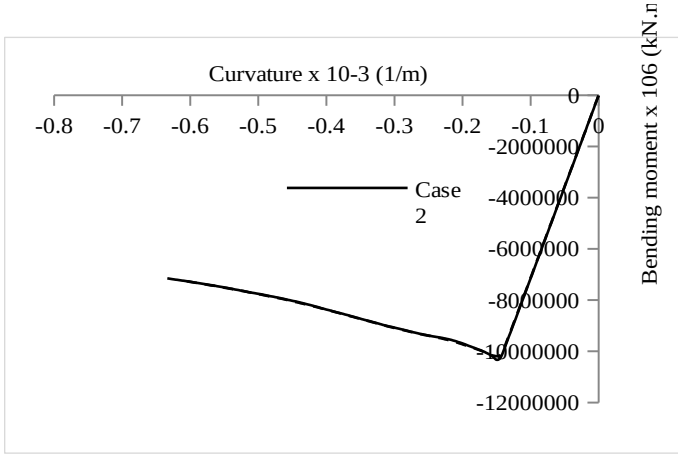


Fig. 9 Double hull oil tanker (Ship T2) with 20% damage

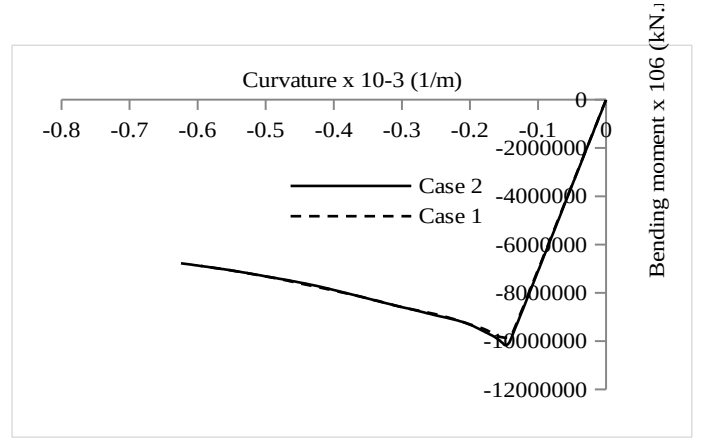


Fig. 10 Double hull oil tanker (T2) with 70% damage

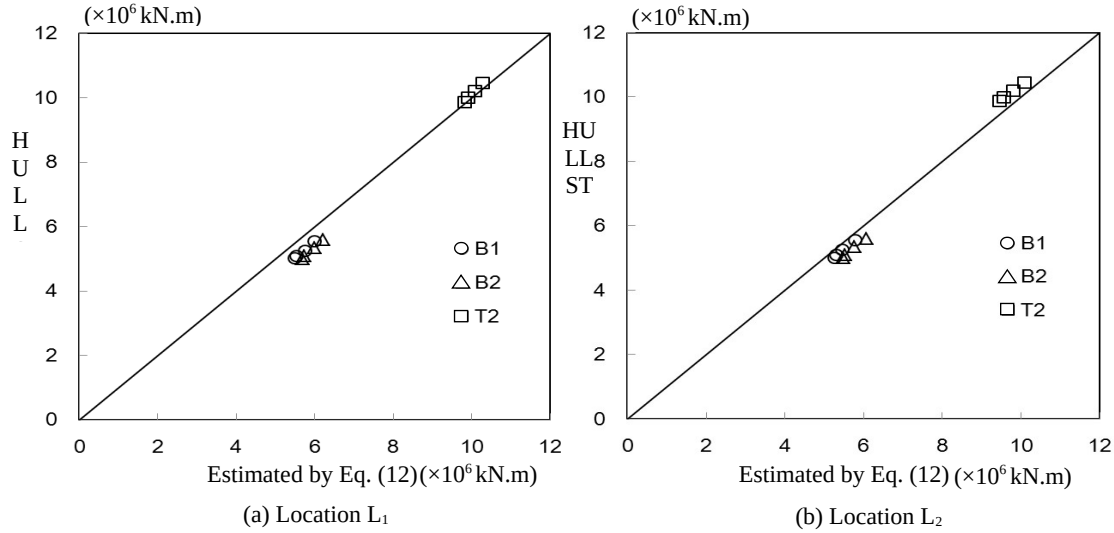


Fig. 11 Comparison of residual hull girder strength M_V between the simplified method and the progressive collapse analysis. Fig. 7 and Fig. 8 shows the results of the moment-curvature relationship obtained by progressive collapse analysis for single hull bulk carrier (B2). It is found that Case 2 generally gives higher ultimate strength than Case 1 because the horizontal curvature is constrained. The ultimate hull girder strength is attained even the horizontal curvature is constrained because of the horizontal bending moment is induced by the incremental equation for horizontal and vertical bending moments and this makes the ultimate hull girder strength becomes higher. The effect of constraint is the largest in Ship B1, and is smaller in Ship B2. For Ship B1, Case 1 strength is 7.3% smaller than Case 2 in sagging condition. The difference between Ship B1 and Ship B2 may be attributed to that of the depth to breadth ratio, member scantlings etc. Fig. 9 and Fig. 10 represent the moment-curvature relationship under sagging condition for double hull oil tanker (T2) for 20% and 70% of damages, respectively. According to the result obtained by progressive collapse analysis of double hull oil tanker (Ship T2), the effect of rotation of neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

The residual strengths of Ship B1, Ship B2 and Ship T2 obtained for the four different damage extents are summarized in Fig. 11. It is found that Eq. (11) gives an estimate of the residual strength which is in good agreement with the result of the progressive collapse analysis.

For bulk carriers, the critical element at the location L_2 gives a better estimate of the residual strength. For the location of L_1 of bulk carriers, the ultimate strength of critical element is evaluated by using that of the element at L_2 . This is consistent with the observed collapse behavior in which the ultimate strength is attained when topside tank region of the damaged side almost fully failed. In the case of a double hull tanker, the location L_1 gives better estimate of the residual strength than L_2 . This is also consistent with the failure behavior of T2 in which the ultimate strength is attained when the deck part almost fully failed.

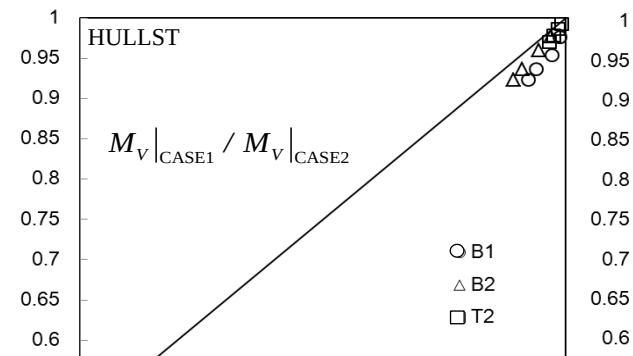


Fig. 12 Comparison of reduction ratio of residual hull girder due to rotation of neutral axis between the simplified method and the progressive collapse analysis (Case 1/Case 2)

CONCLUSIONS

Progressive collapse analysis was performed on two single hull bulk carriers and a double hull oil tanker with asymmetrically damaged cross section applying Smith's method. A closed form formulae of residual strength and that of the reduction ratio of the residual strength considering the rotation of neutral axis are proposed. It is found through a comparison with the results obtained by the progressive collapse analysis that the residual hull girder strength of asymmetrically damaged ships under sagging bending moment can be predicted by the proposed formulae with a reasonable accuracy. The ultimate strength obtained with the horizontal curvature constrained is larger than that without constraint one. The effect of the rotation of neutral axis is the largest for single hull bulk carrier and almost negligible for double hull oil tanker. The difference characteristic for two single hull bulk carrier may be related to that of the depth to breadth ratio, member scantlings etc.

The resultant of bending moment is induced by the accumulation of the horizontal and vertical bending moment based on the reference coordinate system. Fig. 12 shows the comparison of the reduction rates of the residual strength due to rotation of the neutral axis obtained by Eq. (14) and progressive collapse analysis. The influence of the rotation of the neutral axis is larger for a larger damage extent in general. For the case of the subject ships and damages under consideration, the influence is larger in bulk carriers than in tankers. Eq. (14) gives a relatively good estimate of the reduction rate. It can be a good basis of a rational expression of the influence of the rotation of the neutral axis on the reserve ultimate hull girder strength, as required in ship structures. More systematic analyses are definitely needed to develop the formula having larger applicability in ship types and damaged cases.

According to the result obtained by progressive collapse analysis of double hull oil tanker, the effect of rotation of neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

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Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships

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ABSTRACT

The objective of the present study is to investigate the ultimate hull girder strength of asymmetrically damaged ship under sagging condition. Two kinds of ships are taken as the object of the analysis. The cross section of the ship is considered and assumed to be remained plane. The simply supported boundary condition is applied to both sides of the cross section. The ultimate hull girder strength is attained when a plate and/or stiffened plate element at the specified location called “critical element” reach their ultimate strength. To investigate the ultimate hull girder strength, a simplified approach is proposed. The result obtained by simplified approach is compared to the progressive collapse analysis to determine effectiveness and for validation.

KEY WORDS: Single hull bulk carrier, double hull oil tanker, cross section, neutral axis, asymmetrically damaged, ultimate strength, simplified approach.

INTRODUCTION

The ability to predict accurately the ultimate strength of ship hull girder when subjected to longitudinal bending is one of the most important aspects of ship structural design. A collision and grounding damages may takes place on ship's hull, which may threaten safety of ships and surrounding environment. In this regard, to enhance the safety of ship's structure and minimize the risks, the International Maritime Organization (IMO, 2009) has required in Goal Based Standard for New Ship Construction (GBS) to consider the residual strength of the hull girder in specified damage conditions as one of the functional requirements for the structural rules for bulk carriers and tankers.

Many studies have been conducted on the analyses of the residual hull girder strength due to collision and grounding damages. Pedersen (1994) presented a mathematical modeling to estimate the contact pressure between the grounded ship and the sea bottom. The grounding contact force was compared to the force which would crush the forward bottom of the ship. The sectional bending moment due to grounding was determined and compared to the ultimate hull girder strengths. The model experiments and full-scale controlled grounding experiments were also performed to validate the mathematical model. Paik et al. (1998) developed a rapid procedure to identify the possibility of hull girder failure after collision and grounding damages based on the closed-form formulae of the ultimate hull girder strength and section modulus after the damages. Soares et al. (2008) evaluated the ability of simplified structural analysis methods based on the Smith's formulation to predict the ultimate strength of damage ship's hull. Muis Alie, M.Z et al. (2016) investigated the influence of the superstructure to the ultimate strength of Ro-Ro ship under vertical bending moment. The cross section was considered to be analyzed. The result obtained by beam theory with and without superstructure were compared with one another. The assessment of the ultimate hull girder strength was conducted by Muis Alie, M.Z et al. (2017). The

cross section of Ro-Ro ship was taken to be analyzed. The collision and grounding damages were assumed to be located on the side and bottom area, respectively. The damages were created by removing the element from the side shell and bottom part. Ohtsubo et al. (1994) showed the experimental and numerical works on the ship structural damages due to collision and grounding. This was one of the first attempts to apply the explicit Finite Element Method codes, such as LS-DYNA and MSC DYTRAN, to the collision and grounding problems of ships. Oztug et al. (2005) investigated the collision resistance and residual strength of single skin and double skin bulk carriers subjected to damages. Notaro et al. (2010) carried out full nonlinear FE assessments of hull girder capacity in intact and damage conditions. The effects of several influential factor such as model extend and complexity, damage representations and model imperfections were investigated on the different vessels. It was found that the effect of damage extent in vertical direction is more critical than in longitudinal direction, and the damage varies according to the location of the neutral axes including higher stresses in proximity of the damage areas. The various probability levels were considered for the damage extent estimation.

When a hull-girder cross section is symmetric with respect to the centerline and subjected to pure vertical bending moment, the neutral axis for vertical bending is always horizontal and moves only vertically during the progressive collapse behavior. However, when the cross section is asymmetrically damaged, for example, due to a collision, the neutral axis rotates. Both rotation and translation need to be taken into account during the progressive collapse behavior even when only a vertical bending moment is applied, and the problem needs to be treated as a biaxial bending problem. Previous studies using the Smith's method on the ultimate strength of hull girders under biaxial thrust (Oztug and Barltrop, 2008) and the residual strength of damaged hulls (Fang and Das, 2004; Hussein and Guedes Soares, 2009; Choung et al, 2011) consider the rotation and translation of neutral axis in a reasonable way. However, they employ a trial and error approach to detect the position of neutral axis. More easy approach to detect the position of neutral axis is suggested.

BASIC ASSUMPTION

1 The following assumption is made for the prediction of the residual hull girder strength under the sagging condition:

- (1) The ultimate sagging strength is attained when a stiffened panel element at the specified location (hereafter called ‘critical element’) reached the ultimate strength.
- (2) The hull girder cross section is elastic until the failure of the critical member.
- (3) The ultimate strength of the critical member is predicted from the average axial stress and average axial strain relationship calculated by HULLST (Yao and Nikolov, 1992).

EFFECT OF NEUTRAL AXIS ROTATION ON ESTIMATION OF THE ULTIMATE HULL GIRDER STRENGTH

In the elastic cross section, the bending stress at the i -th element (see Fig.1), σ_i , is expressed as

$$\sigma_i = E \left[(y_i - y_G) \phi_H + (z_i - z_G) \phi_V \right] \quad (1)$$

where E is Young's modulus, y_G and z_G the centroid coordinates, and ϕ_H and ϕ_V the horizontal and vertical curvatures, respectively. y_G and z_G are given by

$$y_G = \frac{\left(\sum_{i=1}^N y_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (2)$$

$$z_G = \frac{\left(\sum_{i=1}^N z_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (3)$$

where D_i , A_i , and (y_i, z_i) are the tangential stiffness obtained as a slope of the average stress-average strain curve, cross sectional area and the coordinates of the centroid of individual elements, respectively.

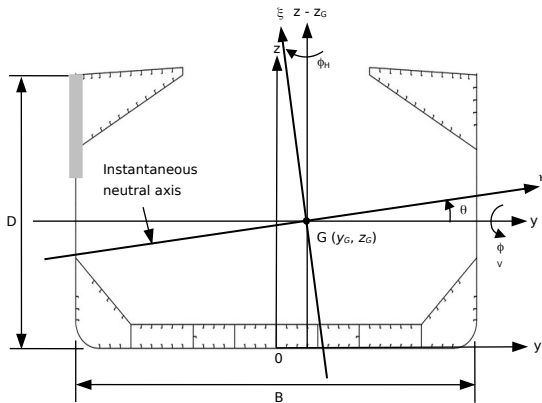


Fig. 1 Neutral axes of the elastic hull girder cross section with asymmetric damage

For the case of asymmetrically damaged cross section, Eqs (4) through (8) are used, and for the intact one, the expressions are given in Eqs (9) and (10). The biaxial moment and curvature relationship is given in the form

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (4)$$

where

$$\begin{aligned} I_{HV} &= I_{VH} = \sum_{i=1}^N (y_i - y_G)(z_i - z_G) A_i \\ I_{HH} &= \sum_{i=1}^N (y_i - y_G)^2 A_i \\ I_{VV} &= \sum_{i=1}^N (z_i - z_G)^2 A_i \end{aligned} \quad (5)$$

where I and M are the moment of inertia and bending moment, respectively. When the vertical bending moment M_V is applied to the cross section with no constraint on the horizontal curvature (Case 1), the horizontal curvature as well as the vertical curvature is induced under the condition of horizontal bending moment $M_H = 0$. The incremental equation to be solved is

$$\begin{Bmatrix} 0 \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (6)$$

Therefore,

$$\begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} = \frac{1}{E(I_{HH} I_{VV} - I_{HV}^2)} \begin{Bmatrix} -I_{HV} M_V \\ I_{HH} M_V \end{Bmatrix} \quad (7)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{-(y_i - y_G) I_{HV} + (z_i - z_G) I_{HH}}{(I_{HH} I_{VV} - I_{HV}^2)} M_V \quad (8)$$

The terms including the moment of inertia, I_{HV} , represent the effect of the rotation of the neutral axis.

On the other hand, when the vertical bending moment is applied to the cross section with the horizontal curvature constrained (Case 2), the bending moment are induced under the condition of $\phi_H = 0$, that is,

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} 0 \\ \phi_V \end{Bmatrix} \quad (9)$$

Therefore,

$$\phi_V = \frac{M_V}{EI_{VV}} \quad (10)$$

Substituting Eq. (10) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{(z_i - z_G)}{I_{VV}} M_V \quad (11)$$

Here, it is assumed that the residual hull girder strength in the sagging condition M_V^u is attained when a critical member at the location of (y_C, z_C) reached its ultimate strength, σ_C^u , namely for Case 1

$$M_V^u|_{CASE\ 1} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \sigma_C^u \quad (12)$$

And for Case 2

$$M_V^u|_{CASE\ 2} = \frac{I_{VV}}{(z_C - z_G)} \sigma_C^u \quad (13)$$

Therefore, the reduction rate of the residual strength due to the rotation of the neutral axis in the framework of the proposed approximate approach is given by ratio of Eq. (12) to Eq. (13) as

$$\frac{M_V^u|_{CASE\ 1}}{M_V^u|_{CASE\ 2}} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \frac{(z_C - z_G)}{I_{VV}} \quad (14)$$

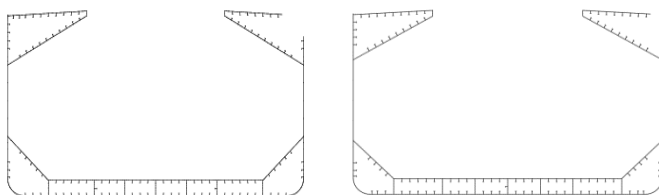
CASE STUDY

Two single-hull bulk carriers, B1 and B2, and one double-hull oil tanker, T2, are taken as the subject ships as shown in Table 1. Ship B1 is designed according to Pre-UR rule and built in 1987 and Ship B2 according to CSR-B having larger cross section and scantling sizes. Ship T2 is designed according to CSR-T.

Table 1 Subject ships

Ship	B1	B2	T2
L (mm)	217,000	219,000	234,000
B (mm)	32,236	32,240	44,000
D (mm)	18,300	19,900	21,200
Design criteria	Pre-IACS UR	IACS CSR-B	IACS CSR-T

The damage of the upper part of side shell due to collision is assumed. The vertical damage extent is taken as 10%, 20%, 40% and 70% of the depth D for both bulk carriers and tanker. The horizontal damage extent is taken as $B/16$, and it is kept constant for all damaged cases. The damaged cross sections of Ship B1 are illustrated in Fig. 2 and those of Ship T2 in Fig. 3. The stiffness of the elements in the damaged area is completely removed. For the double hull tanker, only outer side shell is assumed to be damaged. The locations of the critical deck element are presented in Fig. 4 for single hull bulk carrier and double hull oil tanker, respectively.



(a) 10% damage

(b) 20% damage

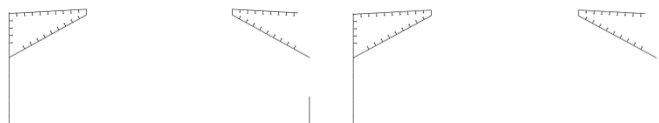
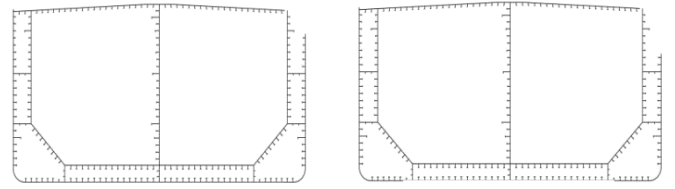
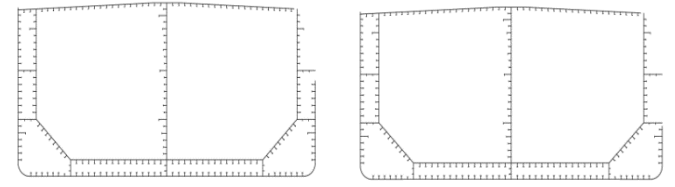


Fig. 2 Single hull bulk carrier (Ship B1)



(a) 10% damage

(b) 20% damage

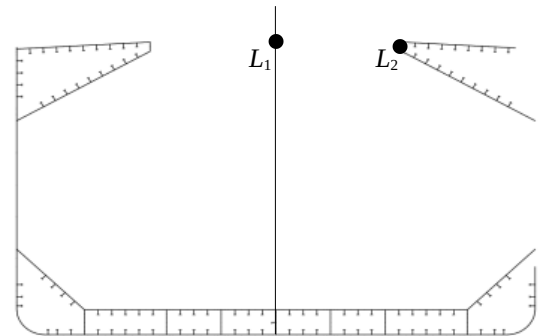


(c) 40% damage

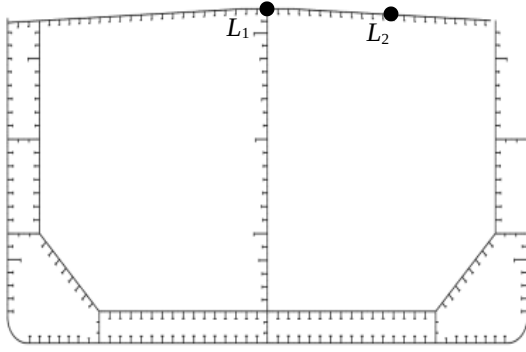
(d) 70% damage

Fig. 3 Double hull oil tanker (Ship T2)

The investigation of the residual hull girder strength under sagging condition is performed by taking two locations of the critical deck elements as shown in Fig. 4. For Single hull bulk carriers (B1 and B2), the locations of the critical element are L_1 and L_2 . L_1 is located at the center line and L_2 at the hatch coaming on the damage side. For the case of double hull oil tanker (T2), L_1 is located at the center line and L_2 at the distance of $B/4$ from the damaged side shell. As for the critical stress, the maximum stress of elements located at points L_1 and/or L is used.



(a) Single hull bulk carrier



(b) Double hull oil tanker

Fig. 4 Locations of the critical deck elements

RESULT AND DISCUSSION

In sagging condition, it is well recognized that the ultimate hull girder strength is almost attained when the primary deck members in longitudinal compression reached their ultimate strength. Also, because the damage takes place at the asymmetric position, in other word, collision damage is placed at the side shell through to the deck part (B/16) and there is no damage located at the bottom part, so that it is very important to investigate the critical member under sagging condition. In the present study, the ultimate strength is analyzed after damage has taken place. The water ingress is not considered in the analysis.

The results obtained by progressive collapse analysis under sagging condition for 20% and 70% damage are presented in Fig. 5 and Fig. 6, respectively. Case 1 considers the rotation of neutral axis and Case 2 does not. The resultant of bending moment versus curvature is plotted.

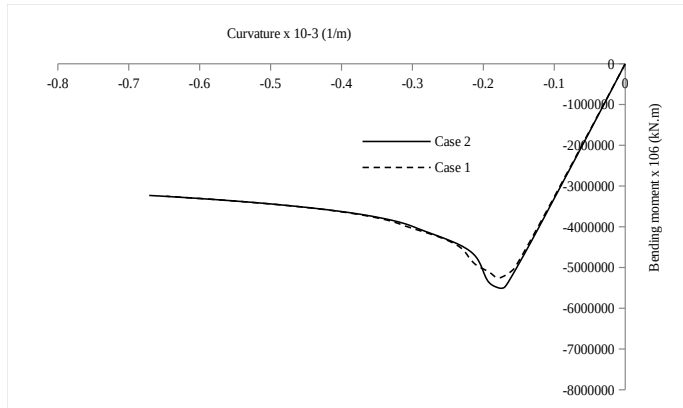


Fig. 5 Single hull bulk carrier (Ship B1) with 20% damage

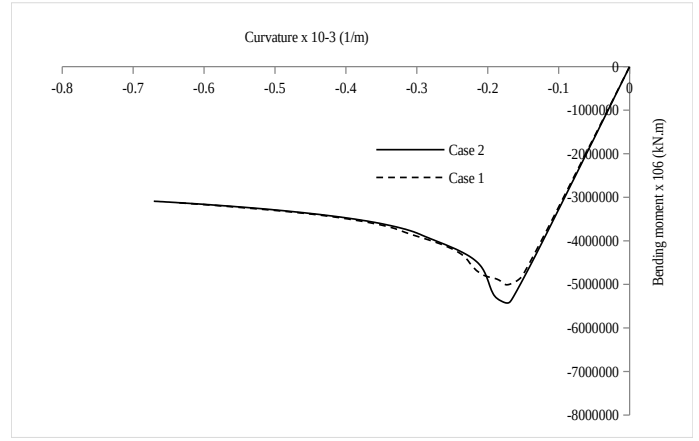


Fig. 6 Single hull bulk carrier (Ship B1) with 70% damage

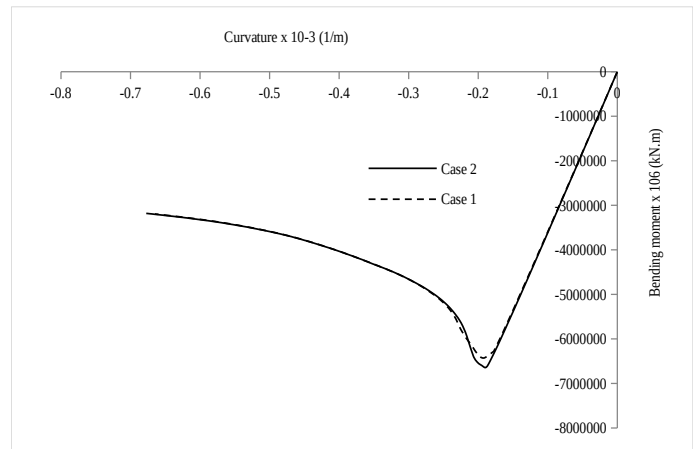


Fig. 7 Single hull bulk carrier (Ship B2) with 20% damage

Similarly, the resultant bending moment and curvature curve for Ship B2 and Ship T2 with 20% and 70% damage are presented in Figs. 7 through 10.

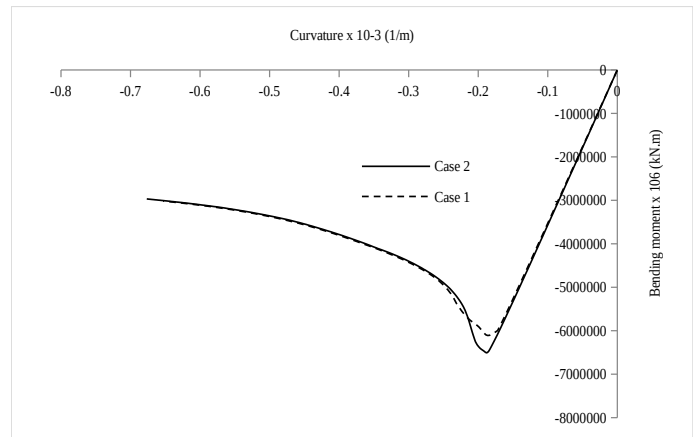


Fig. 8 Single hull bulk carrier (Ship B2) with 70% damage

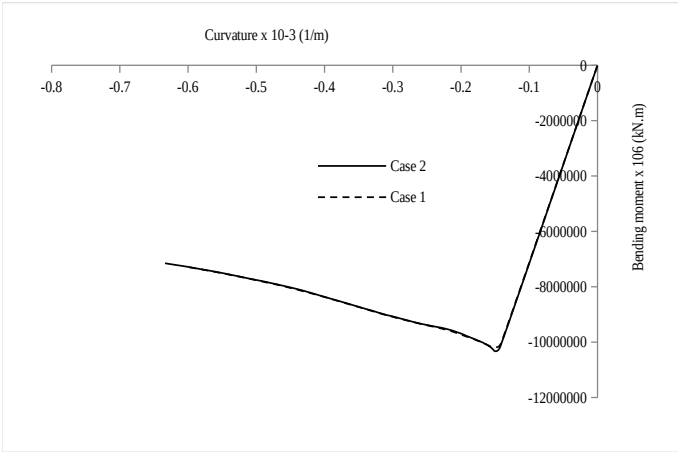


Fig. 9 Double hull oil tanker (Ship T2) with 20% damage

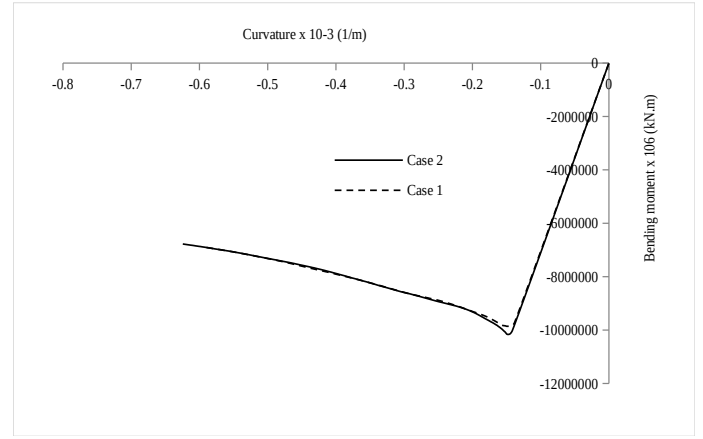


Fig. 10 Double hull oil tanker (T2) with 70% damage

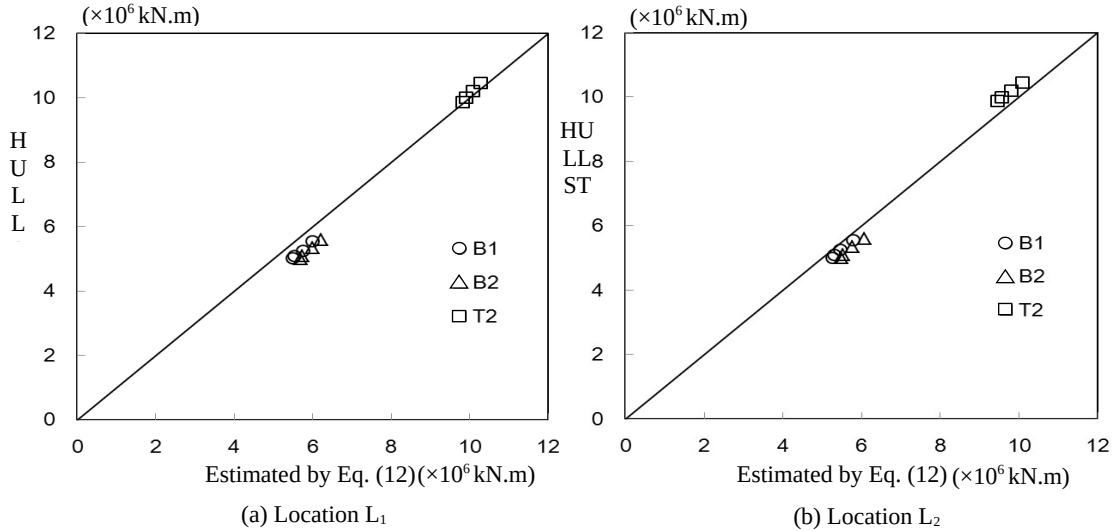


Fig. 11 Comparison of residual hull girder strength M_V between the simplified method and the progressive collapse analysis. Fig. 11 shows the results of the moment-curvature relationship obtained by progressive collapse analysis for single hull bulk carrier (B2). It is found that Case 2 generally gives higher ultimate strength than Case 1 because the horizontal curvature is constrained. The ultimate hull girder strength is attained even the horizontal curvature is constrained because of the horizontal bending moment is induced by the incremental equation for horizontal and vertical bending moments and this makes the ultimate hull girder strength becomes higher. The effect of constraint is the largest in Ship B1, and is smaller in Ship B2. For Ship B1, Case 1 strength is 7.3% smaller than Case 2 in sagging condition. The difference between Ship B1 and Ship B2 may be attributed to that of the depth to breadth ratio, member scantlings etc. Fig. 9 and Fig. 10 represent the moment-curvature relationship under sagging condition for double hull oil tanker (T2) for 20% and 70% of damages, respectively. According to the result obtained by progressive collapse analysis of double hull oil tanker (Ship T2), the effect of rotation of neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

The residual strengths of Ship B1, Ship B2 and Ship T2 obtained for the four different damage extents are summarized in Fig. 11. It is found that Eq. (11) gives an estimate of the residual strength which is in good agreement with the result of the progressive collapse analysis. For bulk carriers, the critical element at the location L_2 gives a better estimate of the residual strength. For the location of L_1 of bulk carriers, the ultimate strength of critical element is evaluated by using that of the element at L_2 . This is consistent with the observed collapse behavior in which the ultimate strength is attained when topside tank region of the damaged side almost fully failed. In the case of a double hull tanker, the location L_1 gives better estimate of the residual strength than L_2 . This is also consistent with the failure behavior of T2 in which the ultimate strength is attained when the deck part almost fully failed.

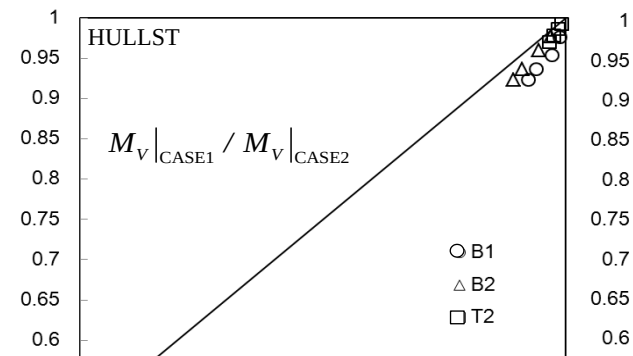


Fig. 12 Comparison of reduction ratio of residual hull girder due to rotation of neutral axis between the simplified method and the progressive collapse analysis (Case 1/Case 2)

CONCLUSIONS

Progressive collapse analysis was performed on two single hull bulk carriers and a double hull oil tanker with asymmetrically damaged cross section applying Smith's method. A closed form formulae of residual strength and that of the reduction ratio of the residual strength considering the rotation of neutral axis are proposed. It is found through a comparison with the results obtained by the progressive collapse analysis that the residual hull girder strength of asymmetrically damaged ships under sagging bending moment can be predicted by the proposed formulae with a reasonable accuracy. The ultimate strength obtained with the horizontal curvature constrained is larger than that without constraint one. The effect of the rotation of neutral axis is the largest for single hull bulk carrier and almost negligible for double hull oil tanker. The difference characteristic for two single hull bulk carrier may be related to that of the depth to breadth ratio, member scantlings etc.

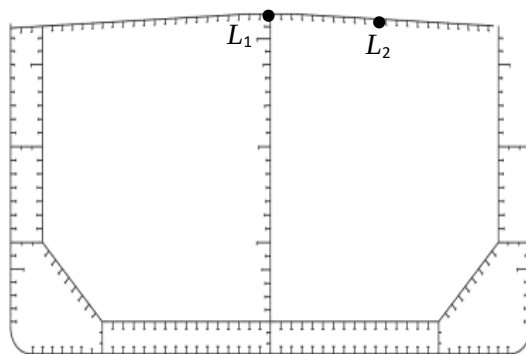
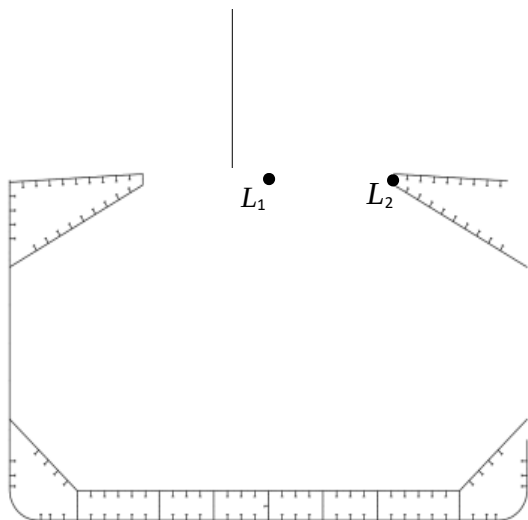
The resultant of bending moment is induced by the accumulation of the horizontal and vertical bending moment based on the reference coordinate system. Fig. 12 shows the comparison of the reduction rates of the residual strength due to rotation of the neutral axis obtained by Eq. (14) and progressive collapse analysis. The influence of the rotation of the neutral axis is larger for a larger damage extent in general. For the case of the subject ships and damages under consideration, the influence is larger in bulk carriers than in tankers. Eq. (14) gives a relatively good estimate of the reduction rate. It can be a good basis of a rational expression of the influence of the rotation of the neutral axis on the reserve ultimate hull girder strength, as required in ship structures. More systematic analyses are definitely needed to develop the formula having larger applicability in ship types and damaged cases.

According to the result obtained by progressive collapse analysis of double hull oil tanker, the effect of rotation of neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

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Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships

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The objective of the present study is to investigate the ultimate hull girder strength of an asymmetrically damaged ship under a sagging condition. Two kinds of ships are taken as the object of analysis. The cross section of the ship is considered and assumed to have remained plane. The simply supported boundary condition is applied to both sides of the cross-section. The ultimate hull girder strength is attained when a plate and/or stiffened plate element at the specified location called “critical element” reach its ultimate strength. To investigate the ultimate hull girder strength, a simplified approach is proposed. The result obtained by the simplified approach is compared with the progressive collapse analysis to determine effectiveness and for validation.

INTRODUCTION

The ability to predict accurately the ultimate strength of ship hull girder when subjected to longitudinal bending is one of the most important aspects of ship structural design. Collision and grounding damage may take place on the ship's hull, which may threaten safety of ships and surrounding environment. In this regard, to enhance the safety of ship's structure and minimize the risks, the International Maritime Organization (IMO, 2009) has required in Goal Based Standard for New Ship Construction (GBS) to consider the residual strength of the hull girder in specified damage conditions as one of the functional requirements for the structural rules for bulk carriers and tankers.

Many studies have been conducted on the analyses of the residual hull girder strength as a result of collision and grounding damages. Pedersen (1994) presented a mathematical model to estimate the contact pressure between the grounded ship and the sea bottom. The grounding contact force was compared with the force that would crush the forward bottom of the ship. The sectional bending moment due to grounding was determined and compared with the ultimate hull girder strengths. The model experiments and full-scale controlled grounding experiments were also performed to validate the mathematical model. Paik et al. (1998) developed a rapid procedure to identify the possibility of hull girder failure after collision and grounding damages based on the closed-form formulae of the ultimate hull girder strength and section modulus after the damages. Guedes Soares et al. (2008) evaluated the ability of simplified structural analysis methods based on Smith's formulation to predict the ultimate strength of damaged ship's hull. Muis Alie et al. (2016) investigated the influence of the superstructure on the ultimate strength of Ro-Ro ship under a vertical bending moment. The cross section was considered to be analyzed. The results obtained by beam theory with and without superstructure were compared with one another. The assessment of the ultimate hull girder strength was conducted by Muis Alie

et al. (2017). The cross-section of Ro-Ro ship was taken to be analyzed. The collision and grounding damages were assumed to be located on the side and bottom areas, respectively. The damages were created by removing the element from the side shell and bottom part. Ohtsubo et al. (1994) showed the experimental and numerical works on the ship structural damages due to collision and grounding. This was one of the first attempts to apply the explicit finite element method codes, such as LS-DYNA and MSC Dytran, to the collision and grounding problems of ships. Özgüç et al. (2005) investigated the collision resistance and residual strength of single-skin and double-skin bulk carriers subjected to damages. Notaro et al. (2010) carried out full nonlinear finite element assessments of hull girder capacity in intact and damage conditions. The effects of several influential factors such as model extend and complexity, damage representations, and model imperfections were investigated on the different vessels. It was found that the effect of damage extent in a vertical direction is more critical than in a longitudinal direction, and the damage varies according to the location of the neutral axes including higher stresses in proximity of the damage areas. The various probability levels were considered for the damage extent estimation.

When a hull-girder cross-section is symmetric with respect to the centerline and subjected to pure vertical bending moment, the neutral axis for vertical bending is always horizontal and moves only vertically during the progressive collapse behavior. However, when the cross-section is asymmetrically damaged, for example, because of a collision, the neutral axis rotates. Both rotation and translation need to be taken into account during the progressive collapse behavior even when only a vertical bending moment is applied, and the problem needs to be treated as a biaxial bending problem. Previous studies using the Smith's method on the ultimate strength of hull girders under biaxial thrust (Özgüç and Barltrop, 2008) and the residual strength of damaged hulls (Fang and Das, 2004; Hussein and Guedes Soares, 2009; Choung et al., 2011) consider the rotation and translation of neutral axis in a reasonable way. However, they employ a trial-and-error approach to detect the position of neutral axis. An easier approach to detect the position of neutral axis is suggested.

BASIC ASSUMPTION

The following assumption is made for the prediction of the residual hull girder strength under the sagging condition:

*ISOPE Member.

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KEY WORDS: Single hull bulk carrier, double hull oil tanker, cross section, neutral axis, asymmetrically damaged, ultimate strength, simplified approach.

(1) The ultimate sagging strength is attained when a stiffened panel element at the specified location (hereafter called “critical element”) reached the ultimate strength.

(2) The hull girder cross-section is elastic until the failure of the critical member.

(3) The ultimate strength of the critical member is predicted from the average axial stress and average axial strain relationship calculated by HULLST (Yao and Nikolov, 1992).

EFFECT OF NEUTRAL AXIS ROTATION ON THE ESTIMATION OF THE ULTIMATE HULL GIRDER STRENGTH

In the elastic cross section, the bending stress at the i -th element (see Fig. 1), σ_i , is expressed as

$$\sigma_i = E\{(y_i - y_G)\phi_H + (z_i - z_G)\phi_V\} \quad (1)$$

where E is Young's modulus, y_G and z_G the centroid coordinates, and ϕ_H and ϕ_V the horizontal and vertical curvatures, respectively. y_G and z_G are given by

$$y_G = \frac{\sum_{i=1}^N y_i D_i A_i}{\sum_{i=1}^N D_i A_i} \quad (2)$$

$$z_G = \frac{\sum_{i=1}^N z_i D_i A_i}{\sum_{i=1}^N D_i A_i} \quad (3)$$

where D_i , A_i , and (y_i, z_i) are the tangential stiffness obtained as a slope of the average stress-average strain curve, cross-sectional area and the coordinates of the centroid of individual elements, respectively.

For the case of an asymmetrically-damaged cross-section, Eqs. 4 through 8 are used, and for the intact one, the expressions are given in Eqs. 9 and 10. The biaxial moment and curvature relationship is given in the form

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (4)$$

where

$$\begin{aligned} I_{HV} &= I_{VH} = \sum_{i=1}^N (y_i - y_G)(z_i - z_G)A_i, \\ I_{HH} &= \sum_{i=1}^N (y_i - y_G)^2 A_i, \\ I_{VV} &= \sum_{i=1}^N (z_i - z_G)^2 A_i \end{aligned} \quad (5)$$

where I and M are the moment of inertia and bending moment, respectively. When the vertical bending moment M_V is applied to the cross-section with no constraint on the horizontal curvature (Case 1), the horizontal curvature as well as the vertical curvature is induced under the condition of horizontal bending moment $M_H = 0$. The incremental equation to be solved is

$$\begin{Bmatrix} 0 \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (6)$$

Therefore,

$$\begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} = \frac{1}{E(I_{HH}I_{VV} - I_{HV}^2)} \begin{Bmatrix} -I_{HV}M_V \\ I_{HH}M_V \end{Bmatrix} \quad (7)$$

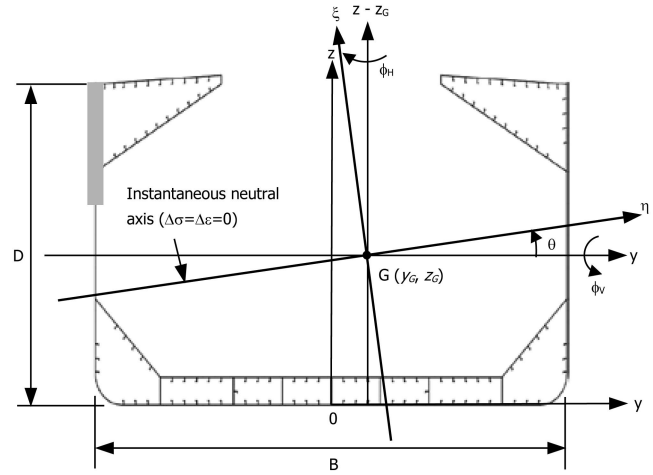


Fig. 1 Neutral axes of the elastic hull girder cross-section with asymmetric damage

Substituting Eq. 7 to Eq. 1, the bending stress σ_i is given by

$$\sigma_i = \frac{-(y_i - y_G)I_{HV} + (z_i - z_G)I_{HH}}{I_{HH}I_{VV} - I_{HV}^2} M_V \quad (8)$$

The terms including the moment of inertia, I_{HV} , represent the effect of the rotation of the neutral axis.

On the other hand, when the vertical bending moment is applied to the cross-section with the horizontal curvature constrained (Case 2), the bending moment is induced under the condition of $\phi_H = 0$, that is,

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} 0 \\ \phi_V \end{Bmatrix} \quad (9)$$

Therefore,

$$\phi_V = \frac{M_V}{EI_{VV}} \quad (10)$$

Substituting Eq. 10 to Eq. 1, the bending stress σ_i is given by

$$\sigma_i = \frac{z_i - z_G}{I_{VV}} M_V \quad (11)$$

Here, it is assumed that the residual hull girder strength in the sagging condition M_V^u is attained when a critical member at the location of (y_C, z_C) reached its ultimate strength, σ_C^u , namely for Case 1:

$$M_V^u \Big|_{\text{CASE 1}} = \frac{I_{HH}I_{VV} - I_{HH}^2}{-(y_C - y_G)I_{HV} + (z_C - z_G)I_{HH}} \sigma_C^u \quad (12)$$

And for Case 2:

$$M_V^u \Big|_{\text{CASE 2}} = \frac{I_{VV}}{z_C - z_G} \sigma_C^u \quad (13)$$

Therefore, the reduction rate of the residual strength due to the rotation of the neutral axis in the framework of the proposed approximate approach is given by ratio of Eq. 12 to Eq. 13 as

$$\frac{M_V^u \Big|_{\text{CASE 1}}}{M_V^u \Big|_{\text{CASE 2}}} = \frac{I_{HH}I_{VV} - I_{HH}^2}{-(y_C - y_G)I_{HV} + (z_C - z_G)I_{HH}} \frac{z_C - z_G}{I_{VV}} \quad (14)$$

Ship	B1	B2	T2
L (mm)	217,000	219,000	234,000
B (mm)	32,236	32,240	44,000
D (mm)	18,300	19,900	21,200
Design criteria	Pre-IACS UR	IACS CSR-B	IACS CSR-T

Table 1 Subject ships

CASE STUDY

Two single-hull bulk carriers, B1 and B2, and one double-hull oil tanker, T2, are taken as the subject ships as shown in Table 1. Ship B1 is designed according to the International Association of Classification Studies (IACS) Pre-UR (Unified Requirements) rule and built in 1987 and Ship B2 according to Common Structural Rules for Bulk Carriers (CSR-BC), having larger cross-section and scantling sizes. Ship T2 is designed according to Common Structural Rules for Oil Tankers (CSR-OT).

The damage of the upper part of side shell due to collision is assumed. The vertical damage extent is taken as 10%, 20%, 40% and 70% of the depth D for both bulk carriers and tanker. The horizontal damage extent is taken as $B/16$, and it is kept constant for all damaged cases. The damaged cross-sections of Ship B1 are illustrated in Fig. 2 and those of Ship T2 in Fig. 3. The stiffness of the elements in the damaged area is completely removed. For the double-hull tanker, only outer side shell is assumed to be damaged. The locations of the critical deck element are presented

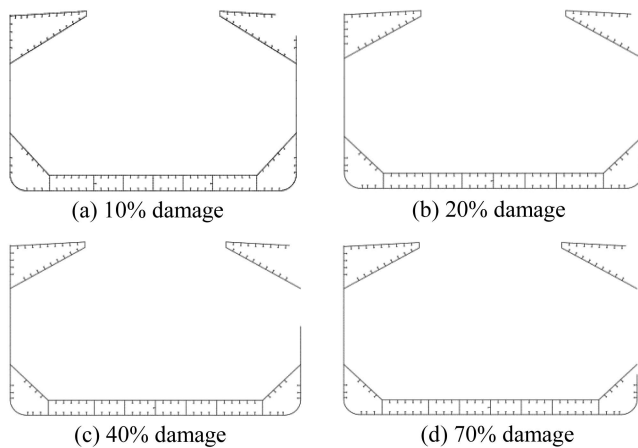


Fig. 2 Single-hull bulk carrier (Ship B1)

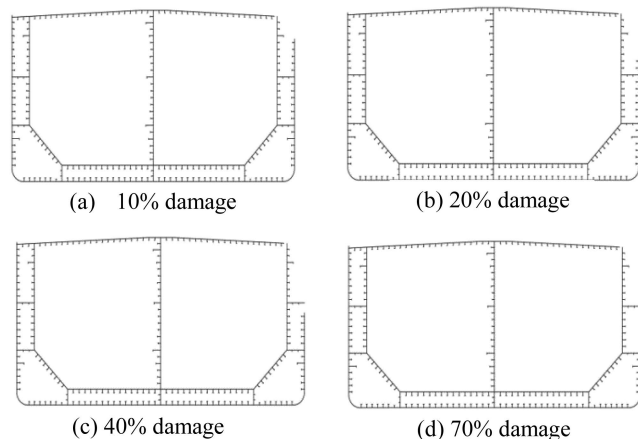


Fig. 3 Double-hull oil tanker (Ship T2)

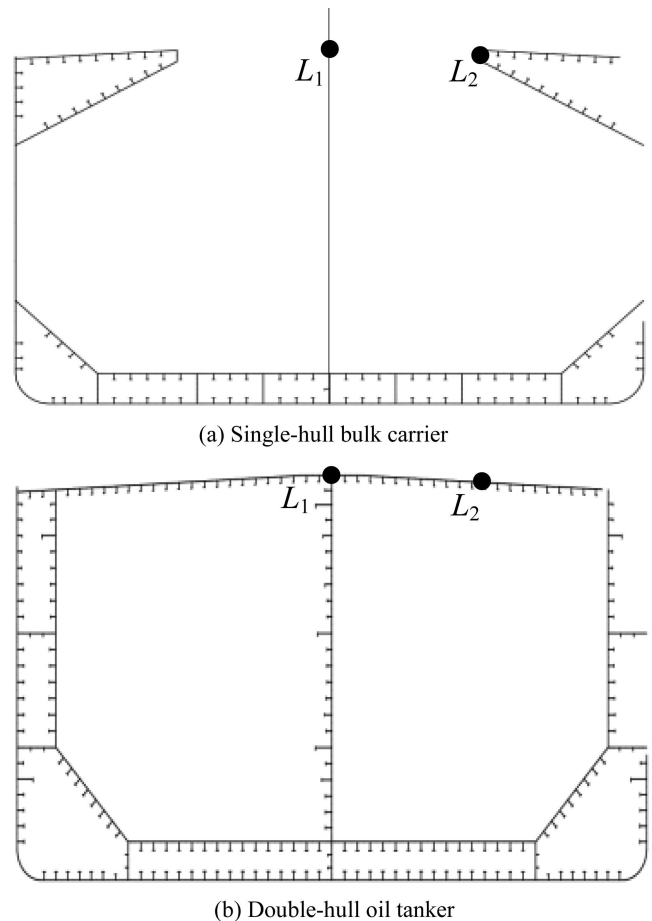


Fig. 4 Locations of the critical deck elements

in Fig. 4 for single-hull bulk carrier and double-hull oil tanker, respectively.

The investigation of the residual hull girder strength under sagging condition is performed by taking two locations of the critical deck elements as shown in Fig. 4. For single-hull bulk carriers (B1 and B2), the locations of the critical element are L_1 and L_2 . L_1 is located at the center line and L_2 at the hatch coaming on the damage side. For the case of double-hull oil tanker (T2), L_1 is located at the center line and L_2 at the distance of $B/4$ from the damaged side shell. As for the critical stress, the maximum stress of elements located at points L_1 and/or L_2 is used.

RESULTS AND DISCUSSION

In sagging condition, it is well recognized that the ultimate hull girder strength is almost attained when the primary deck members in longitudinal compression reached their ultimate strength. Because the damage takes place at the asymmetric position, i.e., collision damage is placed at the side shell through to the deck part ($B/16$) and there is no damage located at the bottom part, it is very important to investigate the critical member under sagging condition. In the present study, the ultimate strength is analyzed after damage has taken place. The water ingress is not considered in the analysis.

The results obtained by progressive collapse analysis under sagging condition for 20% and 70% damage are presented in Fig. 5 and Fig. 6, respectively. Case 1 considers the rotation of neutral axis and Case 2 does not. The resultant of bending moment versus curvature is plotted.

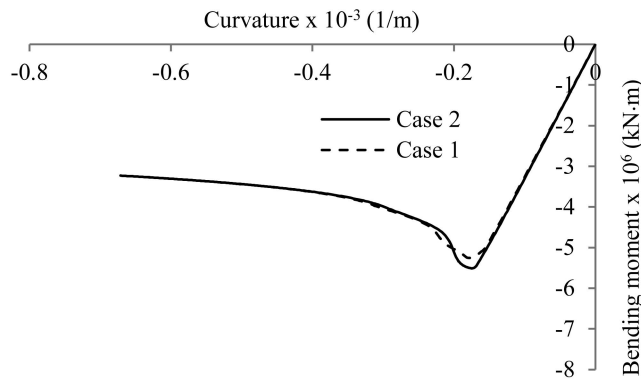


Fig. 5 Single-hull bulk carrier (Ship B1) with 20% damage

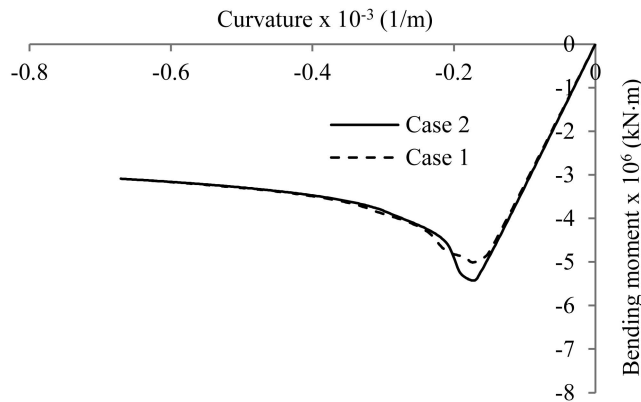


Fig. 6 Single-hull bulk carrier (Ship B1) with 70% damage

Similarly, the resultant bending moment and curvature curve for Ship B2 and Ship T2 with 20% and 70% damage are presented in Figs. 7 through 10.

Figures 7 and 8 show the results of the moment-curvature relationship obtained by progressive collapse analysis for single-hull bulk carrier (B2). It is found that Case 2 generally gives higher ultimate strength than Case 1 because the horizontal curvature is constrained. The ultimate hull girder strength is attained even when the horizontal curvature is constrained because of the horizontal bending moment induced by the incremental equation for horizontal and vertical bending moments, causing the ultimate hull girder strength to increase. The effect of constraint is the largest in Ship B1, and is smaller in Ship B2. For Ship B1, Case

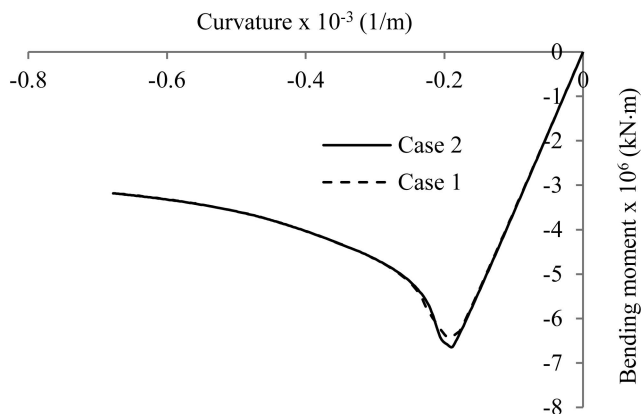


Fig. 7 Single-hull bulk carrier (Ship B2) with 20% damage

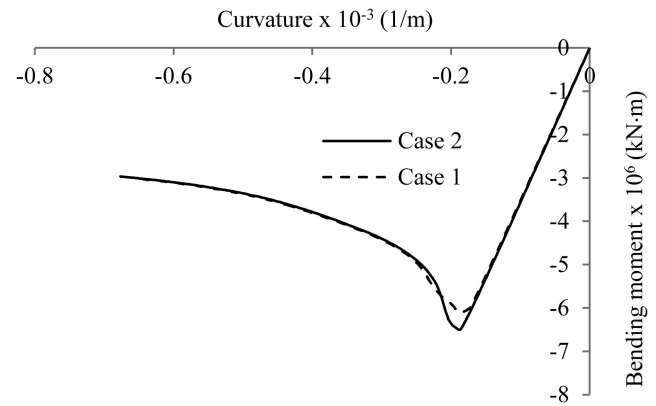


Fig. 8 Single-hull bulk carrier (Ship B2) with 70% damage

1's strength is 7.3% smaller than Case 2's in the sagging condition. The difference between Ship B1 and Ship B2 may be attributed to that of the depth-to-breadth ratio, member scantlings, etc. Figures 9 and 10 represent the moment-curvature relationship under the sagging condition for a double-hull oil tanker (T2) for 20% and 70% of damages, respectively. According to the result obtained by progressive collapse analysis of a double-hull oil tanker (Ship T2), the effect of rotation of the neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

The residual strengths of Ships B1, B2, and T2 obtained for the four different damage extents are summarized in Figs. 11 and 12. It is found that Eq. 11 gives an estimate of the residual strength that is in good agreement with the result of the progressive col-

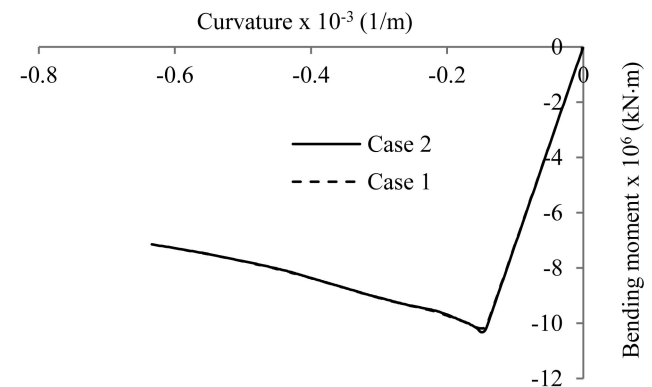


Fig. 9 Double-hull oil tanker (Ship T2) with 20% damage

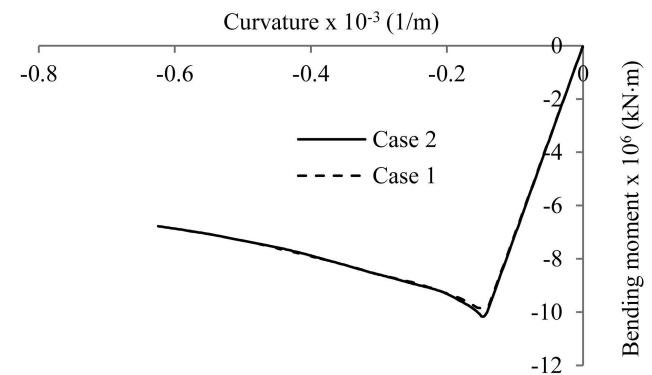


Fig. 10 Double-hull oil tanker (T2) with 70% damage

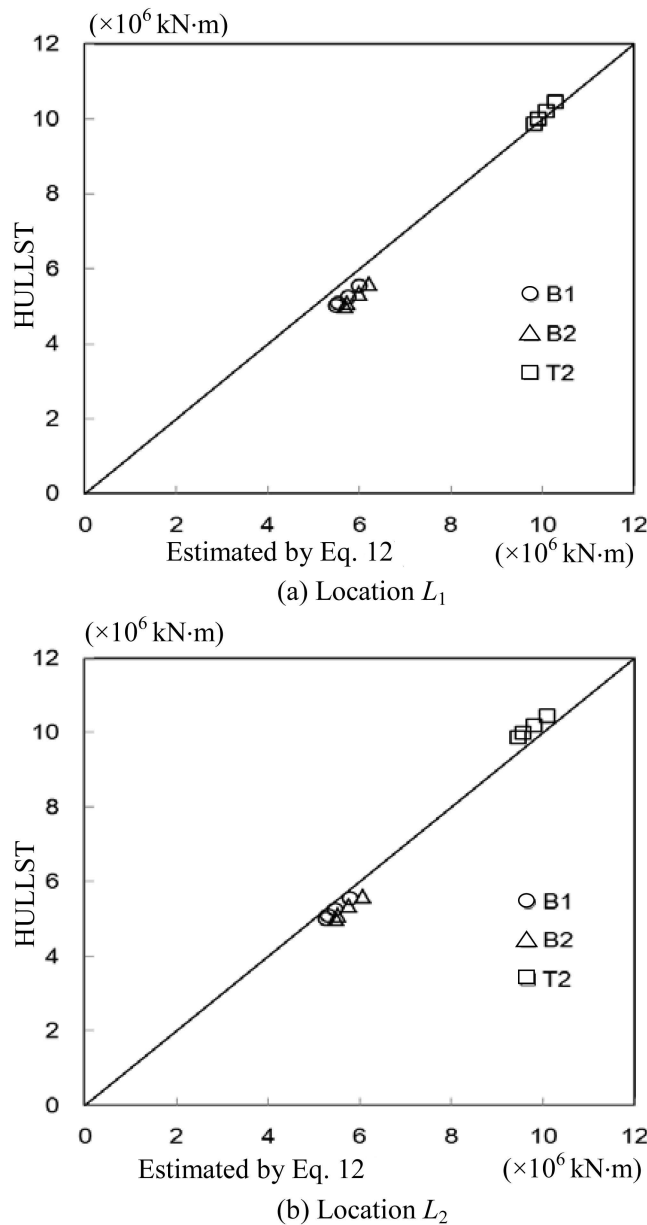


Fig. 11 Comparison of residual hull girder strength M_V between the simplified method and the progressive collapse analysis

lapse analysis. For bulk carriers, the critical element at the location L_2 gives a better estimate of the residual strength. For the location L_1 bulk carriers, the ultimate strength of critical element is evaluated by using that of the element at L_2 . This is consistent with the observed collapse behavior in which the ultimate strength was attained when topside tank region of the damaged side almost fully failed. In the case of a double-hull tanker, location L_1 gives a better estimate of the residual strength than L_2 . This is also consistent with the failure behavior of T2 in which the ultimate strength was attained when the deck part almost fully failed.

CONCLUSIONS

Progressive collapse analysis was performed on two single-hull bulk carriers and a double-hull oil tanker with asymmetrically damaged cross-section. Closed-form formulae of residual strength and that of the reduction ratio of the residual strength considering the rotation of neutral axis are proposed. It is found through

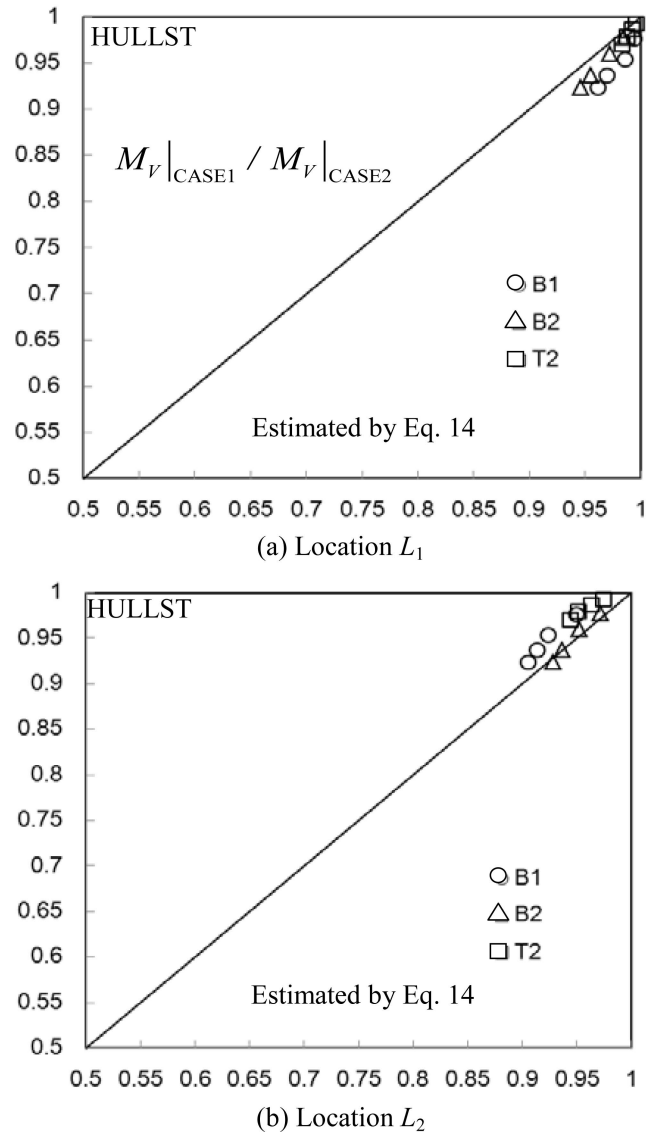


Fig. 12 Comparison of reduction ratio of residual hull girder due to rotation of neutral axis between the simplified method and the progressive collapse analysis (Case 1/Case 2)

a comparison with the results obtained by the progressive collapse analysis that the residual hull girder strength of asymmetrically damaged ships under the sagging bending moment can be predicted by the proposed formulae with reasonable accuracy. The ultimate strength obtained with the horizontal curvature constrained is larger than that without constraint. The effect of the rotation of the neutral axis is the largest for single-hull bulk carrier and almost negligible for the double-hull oil tanker. The difference characteristic for two single-hull bulk carriers may be related to that of the depth-to-breadth ratio, member scantlings, etc.

The resultant of bending moment is induced by the accumulation of the horizontal and vertical bending moments based on the reference coordinate system. Figure 12 shows the comparison of the reduction rates of the residual strength due to rotation of the neutral axis obtained by Eq. 14 and progressive collapse analysis. The influence of the rotation of the neutral axis is larger for a larger damage extent in general. For the case of the subject ships and damages under consideration, the influence is larger in bulk carriers than in tankers. Equation 14 gives a relatively good esti-

mate of the reduction rate. It can be a good basis of a rational expression of the influence of the rotation of the neutral axis on the reserve ultimate hull girder strength, as required in ship structures. More systematic analyses are definitely needed to develop the formula having a larger applicability in ship types and damaged cases.

According to the result obtained by progressive collapse analysis of double-hull oil tanker, the effect of rotation of neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

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Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships

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ABSTRACT

The objective of the present study is to investigate the ultimate hull girder strength of asymmetrically damaged ship under sagging condition. Two kinds of ships are taken as the object of the analysis. The cross section of the ship is considered and assumed to be remained plane. The simply supported boundary condition is applied to both sides of the cross section. The ultimate hull girder strength is attained when a plate and/or stiffened plate element at the specified location called “critical element” reach their ultimate strength. To investigate the ultimate hull girder strength, a simplified approach is proposed. The result obtained by simplified approach is compared to the progressive collapse analysis for the effectiveness and validation.

KEY WORDS: Single hull bulk carrier, double hull oil tanker, cross section, neutral axis, asymmetrically damaged, ultimate strength, simplified approach.

INTRODUCTION

The ability to predict accurately the ultimate strength of ship hull girder when subjected to longitudinal bending is one of the most important aspects of ship structural design. A collision and grounding damages may takes place on ship's hull, which may threaten safety of ships and surrounding environment. In this regard, to enhance the safety of ship's structure and minimize the risks, the International Maritime Organization (IMO, 2009) has required in Goal Based Standard for New Ship Construction (GBS) to consider the residual strength of the hull girder in specified damage conditions as one of the functional requirements for the structural rules for bulk carriers and tankers.

Many studies have been conducted on the analyses of the residual hull girder strength due to collision and grounding damages. Pedersen (1994) presented a mathematical modeling to estimate the contact pressure between the grounded ship and the sea bottom. The grounding contact force was compared to the force which would crush the forward bottom of the ship. The sectional bending moment due to grounding was determined and compared to the ultimate hull girder strengths. The model experiments and full-scale controlled grounding experiments were also performed to validate the mathematical model. Paik et al. (1998) developed a rapid procedure to identify the possibility of hull girder failure after collision and grounding damages

based on the closed-form formulae of the ultimate hull girder strength and section modulus after the damages. Soares et al. (2008) evaluated the ability of simplified structural analysis methods based on the Smith's formulation to predict the ultimate strength of damage ship's hull. Muis Alie, M.Z et al. (2016) investigated the influence of the superstructure to the ultimate strength of Ro-Ro ship under vertical bending moment. The cross section was considered to be analyzed. The result obtained by beam theory with and without superstructure were compared with one another. The assessment of the ultimate hull girder strength was conducted by Muis Alie, M.Z et al. (2017). The cross section of Ro-Ro ship was taken to be analyzed. The collision and grounding damages were assumed to be palced on the side and bottom area, respectively. The damages were created by removing the element from the side shell and bottom part. Ohtsubo et al. (1994) showed the experimental and numerical works on the ship structural damages due to collision and grounding. This was one of the first attempts to apply the explicit Finite Element Method codes, such as LS-DYNA and DYTRAN, to the collision and grounding problems of ships. Ozguc et al. (2005) investigated the collision resistance and residual strength of single skin and double skin bulk carriers subjected to damages. Notaro et al. (2010) carried out full nonlinear FE assessments of hull girder capacity in intact and damage conditions. The effects of several influential factor such as model extend and complexity, damage representations and model imperfections were investigated on the different vessels. It was found that the effect of damage extent in vertical direction is more critical than in longitudinal direction, and the damage varies the location of the neutral axes including higher stresses in proximity of the damage areas. The various probability levels were considered for the damage extent

estimation.

When a hull-girder cross section is symmetric with respect to the centerline and subjected to pure vertical bending moment, the neutral axis for vertical bending is always horizontal and moves only vertically during the progressive collapse behavior. However, when the cross section is asymmetrically damaged, for example, due to a collision, the neutral axis rotates. Both rotation and translation need to be taken into account during the progressive collapse behavior even when only a vertical bending moment is applied, and the problem needs to be treated as a biaxial bending problem. Previous studies using the Smith's method on the ultimate strength of hull girders under biaxial thrust (Ozguc and Barltrop, 2008) and the residual strength of damaged hulls (Fang and Das, 2004; Hussein and Guedes Soares, 2009; Choung et al, 2011) consider the rotation and translation of neutral axis in a reasonable way. However, they employ a trial and error approach to detect the position of neutral axis. More easy approach to detect the position of neutral axis is demanded.

BASIC ASSUMPTION

The following assumption is made for the prediction of the residual hull girder strength under the sagging condition:

- (1) The ultimate sagging strength is attained when a stiffened panel element at the specified location (hereafter called 'critical element') reached the ultimate strength.
- (2) The hull girder cross section is elastic until the failure of the critical member.
- (3) The ultimate strength of the critical member is predicted from the average axial stress and average axial strain relationship calculated by HULLST (Yao and Nikolov, 1992).

EFFECT OF NEUTRAL AXIS ROTATION ON ESTIMATION OF THE ULTIMATE HULL GIRDER STRENGTH

In the elastic cross section, the bending stress at the i -th element (see Fig.1), σ_i , is expressed as

$$\sigma_i = E\{(y_i - y_G)\phi_H + (z_i - z_G)\phi_V\} \quad (1)$$

where E is Young's modulus, y_G and z_G the centroid coordinates, and ϕ_H and ϕ_V the horizontal and vertical curvatures, respectively. y_G and z_G are given by

$$y_G = \frac{\left(\sum_{i=1}^N y_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (2)$$

$$z_G = \frac{\left(\sum_{i=1}^N z_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (3)$$

where D_i , A_i , and (y_i, z_i) are the tangential stiffness obtained as a slope of the average stress-average strain curve, cross sectional area and the coordinates of the centroid of individual elements, respectively.

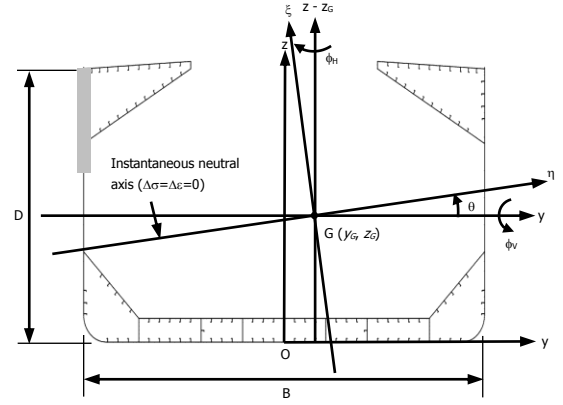


Fig. 1 Neutral axes of the elastic hull girder cross section with asymmetric damage

For the case of asymmetrically damaged cross section, Eqs (4) through (8) are used, and for the intact one, the expressions are given in Eqs (9) and (10). The biaxial moment and curvature relationship is given in the form

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (4)$$

where

$$\begin{aligned} I_{HV} &= I_{VH} = \sum_{i=1}^N (y_i - y_G)(z_i - z_G) A_i \\ I_{HH} &= \sum_{i=1}^N (y_i - y_G)^2 A_i \\ I_{VV} &= \sum_{i=1}^N (z_i - z_G)^2 A_i \end{aligned} \quad (5)$$

where I and M are the moment of inertia and bending moment, respectively. When the vertical bending moment M_V is applied to the cross section with no constraint on the horizontal curvature (Case 1), the horizontal curvature as well as the vertical curvature is induced under the condition of horizontal bending moment $M_H = 0$. The incremental equation to be solved is

$$\begin{Bmatrix} 0 \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (6)$$

Therefore,

$$\begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} = \frac{1}{E(I_{HH} I_{VV} - I_{HV}^2)} \begin{Bmatrix} -I_{HV} M_V \\ I_{HH} M_V \end{Bmatrix} \quad (7)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{-(y_i - y_G)I_{HV} + (z_i - z_G)I_{HH}}{(I_{HH} I_{VV} - I_{HV}^2)} M_V \quad (8)$$

The terms including the moment of inertia, I_{HV} , represent the effect of the rotation of the neutral axis.

On the other hand, when the vertical bending moment is applied to the cross section with the horizontal curvature constrained (Case 2), the bending moment are induced under the condition of $\phi_H = 0$, that is,

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} 0 \\ \phi_V \end{Bmatrix} \quad (9)$$

Therefore,

$$\phi_V = \frac{M_V}{EI_{VV}} \quad (11)$$

Substituting Eq. (10) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{(z_i - z_G)}{I_{VV}} M_V \quad (12)$$

Here, it is assumed that the residual hull girder strength in the sagging condition M_V^u is attained when a critical member at the location of (y_C, z_C) reached its ultimate strength, σ_C^u , namely for Case 1

$$M_V^u|_{CASE1} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \sigma_C^u \quad (13)$$

And for Case 2

$$M_V^u|_{CASE2} = \frac{I_{VV}}{(z_C - z_G)} \sigma_C^u \quad (14)$$

Therefore, the reduction rate of the residual strength due to the rotation of the neutral axis in the framework of the proposed approximate approach is given by ratio of Eq. (12) to Eq. (13) as

$$\frac{M_V^u|_{CASE1}}{M_V^u|_{CASE2}} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \frac{(z_C - z_G)}{I_{VV}} \quad (13)$$

CASE STUDY

Two single-hull bulk carriers, B1 and B2, and one double-hull oil tanker, T2, are taken as the subject ships as shown in Table 1. Ship B1 is designed according to Pre-UR rule and built in 1987 and Ship B2 according to CSR-B having larger cross section and scantling sizes. Ship T2 is designed according to CSR-T.

Table 1 Subject ships

Ship	B1	B2	T2
L (mm)	217,000	219,000	234,000
B (mm)	32,236	32,240	44,000
D (mm)	18,300	19,900	21,200
Design criteria	Pre-IACS UR	IACS CSR-B	IACS CSR-T

The damage of the upper part of side shell due to collision is assumed. The vertical damage extent is taken as 10%, 20%, 40% and 70% of the depth D for both bulk carriers and tanker. The horizontal damage extent is taken as $B/16$, and it is kept constant for all damaged cases. The damaged cross sections of Ship B1 are illustrated in Fig. 2 and those of Ship T2 in Fig. 3. The stiffness of the elements in the damaged area is completely removed. For the double hull tanker, only outer side shell is assumed to be damaged. The locations of the critical deck element are presented in Fig. 4 for single hull bulk carrier and double hull oil tanker, respectively.

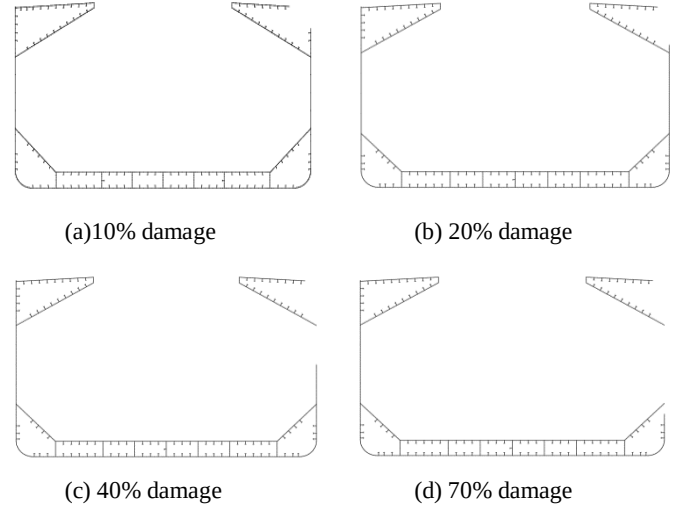


Fig. 2 Single hull bulk carrier (Ship B1)

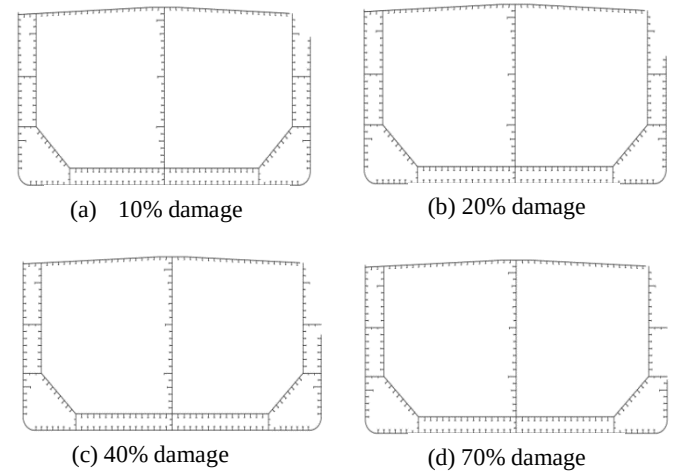
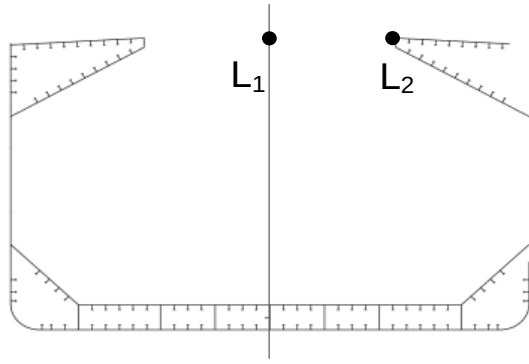
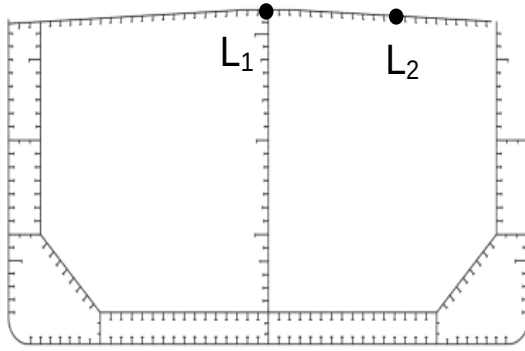


Fig. 3 Double hull oil tanker (Ship T2)

The investigation of the residual hull girder strength under sagging condition is performed by taking two locations of the critical deck elements as shown in Fig. 4. For Single hull bulk carriers (B1 and B2), the locations of the critical element are L_1 and L_2 . L_1 is located at the center line and L_2 at the hatch coaming on the damage side. For the case of double hull oil tanker (T2), L_1 is located at the center line and L_2 at the distance of $B/4$ from the damaged side shell. As for the critical stress, the maximum stress of elements located at points L_1 and/or L is used.



(a) Single hull bulk carrier



(b) Double hull oil tanker

Fig. 4 Locations of the critical deck elements

RESULT AND DISCUSSION

In sagging condition, it is well recognized that the ultimate hull girder strength is almost attained when the primary deck members in longitudinal compression reached their ultimate strength. Also, because the damage takes place at the asymmetric position, in other word, collision damage is placed at the side shell through to the deck part (B/16) and there is no damage located at the bottom part, so that it is very important to investigate the critical member under sagging condition. In the present study, the ultimate strength is analyzed after damage has taken place. The water ingress is not considered in the analysis.

The results obtained by progressive collapse analysis under sagging condition for 20% and 70% damage are presented in Fig. 5 and Fig. 6, respectively. Case 1 considers the rotation of neutral axis and Case 2 does not. The resultant of bending moment versus curvature is plotted.

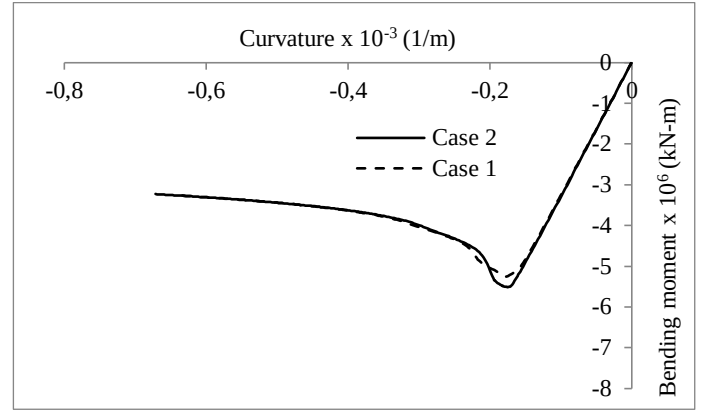


Fig. 5 Single hull bulk carrier (Ship B1) with 20% damage

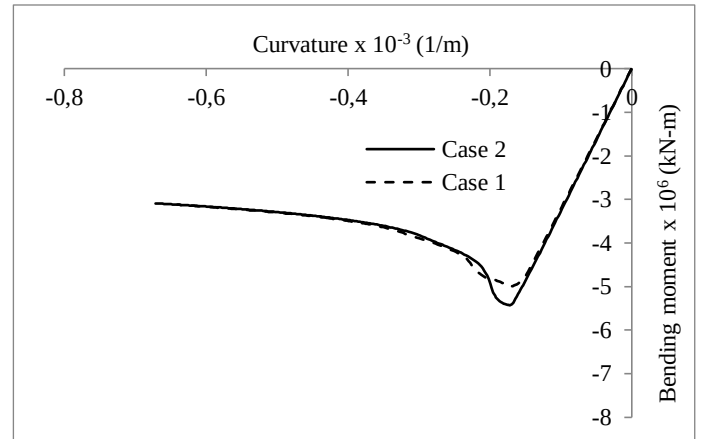


Fig. 6 Single hull bulk carrier (Ship B1) with 70% damage

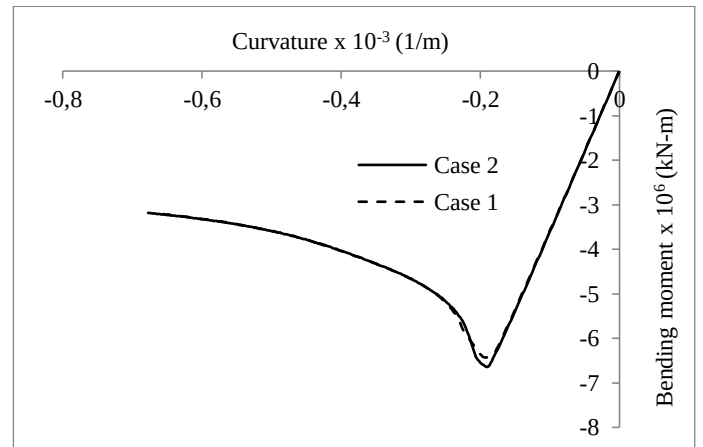


Fig. 7 Single hull bulk carrier (Ship B2) with 20% damage

Similarly, the resultant bending moment and curvature curve for Ship B2 and Ship T2 with 20% and 70% damage are presented in Figs. 7 through 10.

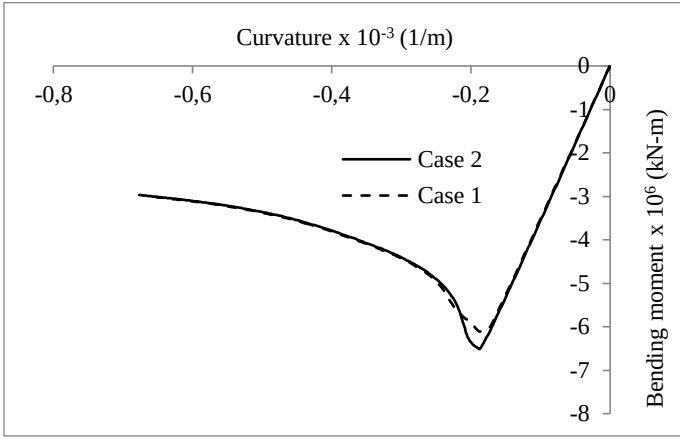


Fig. 8 Single hull bulk carrier (Ship B2) with 70% damage

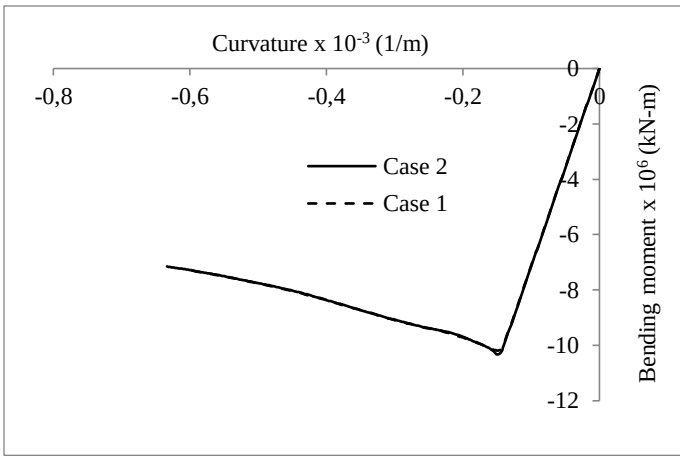


Fig. 9 Double hull oil tanker (Ship T2) with 20% damage

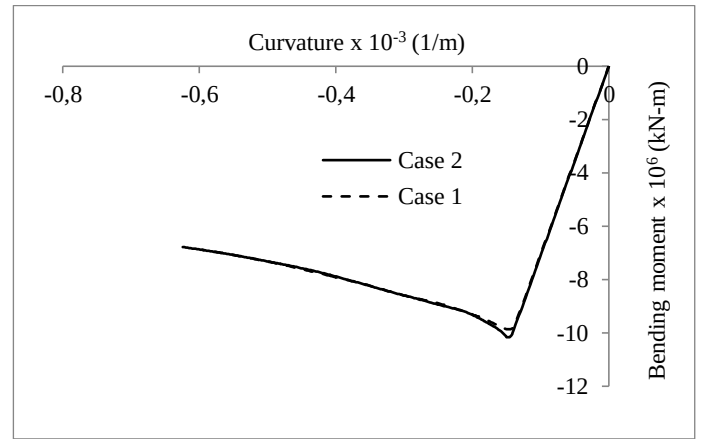


Fig. 10 Double hull oil tanker (T2) with 70% damage

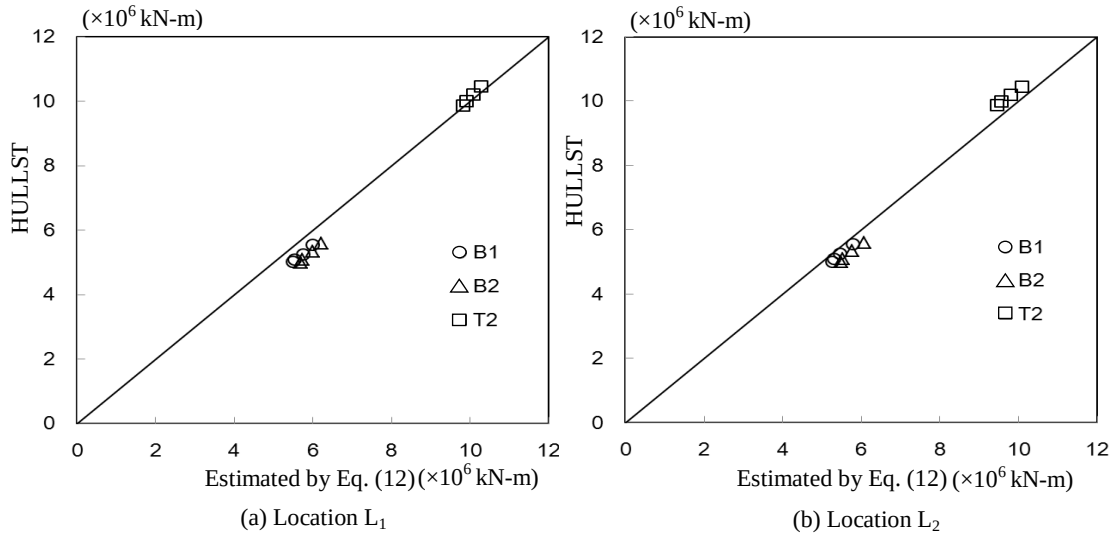


Fig. 11 Comparison of residual hull girder strength M_r between the simplified method and the progressive collapse analysis

Fig. 7 and Fig. 8 shows the results of the moment-curvature relationship obtained by progressive collapse analysis for single hull bulk carrier (B2). It is found that Case 2 generally gives higher ultimate strength than Case 1 because the horizontal curvature is constrained. The ultimate hull girder strength is attained even the horizontal curvature is constrained because of the horizontal bending moment is induced by the incremental equation for horizontal and vertical bending moments and this makes the ultimate hull girder strength becomes higher. The effect of constraint is the largest in Ship B1, and is smaller in Ship B2. For Ship B1, Case 1 strength is 7.3% smaller than Case 2 in sagging condition. The difference between Ship B1 and Ship B2 may be attributed to that of the depth to breadth ratio, member scantlings etc. Fig. 9 and Fig. 10 represent the moment-curvature relationship under sagging condition for double hull oil tanker (T2) for 20% and 70% of damages, respectively. According to the result obtained by progressive collapse analysis of double hull oil tanker (Ship T2), the effect of rotation of neural axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

The residual strengths of Ship B1, Ship B2 and Ship T2 obtained for the four different damage extents are summarized in Fig. 11. It is found that Eq. (11) gives an estimate of the residual strength which is in good agreement with the result of the progressive collapse analysis. For bulk carriers, the critical element at the location L_2 gives a better estimate of the residual strength. For the location of L_1 of bulk carriers, the ultimate strength of critical element is evaluated by using that of the element at L_2 . This is consistent with the observed collapse behavior in which the ultimate strength is attained when topside tank region of the damaged side almost fully failed. In the case of a double hull tanker, the location L_1 gives better estimate of the residual strength than L_2 . This is also consistent with the failure behavior of T2 in which the ultimate strength is attained when the deck part almost fully failed.

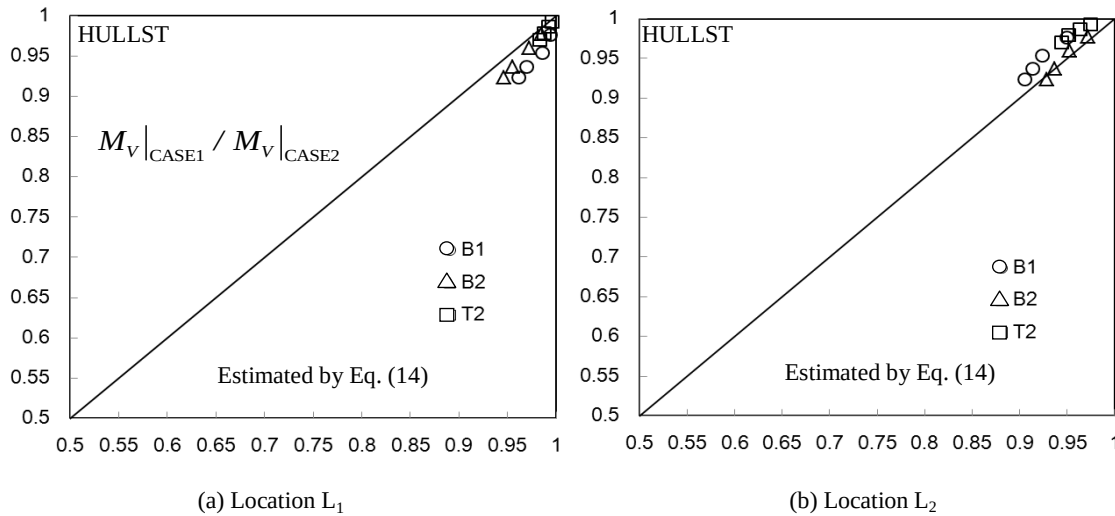


Fig. 12 Comparison of reduction ratio of residual hull girder due to rotation of neutral axis between the simplified method and the progressive collapse analysis (Case 1/Case 2)

CONCLUSIONS

Progressive collapse analysis was performed on two single hull bulk carriers and a double hull oil tanker with asymmetrically damaged cross section applying Smith's method. A closed form formulae of residual strength and that of the reduction ratio of the residual strength considering the rotation of neutral axis are proposed. It is found through a comparison with the results obtained by the progressive collapse analysis that the residual hull girder strength of asymmetrically damaged ships under sagging bending moment can be predicted by the proposed formulae with a reasonable accuracy. The ultimate strength obtained with the horizontal curvature constrained is larger than that without constraint one. The effect of the rotation of neutral axis is the largest for single hull bulk carrier and almost negligible for double hull oil tanker. The difference characteristic for two single hull bulk carrier may be related to that of the depth to breadth ratio, member scantlings etc.

The resultant of bending moment is induced by the accumulation of the horizontal and vertical bending moment based on the reference coordinate system. Fig. 12 shows the comparison of the reduction rates of the residual strength due to rotation of the neutral axis obtained by Eq. (14) and progressive collapse analysis. The influence

of the rotation of the neutral axis is larger for a larger damage extent in general. For the case of the subject ships and damages under consideration, the influence is larger in bulk carriers than in tankers. Eq. (14) gives a relatively good estimate of the reduction rate. It can be a good basis of a rational expression of the influence of the rotation of the neutral axis on the reserve ultimate hull girder strength, as required in ship structures. More systematic analyses are definitely needed to develop the formula having larger applicability in ship types and damaged cases.

According to the result obtained by progressive collapse analysis of double hull oil tanker, the effect of rotation of neural axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

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Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships

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ABSTRACT

The objective of the present study is to investigate the ultimate hull girder strength of asymmetrically damaged ship under sagging condition. Two kinds of ships are taken as the object of the analysis. The cross section of the ship is considered and assumed to be remained plane. The simply supported boundary condition is applied to both sides of the cross section. The ultimate hull girder strength is attained when a plate and/or stiffened plate element at the specified location called “critical element” reach their ultimate strength. To investigate the ultimate hull girder strength, a simplified approach is proposed. The result obtained by simplified approach is compared to the progressive collapse analysis for the effectiveness and validation.

KEY WORDS: Single hull bulk carrier, double hull oil tanker, cross section, neutral axis, asymmetrically damaged, ultimate strength, simplified approach.

INTRODUCTION

The ability to predict accurately the ultimate strength of ship hull girder when subjected to longitudinal bending is one of the most important aspects of ship structural design. A collision and grounding damages may takes place on ship's hull, which may threaten safety of ships and surrounding environment. In this regard, to enhance the safety of ship's structure and minimize the risks, the International Maritime Organization (IMO, 2009) has required in Goal Based Standard for New Ship Construction (GBS) to consider the residual strength of the hull girder in specified damage conditions as one of the functional requirements for the structural rules for bulk carriers and tankers.

Many studies have been conducted on the analyses of the residual hull girder strength due to collision and grounding damages. Pedersen (1994) presented a mathematical modeling to estimate the contact pressure between the grounded ship and the sea bottom. The grounding contact force was compared to the force which would crush the forward bottom of the ship. The sectional bending moment due to grounding was determined and compared to the ultimate hull girder strengths. The model experiments and full-scale controlled grounding experiments were also performed to validate the mathematical model. Paik et al. (1998) developed a rapid procedure to identify the possibility of hull girder failure after collision and grounding damages

based on the closed-form formulae of the ultimate hull girder strength and section modulus after the damages. Soares et al. (2008) evaluated the ability of simplified structural analysis methods based on the Smith's formulation to predict the ultimate strength of damage ship's hull. Toh et al. (2012) developed simplified calculation program to calculate the ultimate strength in intact and damage conditions and the reduction of hull girder ultimate strength is investigated. The calculation result of simplified method is compared to the FE result for both intact and damage conditions. Muis Alie, M.Z et al. (2012) investigated the incidence of neutral axis rotation on residual hull girder strength for asymmetrically damaged ships under longitudinal bending, applying the progressive collapse calculation method and found an explicit expression of neutral axis rotation. After performing a series of progressive collapse analyses on several bulk carriers and tanker, it was found that residual hull girder strength, considering the instantaneous neutral axis is generally lower than the relevant one, obtained by constraining the rotation, as it is commonly assumed in classical procedures. Ohtsubo et al. (1994) showed the experimental and numerical works on the ship structural damages due to collision and grounding. This was one of the first attempts to apply the explicit Finite Element Method codes, such as LS-DYNA and DYTRAN, to the collision and grounding problems of ships. Ozguc et al. (2005) investigated the collision resistance and residual strength of single skin and double skin bulk carriers subjected to damages. Lee et al. (2008) calculated the ultimate strength with collision damage using LS-DYNA and compared the calculated results with the experiment results. It is found that the ultimate strength is reduced as a damage size increased as expected. Notaro et al. (2010) carried out full nonlinear FE assessments of hull girder capacity in intact and damage

conditions. The effects of several **influential** factor such as model extend and complexity, damage representations and model imperfections are investigated on the different vessels. It was found that the effect of damage extent in vertical direction is more critical than in longitudinal direction, and the damage varies the location of the neutral axes including higher stresses in proximity of the damage areas. The various probability levels are considered for the damage extent estimation.

When a hull-girder cross section is symmetric with respect to the centerline and subjected to pure vertical bending moment, the neutral axis for vertical bending is always horizontal and moves only vertically during the progressive collapse behavior. However, when the cross section is asymmetrically damaged, for example, due to a collision, the neutral axis rotates. Both rotation and translation need to be taken into account during the progressive collapse behavior even when only a vertical bending moment is applied, and the problem needs to be treated as a biaxial bending problem. Previous studies using the Smith's method on the ultimate strength of hull girders under biaxial thrust (Ozguc and Barltrop, 2008) and the residual strength of damaged hulls (Fang and Das, 2004; Hussein and Guedes Soares, 2009; Choung et al, 2011) consider the rotation and translation of neutral axis in a reasonable way. However, they employ a trial and error approach to detect the position of neutral axis. More easy approach to detect the position of neutral axis is demanded.

BASIC ASSUMPTION

The following assumption is made for the prediction of the residual hull girder strength under the sagging condition:

- (1) The ultimate sagging strength is attained when a stiffened panel element at the specified location (hereafter called 'critical element') reached the ultimate strength.
- (2) The hull girder cross section is elastic until the failure of the critical member.
- (3) The ultimate strength of the critical member is predicted from the average axial stress and average axial strain relationship calculated by HULLST (Yao and Nikolov).

EFFECT OF NEUTRAL AXIS ROTATION ON ESTIMATION OF THE ULTIMATE HULL GIRDER STRENGTH

In the elastic cross section, the bending stress at the i -th element (see Fig.1), σ_i , is expressed as

$$\sigma_i = E \{ (y_i - y_G) \phi_H + (z_i - z_G) \phi_V \} \quad (1)$$

where E is Young's modulus, y_G and z_G the centroid coordinates, and ϕ_H and ϕ_V the horizontal and vertical curvatures, respectively. y_G and z_G are given by

$$y_G = \frac{\left(\sum_{i=1}^N y_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (2)$$

$$z_G = \frac{\left(\sum_{i=1}^N z_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (3)$$

where D_i , A_i , and (y_i, z_i) are the tangential stiffness obtained as a slope of the average **stress-average strain** curve, cross sectional area and the coordinates of the centroid of individual elements, respectively.

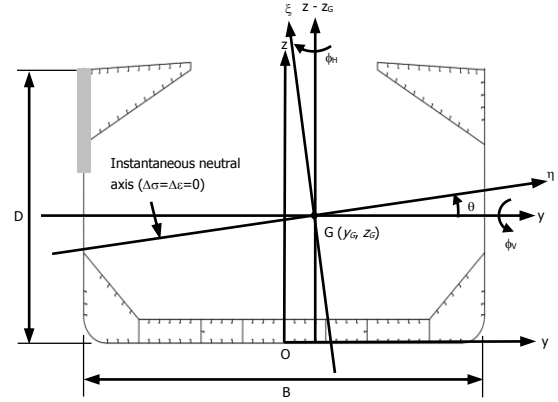


Fig. 1 Neutral axes of the elastic hull girder cross section with asymmetric damage

For the case of **asymmetrically** damaged cross section, Eqs (4) through (8) are used, and for the intact one, the expressions are given in Eqs (9) and (10). The biaxial moment and curvature relationship is given in the form

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (4)$$

where

$$\begin{aligned} I_{HV} &= I_{VH} = \sum_{i=1}^N (y_i - y_G)(z_i - z_G) A_i \\ I_{HH} &= \sum_{i=1}^N (y_i - y_G)^2 A_i \\ I_{VV} &= \sum_{i=1}^N (z_i - z_G)^2 A_i \end{aligned} \quad (5)$$

where I and M are the moment of inertia and bending moment, respectively. When the vertical bending moment M_V is applied to the cross section with no constraint on the horizontal curvature (Case 1), the horizontal curvature as well as the vertical curvature is induced under the condition of horizontal bending moment $M_H = 0$. The incremental equation to be solved is

$$\begin{Bmatrix} 0 \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (6)$$

Therefore,

$$\begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} = \frac{1}{E(I_{HH} I_{VV} - I_{HV}^2)} \begin{Bmatrix} -I_{HV} M_V \\ I_{HH} M_V \end{Bmatrix} \quad (7)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{-(y_i - y_G)I_{HV} + (z_i - z_G)I_{HH}}{(I_{HH} I_{VV} - I_{HV}^2)} M_V \quad (8)$$

The terms including the moment of inertia, I_{HV} , represent the effect of the rotation of the neutral axis.

On the other hand, when the vertical bending moment is applied to the cross section with the horizontal curvature constrained (Case 2), the bending moment are induced under the condition of $\phi_H = 0$, that is,

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} 0 \\ \phi_V \end{Bmatrix} \quad (9)$$

Therefore,

$$\phi_V = \frac{M_V}{EI_{VV}} \quad (10)$$

Substituting Eq. (10) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{(z_i - z_G)}{I_{VV}} M_V \quad (11)$$

Here, it is assumed that the residual hull girder strength in the sagging condition M_V^u is attained when a critical member at the location of (y_C, z_C) reached its ultimate strength, σ_C^u , namely for Case 1

$$M_V^u|_{CASE1} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G)I_{HV} + (z_C - z_G)I_{HH}} \sigma_C^u \quad (12)$$

And for Case 2

$$M_V^u|_{CASE2} = \frac{I_{VV}}{(z_C - z_G)} \sigma_C^u \quad (13)$$

Therefore, the reduction rate of the residual strength due to the rotation of the neutral axis in the framework of the proposed approximate approach is given by ratio of Eq. (12) to Eq. (13) as

$$\frac{M_V^u|_{CASE1}}{M_V^u|_{CASE2}} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G)I_{HV} + (z_C - z_G)I_{HH}} \frac{(z_C - z_G)}{I_{VV}} \quad (14)$$

CASE STUDY

Two single-hull bulk carriers, B1 and B2, and one double-hull oil tanker, T2, are taken as the subject ships as shown in Table 1. Ship B1

is designed according to Pre-UR rule and built in 1987 and Ship B2 according to CSR-B having larger cross section and scantling sizes. Ship T2 is designed according to CSR-T.

Table 1 Subject ships

Ship	B1	B2	T2
L (mm)	217,000	219,000	234,000
B (mm)	32,236	32,240	44,000
D (mm)	18,300	19,900	21,200
Design criteria	Pre-IACS UR	IACS CSR-B	IACS CSR-T

The damage of the upper part of side shell due to collision is assumed. The vertical damage extent is taken as 10%, 20%, 40% and 70% of the depth D for both bulk carriers and tanker. The horizontal damage extent is taken as $B/16$, and it is kept constant for all damaged cases. The damaged cross sections of Ship B1 are illustrated in Fig. 2 and those of Ship T2 in Fig. 3. The stiffness of the elements in the damaged area is completely removed. For the double hull tanker, only outer side shell is assumed to be damaged. The locations of the critical deck element are presented in Fig. 4 for single hull bulk carrier and double hull oil tanker, respectively.

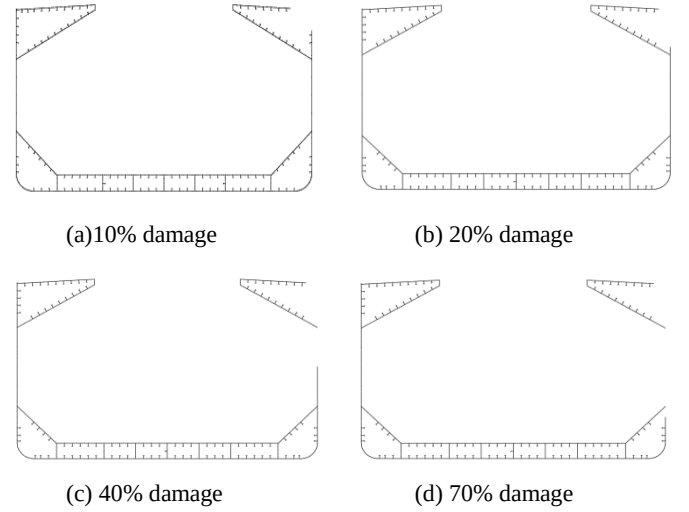


Fig. 2 Single hull bulk carrier (Ship B1)

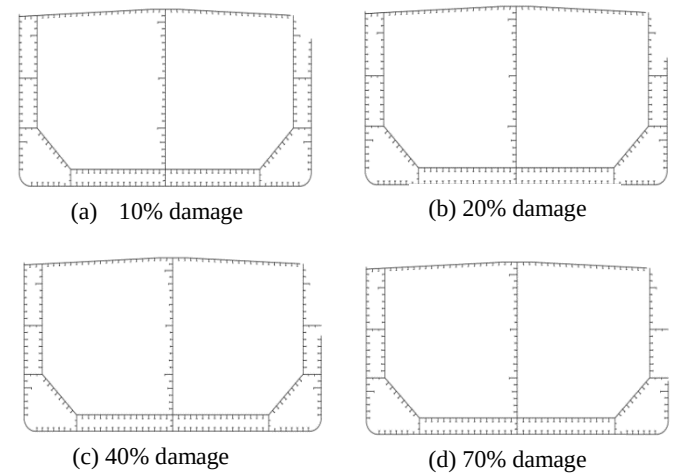
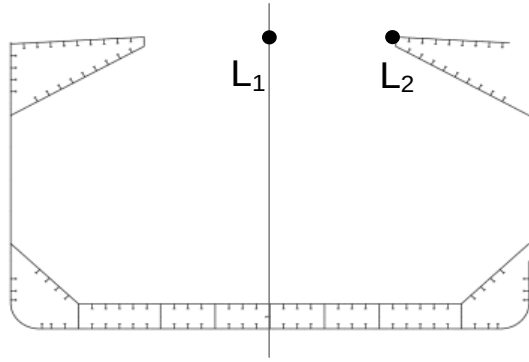
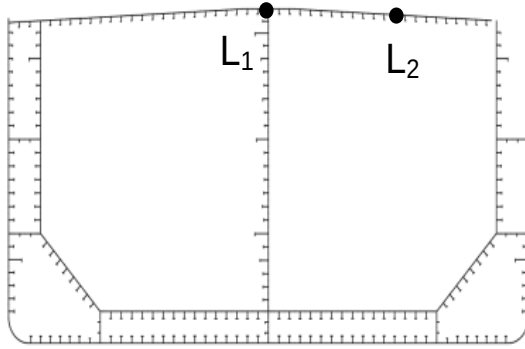


Fig. 3 Double hull oil tanker (Ship T2)

The investigation of the residual hull girder strength under sagging condition is performed by taking two locations of the critical deck elements as shown in Fig. 4. For Single hull bulk carriers (B1 and B2), the locations of the critical element are L_1 and L_2 . L_1 is located at the center line and L_2 at the hatch coaming on the damage side. For the case of double hull oil tanker (T2), L_1 is located at the center line and L_2 at the distance of $B/4$ from the damaged side shell. As for the critical stress, the maximum stress of elements located at points L_1 and/or L is used.



(a) Single hull bulk carrier



(b) Double hull oil tanker

Fig. 4 Locations of the critical deck elements

RESULT AND DISCUSSION

In sagging condition, it is well recognized that the ultimate hull girder strength is almost attained when the primary deck members in longitudinal compression reached their ultimate strength. Also, because the damage takes place at the asymmetric position, in other word, collision damage is placed at the side shell through to the deck part ($B/16$) and there is no damage located at the bottom part, so that it is very important to investigate the critical member under sagging condition. In the present study, the ultimate strength is analyzed after damage has taken place. The water ingress is not considered in the analysis.

The results obtained by progressive collapse analysis under sagging condition for 20% and 70% damage are presented in Fig. 5 and Fig. 6, respectively. Case 1 considers the rotation of neutral axis and Case 2 does not. The resultant of bending moment versus curvature is plotted.

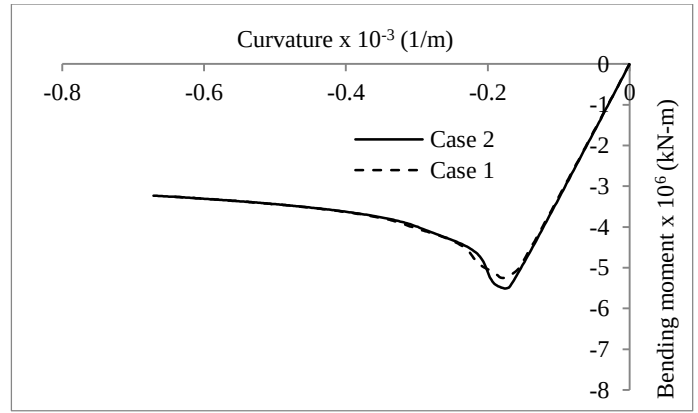


Fig. 5 Single hull bulk carrier (Ship B1) with 20% damage

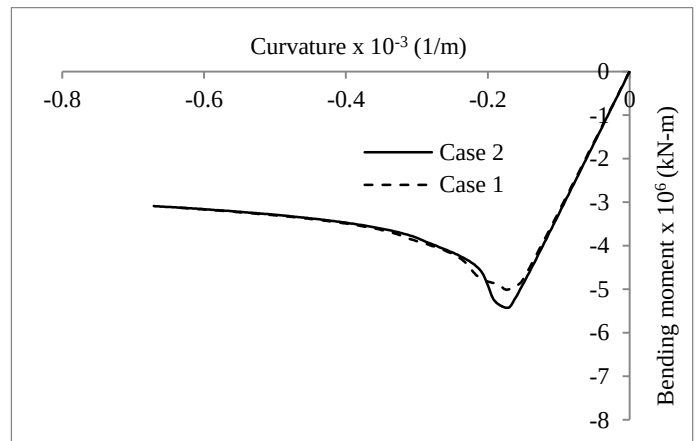


Fig. 6 Single hull bulk carrier (Ship B1) with 70% damage

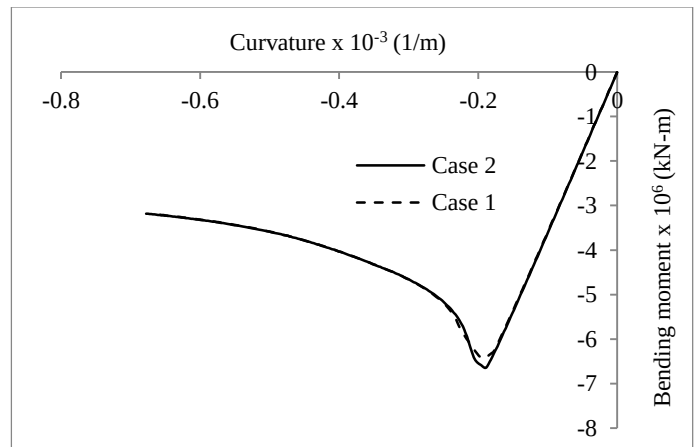


Fig. 7 Single hull bulk carrier (Ship B2) with 20% damage

Similarly, the resultant bending moment and curvature curve for Ship B2 and Ship T2 with 20% and 70% damage are presented in Figs. 7 through 10.

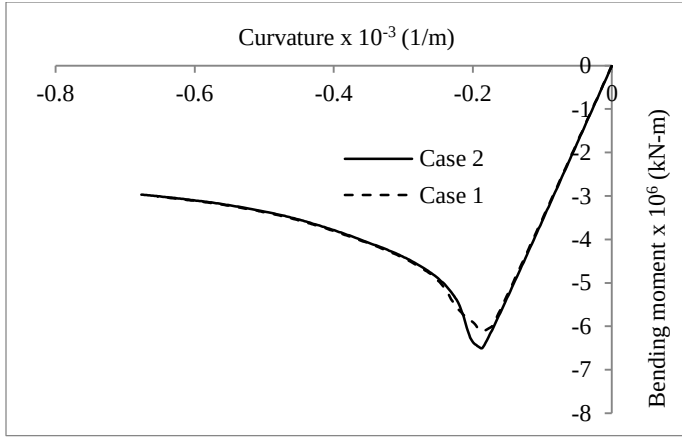


Fig. 8 Single hull bulk carrier (Ship B2) with 70% damage

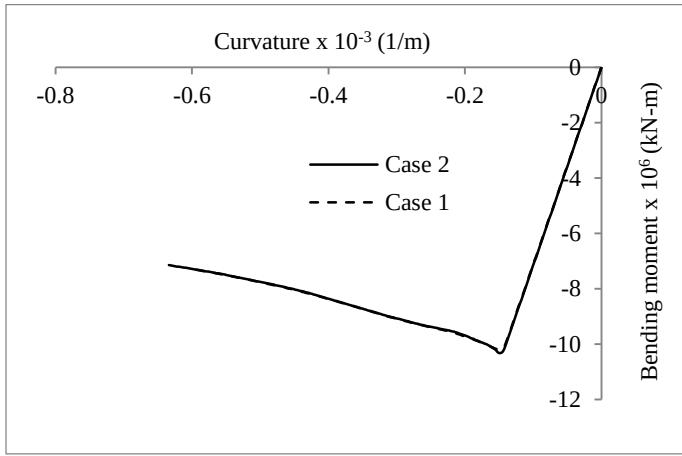


Fig. 9 Double hull oil tanker (Ship T2) with 20% damage

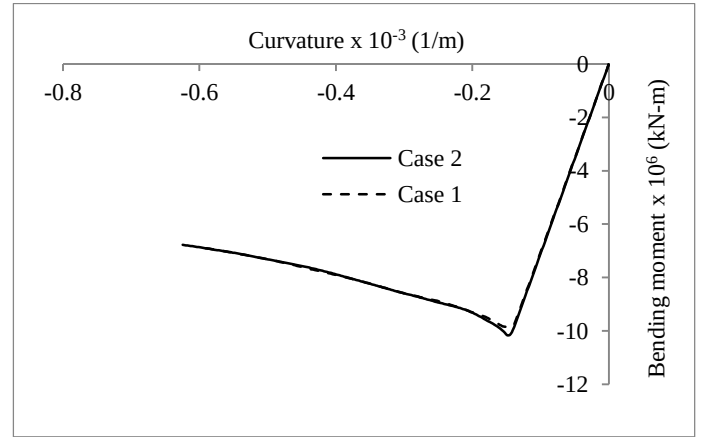


Fig. 10 Double hull oil tanker (T2) with 70% damage

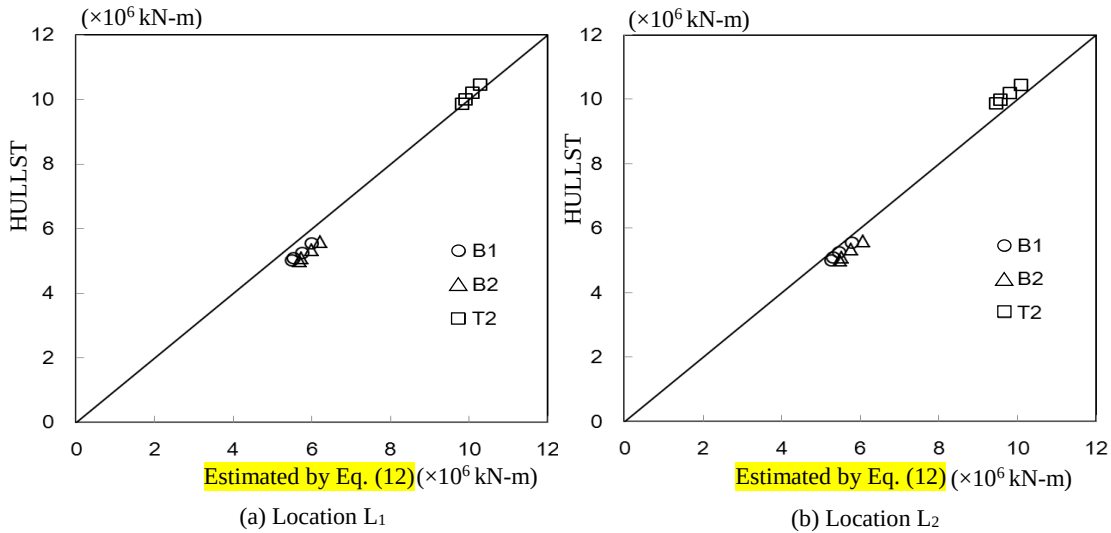


Fig. 11 Comparison of residual hull girder strength M_V between the simplified method and the progressive collapse analysis

Fig. 7 and Fig. 8 shows the results of the moment-curvature relationship obtained by progressive collapse analysis for single hull bulk carrier (B2). It is found that Case 2 generally gives higher ultimate strength than Case 1 because the horizontal curvature is constrained. The ultimate hull girder strength is attained even the horizontal curvature is constrained because of the horizontal bending moment is induced by the incremental equation for horizontal and vertical bending moments and this makes the ultimate hull girder strength becomes higher. The effect of constraint is the largest in Ship B1, and is smaller in Ship B2. For Ship B1, Case 1 strength is 7.3% smaller than Case 2 in sagging condition. The difference between Ship B1 and Ship B2 may be attributed to that of the depth to breadth ratio, member scantlings etc. Fig. 9 and Fig. 10 represent the moment-curvature relationship under sagging condition for double hull oil tanker (T2) for 20% and 70% of damages, respectively. According to the result obtained by progressive collapse analysis of double hull oil tanker (Ship T2), the effect of rotation of neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

The residual strengths of Ship B1, Ship B2 and Ship T2 obtained for the four different damage extents are summarized in Fig. 11. It is found that Eq. (11) gives an estimate of the residual strength which is in good agreement with the result of the progressive collapse analysis. For bulk carriers, the critical element at the location L_2 gives a better estimate of the residual strength. For the location of L_1 of bulk carriers, the ultimate strength of critical element is evaluated by using that of the element at L_2 . This is consistent with the observed collapse behavior in which the ultimate strength is attained when topside tank region of the damaged side almost fully failed. In the case of a double hull tanker, the location L_1 gives better estimate of the residual strength than L_2 . This is also consistent with the failure behavior of T2 in which the ultimate strength is attained when the deck part almost fully failed.

of the rotation of the neutral axis is larger for a larger damage extent in general. For the case of the subject ships and damages under consideration, the influence is larger in bulk carriers than in tankers. Eq. (14) gives a relatively good estimate of the reduction rate. It can be a good basis of a rational expression of the influence of the rotation of the neutral axis on the reserve ultimate hull girder strength, as required in ship structures. More systematic analyses are definitely needed to develop the formula having larger applicability in ship types and damaged cases.

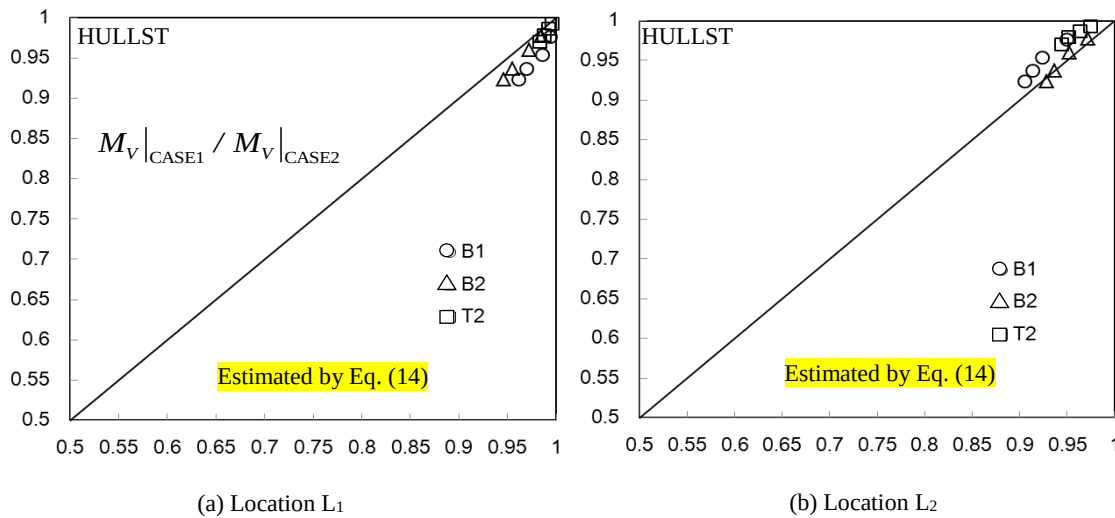


Fig. 12 Comparison of reduction ratio of residual hull girder due to rotation of neutral axis between the simplified method and the progressive collapse analysis (Case 1/Case 2)

CONCLUSIONS

Progressive collapse analysis was performed on two single hull bulk carriers and a double hull oil tanker with asymmetrically damaged cross section applying Smith's method. A closed form formulae of residual strength and that of the reduction ratio of the residual strength considering the rotation of neutral axis are proposed. It is found through a comparison with the results obtained by the progressive collapse analysis that the residual hull girder strength of asymmetrically damaged ships under sagging bending moment can be predicted by the proposed formulae with a reasonable accuracy. The ultimate strength obtained with the horizontal curvature constrained is larger than that without constraint one. The effect of the rotation of neutral axis is the largest for single hull bulk carrier and almost negligible for double hull oil tanker. The difference characteristic for two single hull bulk carrier may be related to that of the depth to breadth ratio, member scantlings etc. The resultant of bending moment is induced by the accumulation of the horizontal and vertical bending moment based on the reference coordinate system. Fig. 12 shows the comparison of the reduction rates of the residual strength due to rotation of the neutral axis obtained by Eq. (14) and progressive collapse analysis. The influence

According to the result obtained by progressive collapse analysis of double hull oil tanker, the effect of rotation of neural axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

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Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships

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ABSTRACT

The objective of the present study is to investigate the ultimate hull girder strength of asymmetrically damaged ship under sagging condition. Two kinds of ship are taken as the object of the analysis. The cross section of the ship is considered and assumed to be remained plane. The [simply supported boundary condition](#) is applied to both sides of the cross section. The ultimate hull girder strength is attained when a plate and/or stiffened plate element at the specified location called “critical element” reach their ultimate strength. To investigate the ultimate hull girder strength, a simplified approach is proposed. The result obtained by simplified approach is compared to the progressive collapse analysis for the effectiveness and validation.

KEY WORDS: Single hull bulk carrier, double hull oil tanker, cross section, neutral axis, asymmetrically damaged, ultimate strength, simplified approach.

INTRODUCTION

The ability to predict accurately the ultimate strength of ship hull girder when subjected to longitudinal bending is one of the most important aspects of ship structural design. A collision and grounding damages may takes place on ship's hull, which may threaten [safety of ship](#) and surrounding environment. In this regard, to enhance the safety of ship's structure and minimize the risks, the International Maritime Organization (IMO, 2009) has required in Goal Based Standard for New Ship Construction (GBS) to consider the residual strength of the hull girder in specified damage conditions as one of the functional requirements for the structural rules for bulk carriers and tankers.

Many studies have been conducted on the analyses of the residual hull girder strength due to collision and grounding damaged. Pedersen (1994) presented a mathematical modeling to estimate the contact pressure between the grounded ship and the sea bottom. The grounded contact force was compared to the force which would crush the forward bottom of the ship. The sectional bending moment due to grounding was determined and compared to the ultimate hull girder strengths. The model experiments and full-scale controlled grounding experiments were also performed to validate the mathematical model. Paik et al. (1998) developed a rapid procedure to identify the possibility of hull girder failure after collision and grounding damages

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conditions. The effects of several influential factor such as model extend and complexity, damage representations and model imperfections are investigated on the different vessels. It was found that the effect of damage extent in vertical direction is more critical than in longitudinal direction, and the damage varies the location of the neutral axes including higher stresses in proximity of the damage areas. The various probability levels are considered for the damage extent estimation.

When a hull-girder cross section is symmetric with respect to the centerline and subjected to pure vertical bending moment, the neutral axis for vertical bending is always horizontal and moves only vertically during the progressive collapse behavior. However, when the cross section is asymmetrically damaged, for example, due to a collision, the neutral axis rotates. Both rotation and translation need to be taken into account during the progressive collapse behavior even when only a vertical bending moment is applied, and the problem needs to be treated as a biaxial bending problem. Previous studies using the Smith's method on the ultimate strength of hull girders under biaxial thrust (Ozguc and Barltrop, 2008) and the residual strength of damaged hulls (Fang and Das, 2004; Hussein and Guedes Soares, 2009; Choung et al, 2011) consider the rotation and translation of neutral axis in a reasonable way. However, they employ a trial and error approach to detect the position of neutral axis. More easy approach to detect the position of neutral axis is demanded.

BASIC ASSUMPTION

The following assumption is made for the prediction of the residual hull girder strength under the sagging condition:

- (1) The ultimate sagging strength is attained when a stiffened panel element at the specified location (hereafter called 'critical element') reached the ultimate strength.
- (2) The hull girder cross section is elastic until the failure of the critical member.
- (3) The ultimate strength of the critical member is predicted from the average axial stress and average axial strain relationship calculated by HULLST (Yao and Nikolov).

EFFECT OF NEUTRAL AXIS ROTATION ON ESTIMATION OF THE ULTIMATE HULL GIRDER STRENGTH

In the elastic cross section, the bending stress at the i -th element (see Fig.1), σ_i , is expressed as

$$\sigma_i = E \{ (y_i - y_G) \phi_H + (z_i - z_G) \phi_V \} \quad (1)$$

where E is Young's modulus, y_G and z_G the centroid coordinates, and ϕ_H and ϕ_V the horizontal and vertical curvatures, respectively. y_G and z_G are given by

$$y_G = \frac{\left(\sum_{i=1}^N y_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (2)$$

$$z_G = \frac{\left(\sum_{i=1}^N z_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (3)$$

where D_i , A_i , and (y_i, z_i) are the tangential stiffness obtained as a slope of the average stress-average strain curve, cross sectional area and the coordinates of the centroid of individual elements, respectively.

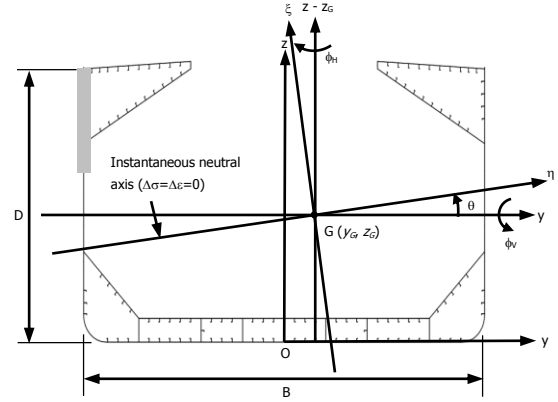


Fig. 1 Neutral axes of the elastic hull girder cross section with asymmetric damage

For the case of asymmetrically damaged cross section, Eqs (4) through (8) are used, and for the intact one, the expressions are given in Eqs (9) and (10). The biaxial moment and curvature relationship is given in the form

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (4)$$

where

$$\begin{aligned} I_{HV} &= I_{VH} = \sum_{i=1}^N (y_i - y_G)(z_i - z_G) A_i \\ I_{HH} &= \sum_{i=1}^N (y_i - y_G)^2 A_i \\ I_{VV} &= \sum_{i=1}^N (z_i - z_G)^2 A_i \end{aligned} \quad (5)$$

where I and M are the moment of inertia and bending moment, respectively. When the vertical bending moment M_V is applied to the cross section with no constraint on the horizontal curvature (Case 1), the horizontal curvature as well as the vertical curvature is induced under the condition of horizontal bending moment $M_H = 0$. The incremental equation to be solved is

$$\begin{Bmatrix} 0 \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (6)$$

Therefore,

$$\begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} = \frac{1}{E(I_{HH} I_{VV} - I_{HV}^2)} \begin{Bmatrix} -I_{HV} M_V \\ I_{HH} M_V \end{Bmatrix} \quad (7)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{-(y_i - y_G)I_{HV} + (z_i - z_G)I_{HH}}{(I_{HH} I_{VV} - I_{HV}^2)} M_V \quad (8)$$

The terms including the moment of inertia, I_{HV} , represent the effect of the rotation of the neutral axis.

On the other hand, when the vertical bending moment is applied to the cross section with the horizontal curvature constrained (Case 2), the bending moment are induced under the condition of $\phi_H = 0$, that is,

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} 0 \\ \phi_V \end{Bmatrix} \quad (9)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{(z_i - z_G)}{I_{VV}} M_V \quad (10)$$

Here, it is assumed that the residual hull girder strength in the sagging condition M_V^u is attained when a critical member at the location of $(y_C - z_C)$ reached its ultimate strength, σ_C^u , namely for Case 1

$$M_V^u|_{CASE1} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G)I_{HV} + (z_C - z_G)I_{HH}} \sigma_C^u \quad (11)$$

And for Case 2

$$M_V^u|_{CASE2} = \frac{I_{VV}}{(z_C - z_G)} \sigma_C^u \quad (12)$$

Therefore, the reduction rate of the residual strength due to the rotation of the neutral axis in the framework of the proposed approximate approach is given by ratio of Eq. (11) to Eq. (12) as

$$\frac{M_V^u|_{CASE1}}{M_V^u|_{CASE2}} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G)I_{HV} + (z_C - z_G)I_{HH}} \frac{(z_C - z_G)}{I_{VV}} \quad (13)$$

CASE STUDY

Two single-hull bulk carriers, B1 and B2, and one double-hull oil tanker, T2, are taken as the subject ships as shown in Table 1. Ship B1 is designed according to Pre-UR rule and built in 1987 and Ship B2 according to CSR-B having larger cross section and scantling sizes. Ship T2 is designed according to CSR-T.

Ship	B1	B2	T2
L (mm)	217,000	219,000	234,000
B (mm)	32,236	32,240	44,000
D (mm)	18,300	19,900	21,200
Design criteria	Pre-IACS UR	IACS CSR-B	IACS CSR-T

Table 1 Subject ships

The damage of the upper part of side shell due to collision is assumed. The vertical damage extent is taken as 10%, 20%, 40% and 70% of the depth D for both bulk carrier and tanker. The horizontal damage extent is taken as $B/16$, and it is kept constant for all damaged cases. The damaged cross sections of Ship B1 are illustrated in Fig. 2 and those of Ship T2 in Fig. 3. The stiffness of the elements in the damaged area is completely removed. For the double hull tanker, only outer side shell is assumed to be damaged. The locations of the critical deck element are presented in Fig. 4 for single hull bulk carrier and double hull oil tanker, respectively.

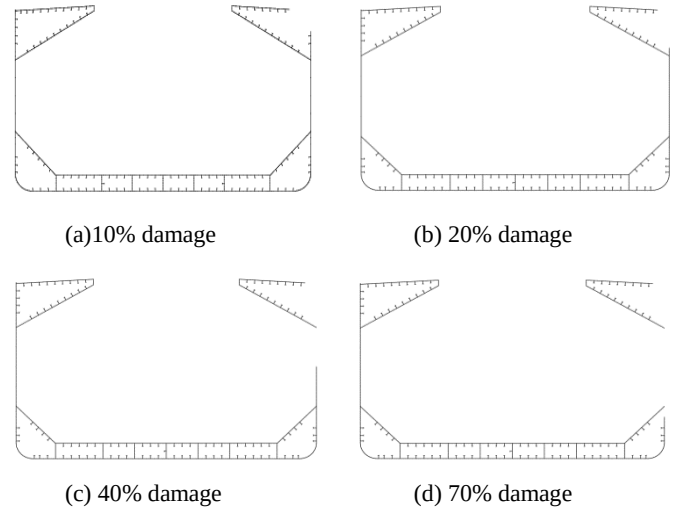


Fig. 2 Single hull bulk carrier (Ship B1)

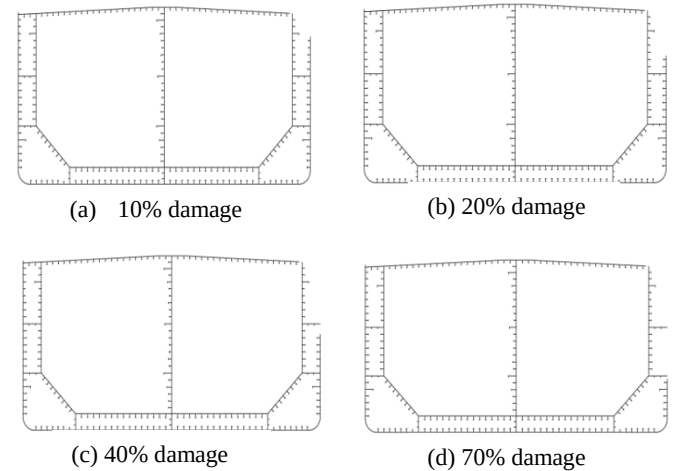
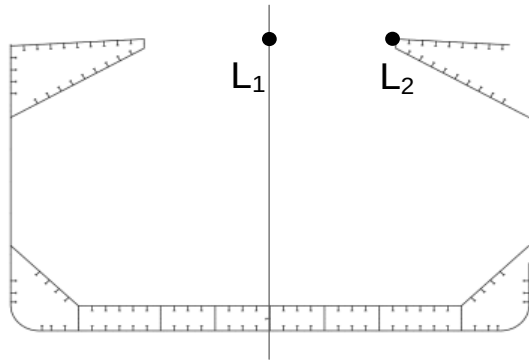
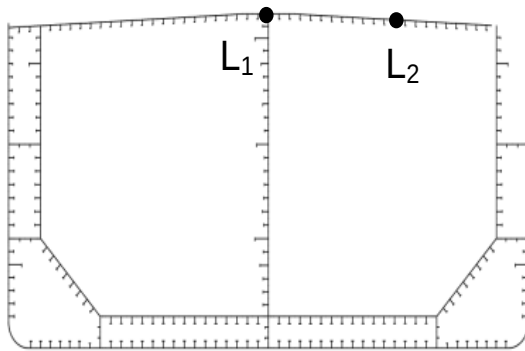


Fig. 3 Double hull oil tanker (Ship T2)

The investigation of the residual hull girder strength under sagging condition is performed by taking two locations of the critical deck elements as shown in Fig. 4. Single hull bulk carrier (B1 and B2), the locations of the critical element are L_1 and L_2 , L_1 is located at the center line and L_2 at the hatch coaming on the damage side. For the case of double hull oil tanker (T2), L_1 is located at the center line and L_2 at the distance of $B/4$ from the [damaged side shell](#).



(a) Single hull bulk carrier



(b) Double hull oil tanker

Fig. 4 Locations of the critical deck elements

RESULT AND DISCUSSION

In sagging condition, it is well recognized that the ultimate hull girder strength is almost attained when the primary deck members in longitudinal compression reached their ultimate strength. Also, because the damage takes place at the asymmetric position, in other word, collision damage [is placed at](#) the side shell through to the deck part (B/16) and there is no damage located at the bottom part, so that it is very important to investigate the critical member under sagging condition. In the present study, the ultimate strength is analyzed after [damage has taken place](#). The water ingress is not considered in the analysis.

The results obtained by progressive collapse analysis under sagging condition for 20% and 70% damage are presented in Fig. 5 and Fig. 6, respectively. Case 1 considers the rotation of neutral axis and Case 2 does not. The resultant of bending moment versus curvature is plotted.

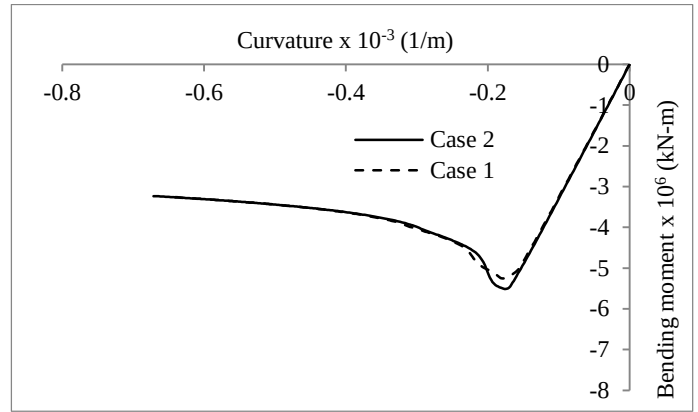


Fig. 5 Single hull bulk carrier (Ship B1) with 20% damage

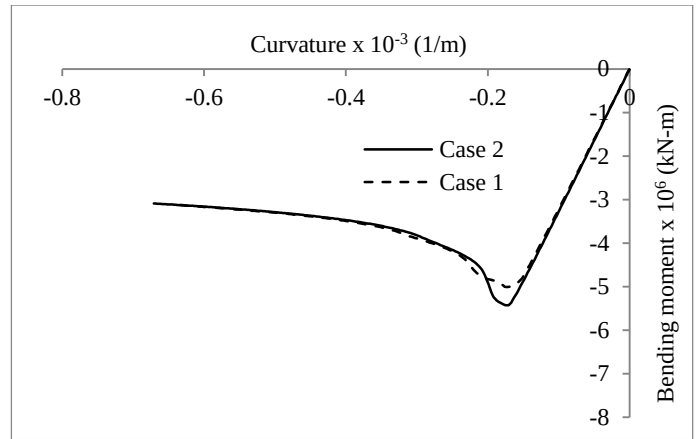


Fig. 6 Single hull bulk carrier (Ship B1) with 70% damage

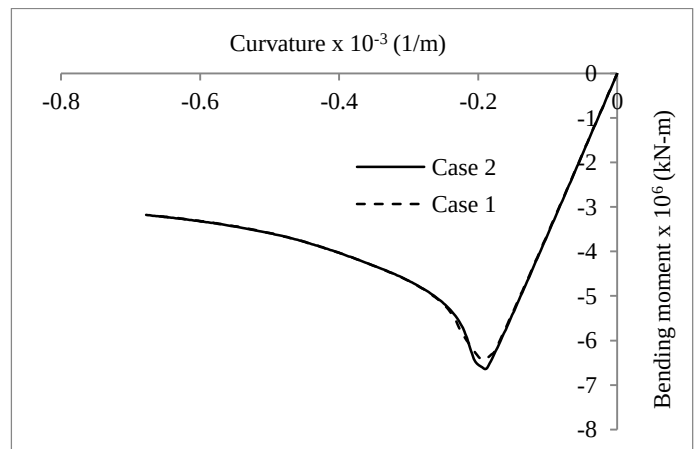


Fig. 7 Single hull bulk carrier (Ship B2) with 20% damage

Similarly, the resultant bending moment and curvature curve for Ship B2 and Ship T2 with 20% and 70% damage are presented in Figs. 7 through 10.

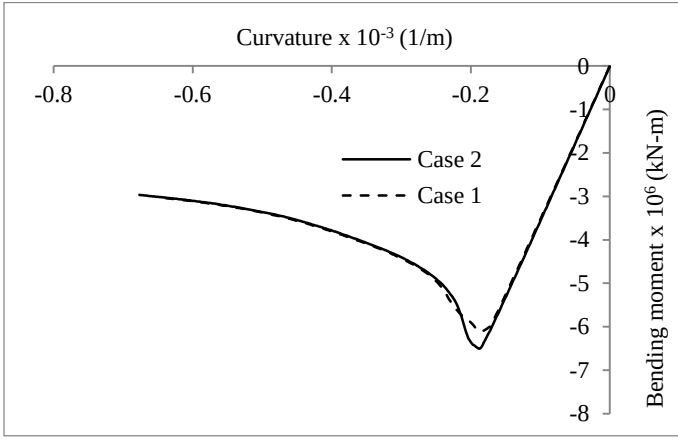


Fig. 8 Single hull bulk carrier (Ship B2) with 70% damage

Fig. 7 and Fig. 8 shows the results of the moment-curvature relationship obtained by progressive collapse analysis for single hull bulk carrier (B2). It is found that Case 2 generally gives larger ultimate strength than Case 1 because the horizontal curvature is constrained. The ultimate hull girder strength is attained even the horizontal curvature is constrained because of the horizontal bending moment is induced by the incremental equation for horizontal and vertical bending moments and this makes the ultimate hull girder strength becomes higher. The effect is largest in Ship B1, smaller in Ship B2, and almost negligible in Ship T2. For Ship B1, Case 1 strength is 7.3% smaller than Case 2 in sagging condition. The difference between Ship B1 and Ship B2 may be related to that of the depth to breadth ratio, member scantlings etc. Fig. 9 and Fig. 10 represent the moment-curvature relationship under sagging condition for double hull oil tanker (T2) for 20% and 70% of damages, respectively. According to the result obtained by progressive collapse analysis of double hull oil tanker (Ship T2), the effect of rotation of neural axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

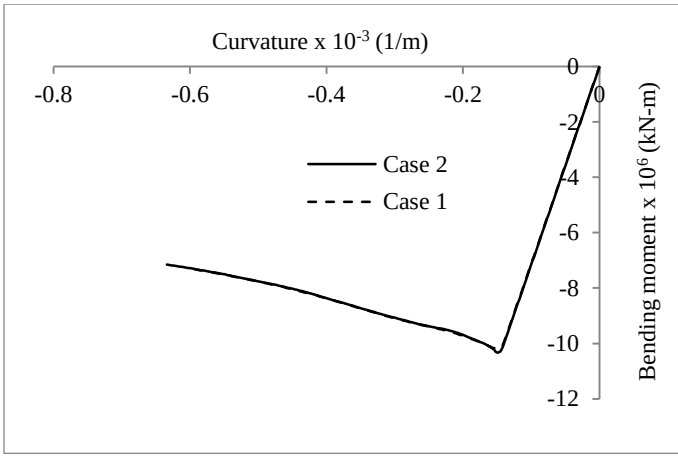


Fig. 9 Double hull oil tanker (Ship T2) with 20% damage

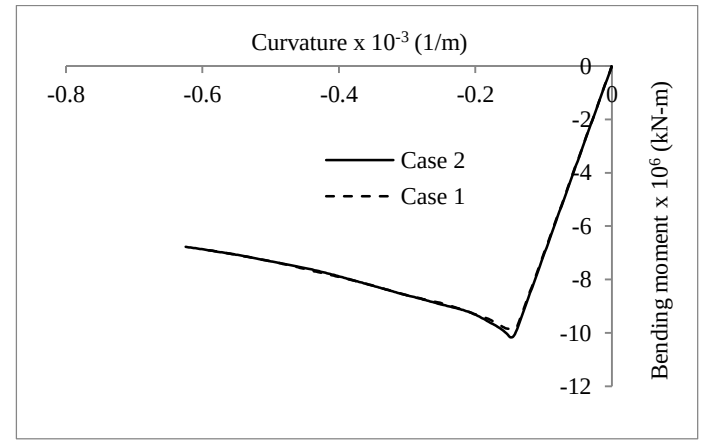


Fig. 10 Double hull oil tanker (T2) with 70% damage

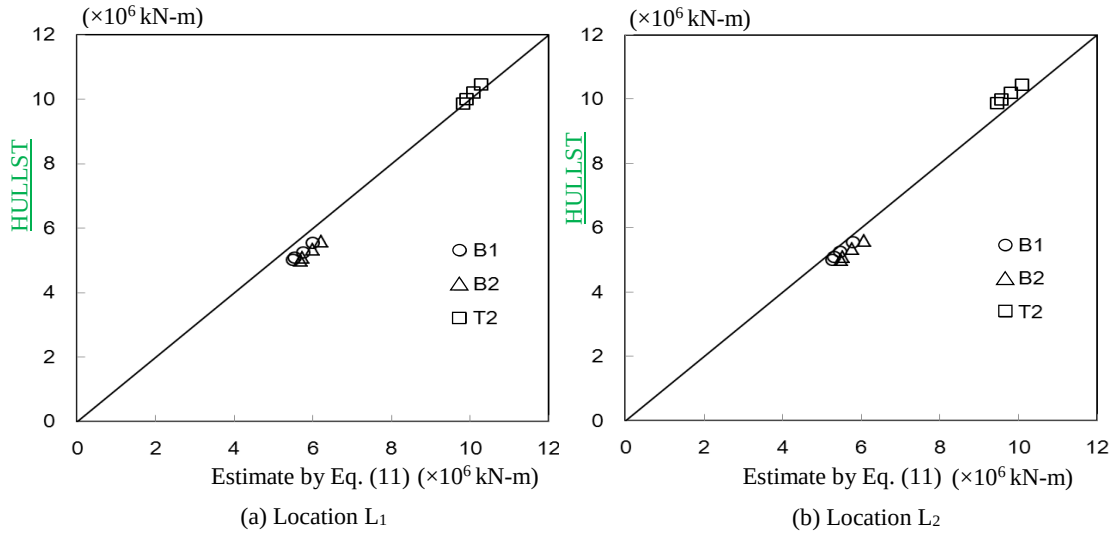


Fig. 11 Comparison of residual hull girder strength M_v between the simplified method and the progressive collapse analysis

The residual strengths of Ship B1, Ship B2 and Ship T2 obtained for the four different damage extents are summarized in Fig. 11. It is found that Eq. (11) gives an estimate of the residual strength which is in good agreement with the result of the progressive collapse analysis. For bulk carriers, the critical element at the location L₂ gives a better estimate of the residual strength. This is consistent with the observed collapse behavior in which the ultimate strength is attained when topside tank region of the damaged side almost fully failed. In the case of tankers, the location L₁ gives better estimate of the residual strength than L₂. This is also consistent with the failure behavior of T2 in which the ultimate strength is attained when the deck part almost fully failed.

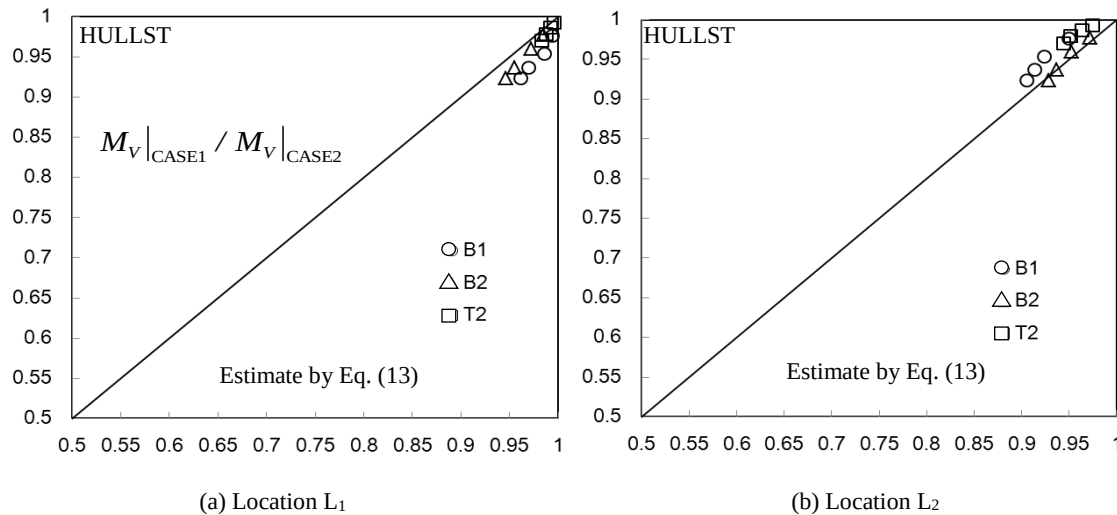


Fig. 12 Comparison of reduction ratio of residual hull girder due to rotation of neutral axis between the simplified method and the progressive collapse analysis (Case 1/Case 2)

CONCLUSIONS

Progressive collapse analysis was performed on two single hull bulk carriers and a double hull oil tanker with asymmetrically damaged cross section applying Smith's method. A closed form formulae of residual strength and that of the reduction ratio of the residual strength due to the rotation of neutral axis are proposed. It is found through a comparison with the results obtained by the progressive collapse analysis that the residual hull girder strength of asymmetrically damaged ships under sagging bending moment can be predicted by the proposed formulae with a reasonable accuracy. The ultimate strength obtained with the horizontal curvature constrained is larger than that without constraint one. The ultimate hull girder strength is attained under condition the horizontal curvature constrained because the horizontal bending moment is induced by the incremental equation for horizontal and vertical bending moments and this makes the ultimate hull girder strength higher. The effect is largest for single hull bulk carrier and almost negligible for double hull oil tanker. The difference characteristic for two single hull bulk carrier may be related to that of the depth to breadth ratio, member scantlings etc. The resultant of bending moment is induced by the accumulation of the horizontal and vertical bending moment based on the reference coordinate system. Fig. 12 shows the comparison the reduction rates of the residual strength due to rotation of the neutral axis obtained by

Eq. (13) and progressive collapse analysis. The influence of the rotation of the neutral axis is larger for a larger damage extent in general. For the case of the subject ships and damages under consideration, the influence is larger in bulk carriers than in tankers. Eq. (13) gives a relatively good estimate of the reduction rate. It can be a good basis of a rational expression of the influence of the rotation of the neutral axis on the reserved hull girder strength, as required in ship structures. More systematic analyses are definitely needed to develop the formula having larger applicability in ship types and damaged cases.

According to the result obtained by progressive collapse analysis of double hull oil tanker, the effect of rotation of neural axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

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INTRODUCTION

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BASIC ASSUMPTION

The following assumption is made for the prediction of the residual hull girder strength under the sagging condition:

- (1) The ultimate sagging strength is attained when a stiffened panel element at the specified location (hereafter called 'critical element') reached the ultimate strength.
- (2) The hull girder cross section is elastic until the failure of the critical member.
- (3) The ultimate strength of the critical member is predicted from the average axial stress and average axial strain relationship calculated by HULLST (Yao and Nikolov).

EFFECT OF NEUTRAL AXIS ROTATION ON ESTIMATION OF THE ULTIMATE HULL GIRDER STRENGTH

In the elastic cross section, the bending stress at the i -th element (see Fig.1), σ_i , is expressed as

$$\sigma_i = E \{ (y_i - y_G) \phi_H + (z_i - z_G) \phi_V \} \quad (1)$$

where E is Young's modulus, y_G and z_G the centroid coordinates, and ϕ_H and ϕ_V the horizontal and vertical curvatures, respectively. y_G and z_G are given by

$$y_G = \frac{\left(\sum_{i=1}^N y_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (2)$$

$$z_G = \frac{\left(\sum_{i=1}^N z_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (3)$$

Where D_i , A_i , y_i and z_i are the tangential stiffeners obtained as a slope of the average stress-strain relationship, cross section and the coordinate position of the individual elements, respectively.

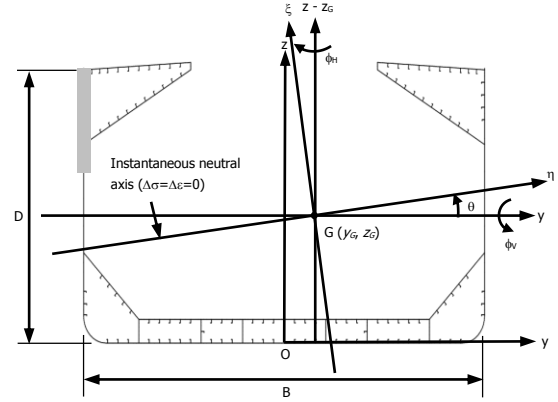


Fig. 1 Neutral axes of the elastic hull girder cross section with asymmetric damage

For the case of asymmetric damage cross section, the equations are used from Eqs. (4) to (8), and for the intact one, the expressions are given in Eqs. 9 and (10). The biaxial moment and curvature relationship is given in the form

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (4)$$

where

$$\begin{aligned} I_{HV} &= I_{VH} = \sum_{i=1}^N (y_i - y_G)(z_i - z_G) A_i \\ I_{HH} &= \sum_{i=1}^N (y_i - y_G)^2 A_i \\ I_{VV} &= \sum_{i=1}^N (z_i - z_G)^2 A_i \end{aligned} \quad (5)$$

Where I and M is the moment of inertia and bending moment, respectively. When the vertical bending moment M_V is applied to the cross section with no constraint on the horizontal curvature (Case 1), the horizontal curvature as well as the vertical curvature is induced under the condition of horizontal bending moment $M_H = 0$. The incremental equation to be solved is

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Therefore,

$$\begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} = \frac{1}{E(I_{HH} I_{VV} - I_{HV}^2)} \begin{Bmatrix} -I_{HV} M_V \\ I_{HH} M_V \end{Bmatrix} \quad (7)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{-(y_i - y_G)I_{HV} + (z_i - z_G)I_{HH}}{(I_{HH} I_{VV} - I_{HV}^2)} M_V \quad (8)$$

The terms including the moment of inertia, I_{HV} , represent the effect of the rotation of the neutral axis.

On the other hand, when the vertical bending moment is applied to the cross section with the horizontal curvature constrained (Case 2), the bending moment are induced under the condition of $\phi_H = 0$, that is,

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} 0 \\ \phi_V \end{Bmatrix} \quad (9)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{(z_i - z_G)}{I_{VV}} M_V \quad (10)$$

Here, it is assumed that the residual hull girder strength in the sagging condition M_V^u is attained when a critical member at the location of $(y_C - z_C)$ reached its ultimate strength, σ_C^u , namely for Case 1

$$M_V^u|_{CASE1} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G)I_{HV} + (z_C - z_G)I_{HH}} \sigma_C^u \quad (11)$$

And for Case 2

$$M_V^u|_{CASE2} = \frac{I_{VV}}{(z_C - z_G)} \sigma_C^u \quad (12)$$

Therefore, the reduction rate of the residual strength due to the rotation of the neutral axis in the framework of the proposed approximate approach is given by ratio of Eq. (11) to Eq. (12) as

$$\frac{M_V^u|_{CASE1}}{M_V^u|_{CASE2}} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G)I_{HV} + (z_C - z_G)I_{HH}} \frac{(z_C - z_G)}{I_{VV}} \quad (13)$$

CASE STUDY

Two single-hull bulk carriers, B1 and B2, and one double-hull oil tanker, T2, are taken as the subject ships as shown in Table 1. Ship B1 is designed according to Pre-UR rule and built in 1987 and Ship B2 according to CSR-B having larger cross section and scantling sizes. Ship T2 is designed according to CSR-T.

Ship	B1	B2	T2
L (mm)	217,000	219,000	234,000
B (mm)	32,236	32,240	44,000
D (mm)	18,300	19,900	21,200
Design criteria	Pre-IACS UR	IACS CSR-B	IACS CSR-T

Table 1 Subject ships

The damage of the upper part of side shell due to collision is assumed. The vertical damage extent is taken as 10%, 20%, 40% and 70% of the depth D for both bulk carrier and tanker. The horizontal damage extent is taken as $B/16$, and it is kept constant for all damaged cases. The damaged cross sections of Ship B1 are illustrated in Fig. 2 and those of Ship T2 in Fig. 3. The stiffness of the elements in the damaged area is completely removed. For the double hull tanker, only outer side shell is assumed to be damaged. The locations of the critical deck element are presented in Fig. 4 for single hull bulk carrier and double hull oil tanker, respectively.

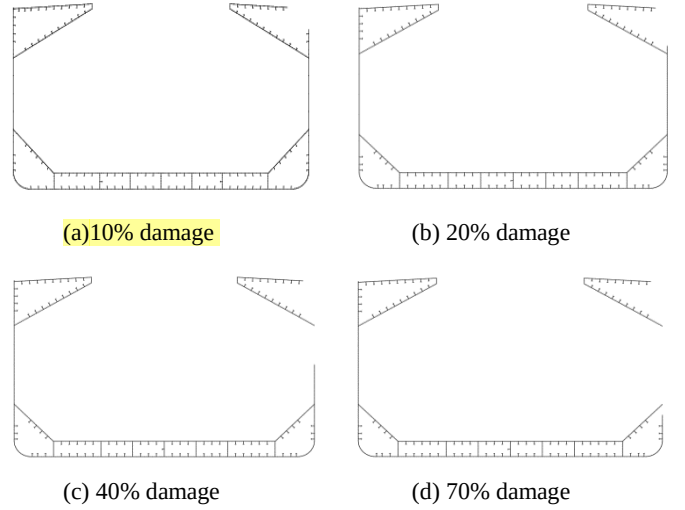


Fig. 2 Single hull bulk carrier (Ship B1)

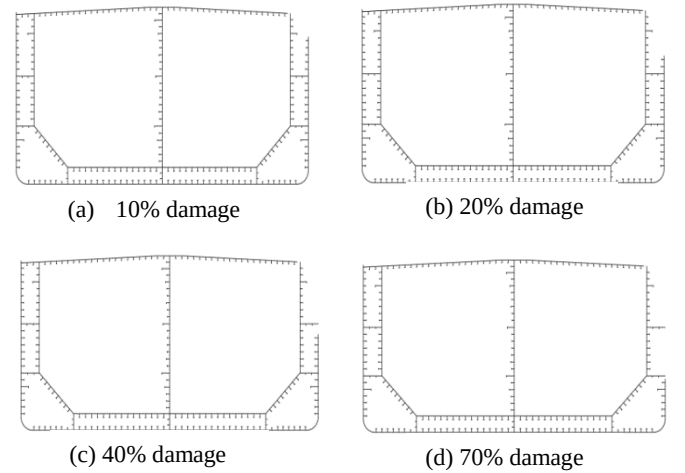
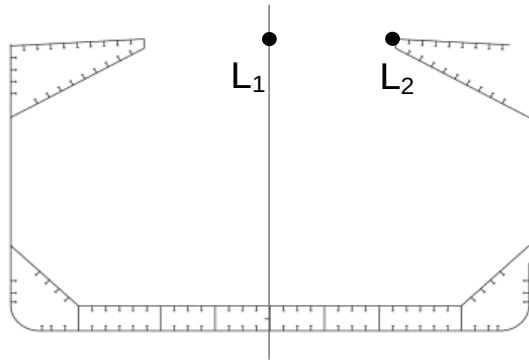
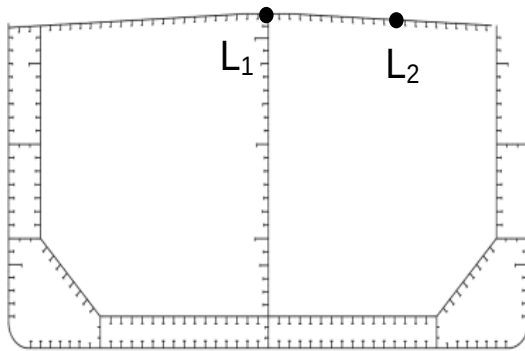


Fig. 3 Double hull oil tanker (Ship T2)

The investigation of the residual hull girder strength under sagging condition is performed by taking two locations of the critical deck elements as shown in Fig. 4. Single hull bulk carrier (B1 and B2), the locations of the critical element are L_1 and L_2 , L_1 is located at the center line and L_2 at the hatch coaming on the damage side. For the case of double hull oil tanker (T2), L_1 is located at the center line and L_2 at the distance of $B/4$ from the damage side shell.



(a) Single hull bulk carrier



(b) Double hull oil tanker

Fig. 4 Locations of the critical deck elements

RESULT AND DISCUSSION

In sagging condition, it is well recognized that the ultimate hull girder strength is almost attained when the primary deck members in longitudinal compression reached their ultimate strength. Also, because the damage takes place at the asymmetric position, in other word, collision damage is place at the side shell through to the deck part (B/16) and there is no damage located at the bottom part, so that it is very important to investigate the critical member under sagging condition. In the present study, the ultimate strength is analyzed after damaged takes place. The water ingress is not considered in the analysis.

The results obtained by progressive collapse analysis under sagging condition for 20% and 70% damage are presented in Fig. 5 and Fig. 6, respectively. Case 1 considers the rotation of neutral axis and Case 2 does not. The moment-curvature relationship is given by

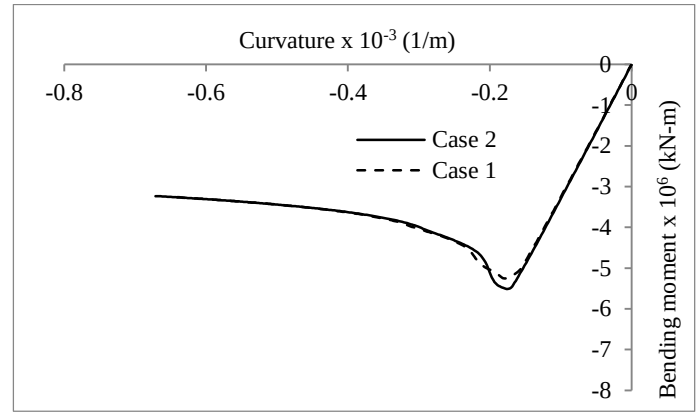


Fig. 5 Single hull bulk carrier (Ship B1) with 20% damage

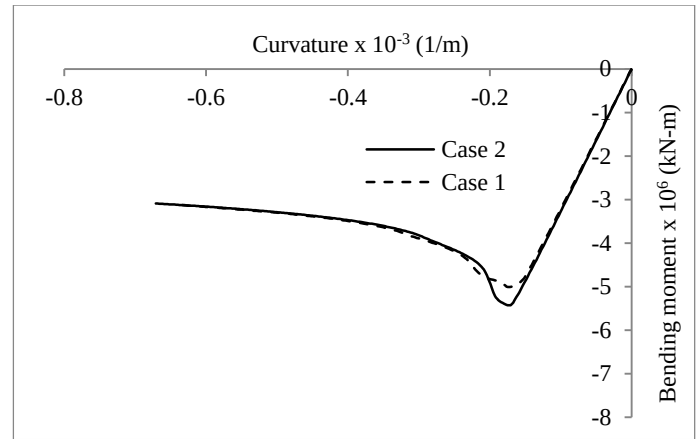


Fig. 6 Single hull bulk carrier (Ship B1) with 70% damage

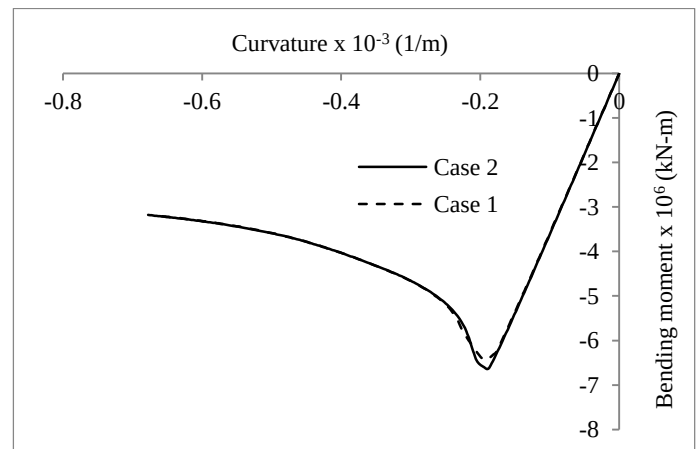


Fig. 7 Single hull bulk carrier (Ship B2) with 20% damage

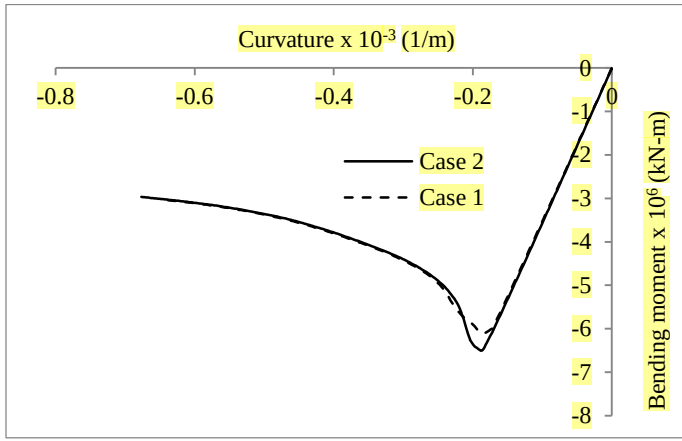


Fig. 8 Single hull bulk carrier (Ship B2) with 70% damage

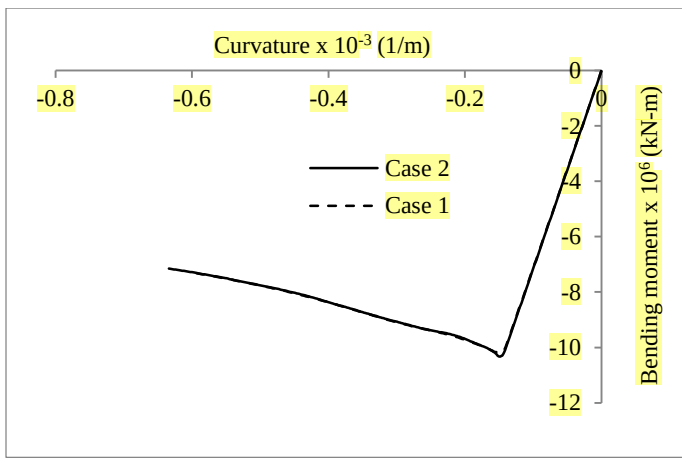


Fig. 9 Double hull oil tanker (Ship T2) with 20% damage

Fig. 7 and Fig. 8 shows the results of the moment-curvature relationship obtained by progressive collapse analysis for single hull bulk carrier (B2). It is found that Case 2 generally gives larger ultimate strength than Case 1 because the horizontal curvature is constrained. The ultimate hull girder strength is attained even the horizontal curvature is constrained because of the horizontal bending moment is induced by the stiffened matrix interaction for horizontal and vertical and this makes the ultimate hull girder strength becomes higher. The effect is largest in Ship B1, smaller in Ship B2, and almost negligible in Ship T2. For Ship B1, Case 1 strength is 7.3% smaller than Case 2 in sagging condition. The difference between Ship B1 and Ship B2 may be related to that of the depth to breadth ratio, member scantlings etc. Fig. 9 and Fig. 10 represent the moment-curvature relationship under sagging condition for double hull oil tanker (T2) for 20% and 70% of damaged, respectively. According to the result obtained by progressive collapse analysis of double hull oil tanker (Ship T2), the effect of rotation of neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

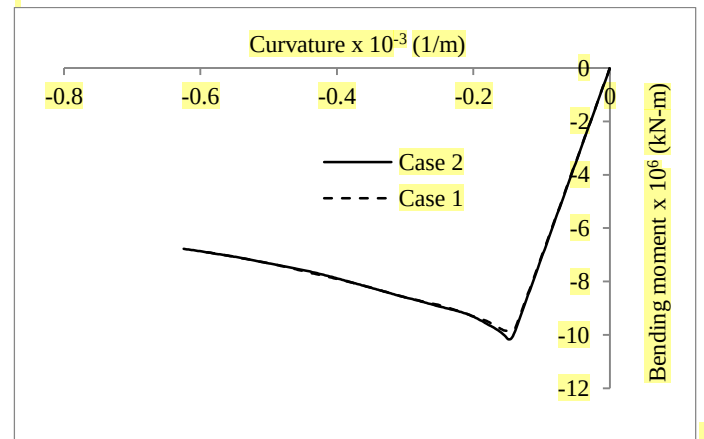
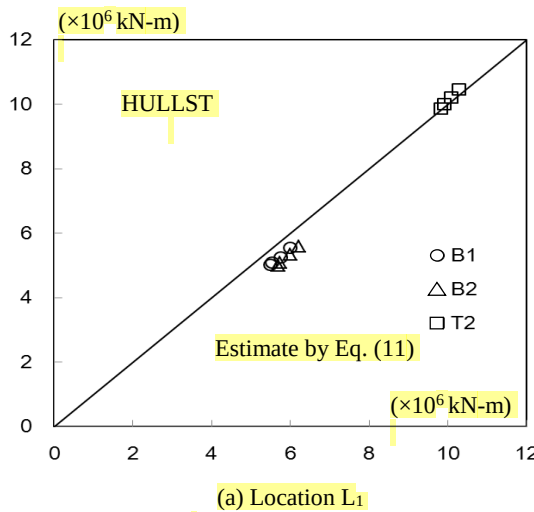
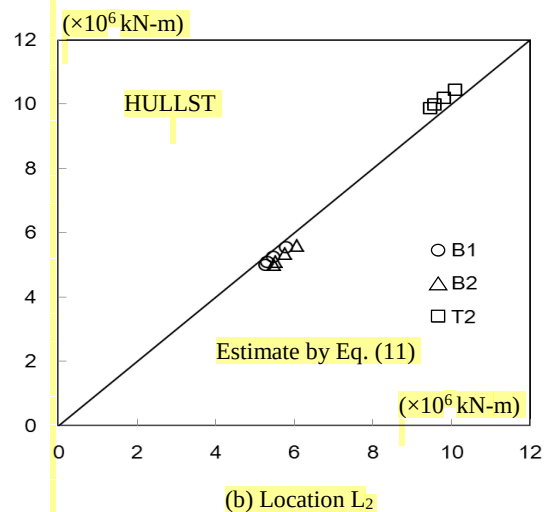


Fig. 10 Double hull oil tanker (T2) with 70% damage



(a) Location L₁



(b) Location L₂

Fig. 11 Comparison of residual hull girder strength M_V between the simplified method and the progressive collapse analysis

The residual strengths of Ship B1, Ship B2 and Ship T2 obtained for the four different damage extents are summarized in Fig. 11. It is found that Eq. (11) gives an estimate of the residual strength which is in good agreement with the result of the progressive collapse analysis. For bulk carriers, the critical element at the location L₂ gives a better estimate of the residual strength. This is consistent with the observed collapse behavior in which the ultimate strength is attained when topside tank region of the damage side almost fully failed. The location L₁ cannot well take account of the effect of the horizontal curvature induced by M_V , resulting in the slight overestimate of the strength. In the case of tankers, the location L₁ gives better estimate of the residual strength than L₂. This is also consistent with the failure behavior of T2 in which the ultimate strength is attained when the deck part almost fully failed.

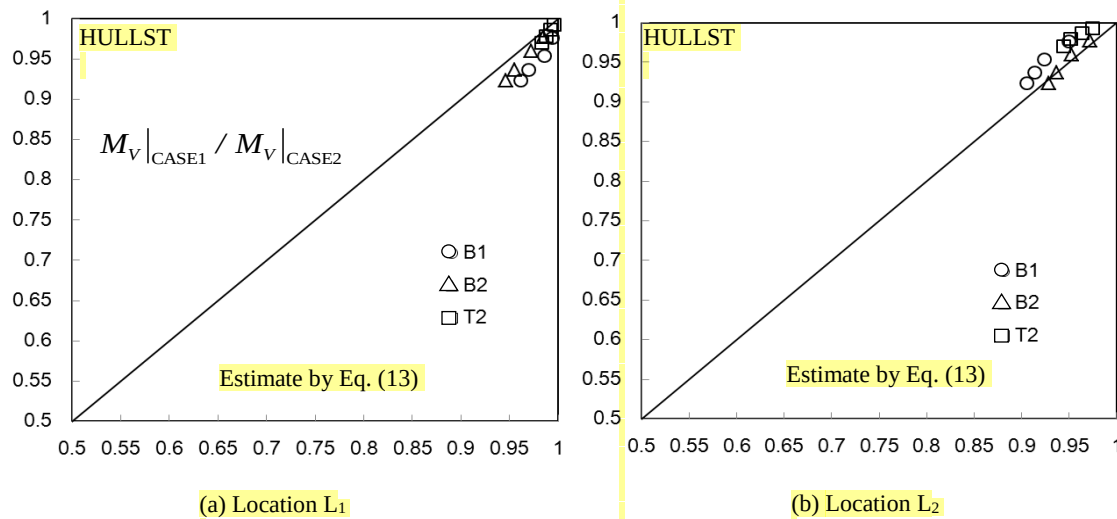


Fig. 12 Comparison of reduction ratio of residual hull girder due to rotation of neutral axis between the simplified method and the progressive collapse analysis (Case 1/Case 2)

CONCLUSIONS

The ultimate hull girder strength analysis of single hull bulk carriers and a double hull oil tanker with asymmetrically damaged cross section has been performed using the simplified approach under sagging condition by performing the elastic cross-sectional properties and critical member elements. A closed form formulae of residual strength and that of the reduction ratio of the residual strength due to the rotation of neutral axis are proposed. It is found through a comparison with the results obtained by the progressive collapse analysis that the residual hull girder strength of asymmetrically damaged ships under sagging bending moment can be predicted by the proposed formulae with a reasonable accuracy. The ultimate strength obtained with the horizontal curvature constrained is larger than without constrained one. The ultimate hull girder strength is attained even the horizontal curvature is constrained because of the horizontal bending moment is induced by the stiffened matrix interaction for horizontal and vertical and this makes the ultimate hull girder strength becomes higher. The effect is largest for single hull bulk carrier and almost negligible for double hull oil tanker. The difference characteristic for two single hull bulk carrier may be related to that of the depth to breadth ratio, member scantlings etc.

The resultant of bending moment is induced by the accumulation of the horizontal and vertical bending moment based on the reference coordinate system. Fig. 12 shows the comparison the reduction rates of the residual strength due to rotation of the neutral axis obtained by Eq. (13) and progressive collapse analysis. The influence of the rotation of the neutral axis is larger for a larger damage extent in general. For the case of the subject ships and damages under consideration, the influence is larger in bulk carriers than in tankers. Eq. (13) gives a relatively good estimate of the reduction rate. It can be a good basis of a rational expression of the influence of the rotation of the neutral axis on the reserved hull girder strength, as required in ship structures. More systematic analyses are definitely needed to develop the formula having larger applicability in ship types and damaged cases.

According to the result obtained by progressive collapse analysis of double hull oil tanker, the effect of rotation of neural axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

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Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships

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Gowa, South Sulawesi, Indonesia

ABSTRACT

The objective of the present study is to investigate the ultimate hull girder strength of asymmetrically damaged ship under sagging condition. Two kinds of ship are taken as the object of the analysis. The cross section of the ship is considered and assumed to be remained plane. The simply supported of boundary condition is applied to both sides of the cross section. The ultimate hull girder strength is attained when a plate and/or stiffened plate element at the specified location called “critical element” reach their ultimate strength. To investigate the ultimate hull girder strength, a simplified approach is proposed. The result obtained by simplified approach is compared to the progressive collapse analysis for the effectiveness and validation.

KEY WORDS: Single hull bulk carrier, double hull oil tanker, cross section, neutral axis, asymmetrically damaged, ultimate strength, simplified approach.

INTRODUCTION

The ability to predict accurately the ultimate strength of ship hull girder when subjected to longitudinal bending is one of the most important aspects of ship structural design. A collision and grounding damages may takes place on ship's hull, which may threaten safety ship and surrounding environment. In this regard, to enhance the safety of ship's structure and minimize the risks, the International Maritime Organization (IMO, 2009) has required in Goal Based Standard for New Ship Construction (GBS) to consider the residual strength of the hull girder in specified damage conditions as one of the functional requirements for the structural rules for bulk carriers and tankers.

Many studies have been conducted on the analyses of the residual hull girder strength due to collision and grounding damaged. Pedersen (1994) presented a mathematical modeling to estimate the contact pressure between the grounded ship and the sea bottom. The grounded contact force was compared to the force which would crush the forward bottom of the ship. The sectional bending moment due to grounding was determined and compared to the ultimate hull girder strengths. The model experiments and full-scale controlled grounding experiments were also performed to validate the mathematical model. Paik et al. (1998) developed a rapid procedure to identify the possibility of hull girder failure after collision and grounding damages

based on the closed-form formulae of the ultimate hull girder strength and section modulus after the damages. Soares et al. (2008) evaluated the ability of simplified structural analysis methods based on the Smith's formulation to predict the ultimate strength of damage ship's hull. Toh et al. (2012) developed simplified calculation program to calculate the ultimate strength in intact and damage condition and the reduction of hull girder ultimate strength is investigated. The calculation result of simplified method is compared to the FE result for both intact and damage condition. Muis Alie, M.Z et al. (2012) investigated the incidence of neutral axis rotation on residual hull girder strength for asymmetrical damaged ships under longitudinal bending, applying the progressive collapse method and finding an explicit expression of neutral axis rotation. After performing a series of progressive collapse analyses on several bulk carriers and tanker, it was found that residual hull girder strength, considering the instantaneous neutral axis is generally lower than the relevant one, obtained by constraining the rotation, as it is commonly assumed in classical procedures. Ohtsubo et al. (1994) showed the experimental and numerical work on the ship structural damages due to collision and grounding. This was one of the first attempts to apply the explicit Finite Element Method codes, such as LS-DYNA and DYTRAN, to the collision and grounding problems of ships. Ozguc et al. (2005) investigated the collision resistance and residual strength of single skin and double skin bulk carriers subjected to damages. Lee et al. (2008) calculate the ultimate strength with collision damage using LS-DYNA and compared with the experiment results. It is found that the ultimate strength is reduced as a damage size increased as expected. Notaro et al. (2010) carried out full nonlinear FE assessments of hull girder capacity in intact and damage conditions. The effects of several

influences factors such as model extend and complexity, damage representations and model imperfections are investigated on the different vessels. It was found that the effect of damage extent in vertical direction is more critical than in longitudinal direction, and the damage varies the location of the neutral axes including higher stresses in proximity of the damage areas. The various probability levels are considered for the damage extent estimation.

When a hull-girder cross section is symmetric with respect to the centerline and subjected to pure vertical bending moment, the neutral axis for vertical bending is always horizontal and moves only vertically during the progressive collapse behavior. However, when the cross section is asymmetrically damaged due, for example, to a collision, the neutral axis rotates. Both rotation and translation need to be taken into account during the progressive collapse behavior even when only a vertical bending moment is applied, and the problem needs to be treated as a biaxial bending problem. Previous studies using the Smith's method on the ultimate strength of hull girders under biaxial thrust (Ozguc and Barltrop, 2008) and the residual strength of damaged hulls (Fang and Das, 2004; Hussein and Guedes Soares, 2009; Choung et al, 2011) consider the rotation and translation of neutral axis in a reasonable way. However, they employ a trial and error approach to detect the position of neutral axis. More easy approach to detect the position of neutral axis is demanded.

BASIC ASSUMPTION

The following assumption is made for the prediction of the residual hull girder strength under the sagging condition:

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$$z_G = \frac{\left(\sum_{i=1}^N z_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (3)$$

Where D_i , A_i , y_i and z_i are the tangential stiffeners obtained as a slope of the average stress-strain relationship, cross section and the coordinate position of the individual elements, respectively.

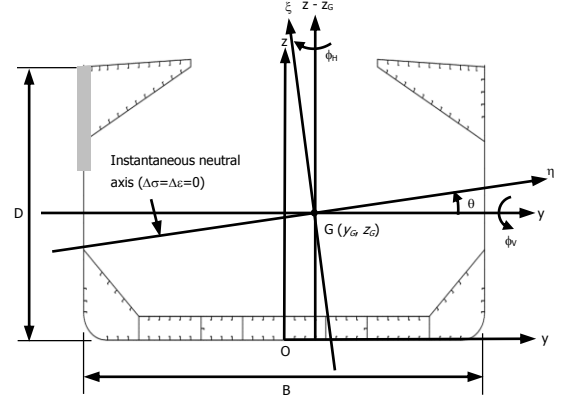


Fig. 1 Neutral axes of the elastic hull girder cross section with asymmetric damage

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where

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Therefore,

$$\begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} = \frac{1}{E(I_{HH} I_{VV} - I_{HV}^2)} \begin{Bmatrix} -I_{HV} M_V \\ I_{HH} M_V \end{Bmatrix} \quad (7)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

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The terms including the moment of inertia, I_{HV} , represent the effect of the rotation of the neutral axis.

On the other hand, when the vertical bending moment is applied to the cross section with the horizontal curvature constrained (Case 2), the bending moment are induced under the condition of $\phi_H = 0$, that is,

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} 0 \\ \phi_V \end{Bmatrix} \quad (9)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

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Here, it is assumed that the residual hull girder strength in the sagging condition M_V^u is attained when a critical member at the location of $(y_C - z_C)$ reached its ultimate strength, σ_C^u , namely for Case 1

$$M_V^u|_{CASE1} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G)I_{HV} + (z_C - z_G)I_{HH}} \sigma_C^u \quad (11)$$

And for Case 2

$$M_V^u|_{CASE2} = \frac{I_{VV}}{(z_C - z_G)} \sigma_C^u \quad (12)$$

Therefore, the reduction rate of the residual strength due to the rotation of the neutral axis in the framework of the proposed approximate approach is given by ratio of Eq. (11) to Eq. (12) as

$$\frac{M_V^u|_{CASE1}}{M_V^u|_{CASE2}} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G)I_{HV} + (z_C - z_G)I_{HH}} \frac{(z_C - z_G)}{I_{VV}} \quad (13)$$

CASE STUDY

Two single-hull bulk carriers, B1 and B2, and one double-hull oil tanker, T2, are taken as the subject ships as shown in Table 1. Ship B1 is designed according to Pre-UR rule and built in 1987 and Ship B2 according to CSR-B having larger cross section and scantling sizes. Ship T2 is designed according to CSR-T.

Ship	B1	B2	T2
L (mm)	217,000	219,000	234,000
B (mm)	32,236	32,240	44,000
D (mm)	18,300	19,900	21,200
Design criteria	Pre-IACS UR	IACS CSR-B	IACS CSR-T

Table 1 Subject ships

The damage of the upper part of side shell due to collision is assumed. The vertical damage extent is taken as 10%, 20%, 40% and 70% of the depth D for both bulk carrier and tanker. The horizontal damage extent is taken as $B/16$, and it is kept constant for all damaged cases. The damaged cross sections of Ship B1 are illustrated in Fig. 2 and those of Ship T2 in Fig. 3. The stiffness of the elements in the damaged area is completely removed. For the double hull tanker, only outer side shell is assumed to be damaged. The locations of the critical deck element are presented in Fig. 4 for single hull bulk carrier and double hull oil tanker, respectively.

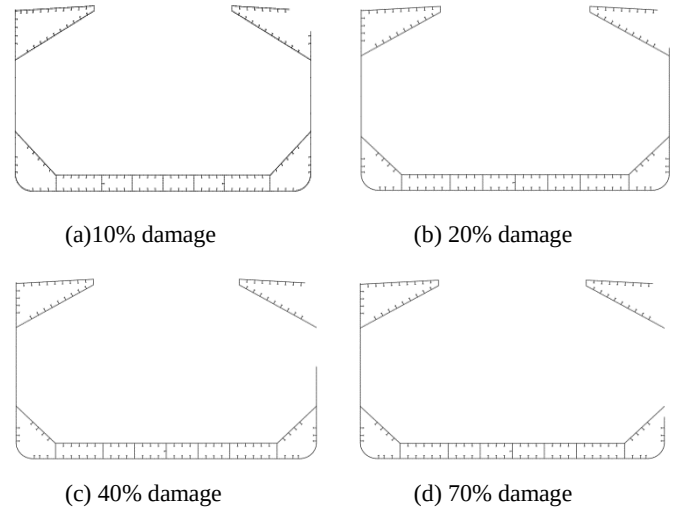


Fig. 2 Single hull bulk carrier (Ship B1)

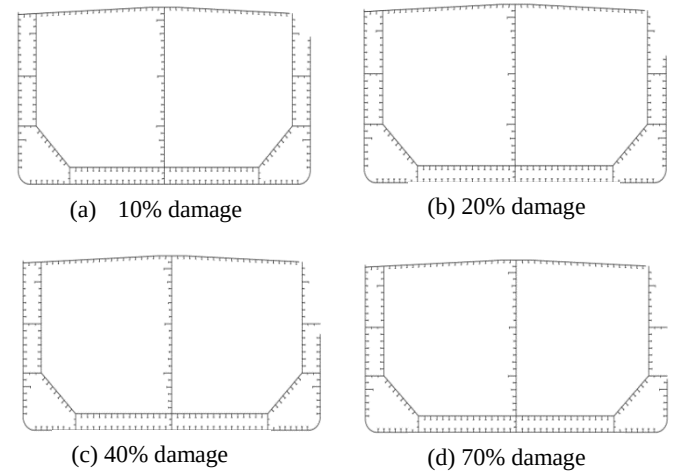
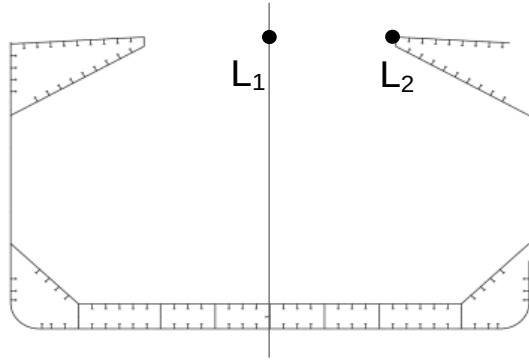
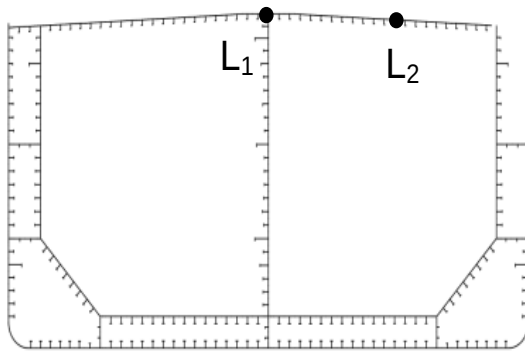


Fig. 3 Double hull oil tanker (Ship T2)

The investigation of the residual hull girder strength under sagging condition is performed by taking two locations of the critical deck elements as shown in Fig. 4. Single hull bulk carrier (B1 and B2), the locations of the critical element are L_1 and L_2 , L_1 is located at the center line and L_2 at the hatch coaming on the damage side. For the case of double hull oil tanker (T2), L_1 is located at the center line and L_2 at the distance of $B/4$ from the damage side shell.



(a) Single hull bulk carrier



(b) Double hull oil tanker

Fig. 4 Locations of the critical deck elements

RESULT AND DISCUSSION

In sagging condition, it is well recognized that the ultimate hull girder strength is almost attained when the primary deck members in longitudinal compression reached their ultimate strength. Also, because the damage takes place at the asymmetric position, in other word, collision damage is place at the side shell through to the deck part (B/16) and there is no damage located at the bottom part, so that it is very important to investigate the critical member under sagging condition. In the present study, the ultimate strength is analyzed after damaged takes place. The water ingress is not considered in the analysis.

The results obtained by progressive collapse analysis under sagging condition for 20% and 70% damage are presented in Fig. 5 and Fig. 6, respectively. Case 1 considers the rotation of neutral axis and Case 2 does not. The moment-curvature relationship is given by

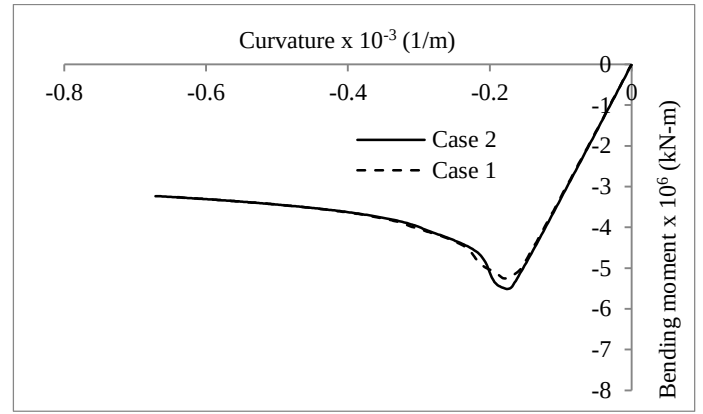


Fig. 5 Single hull bulk carrier (Ship B1) with 20% damage

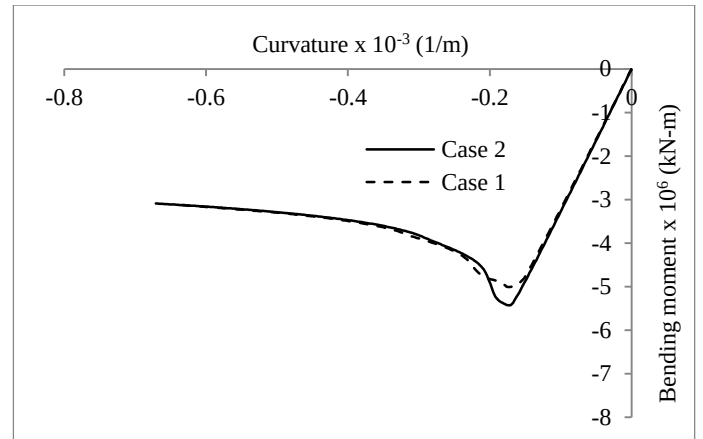


Fig. 6 Single hull bulk carrier (Ship B1) with 70% damage

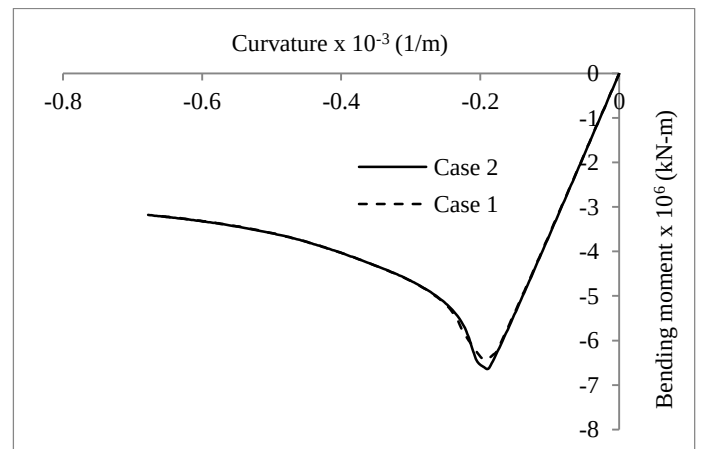


Fig. 7 Single hull bulk carrier (Ship B2) with 20% damage

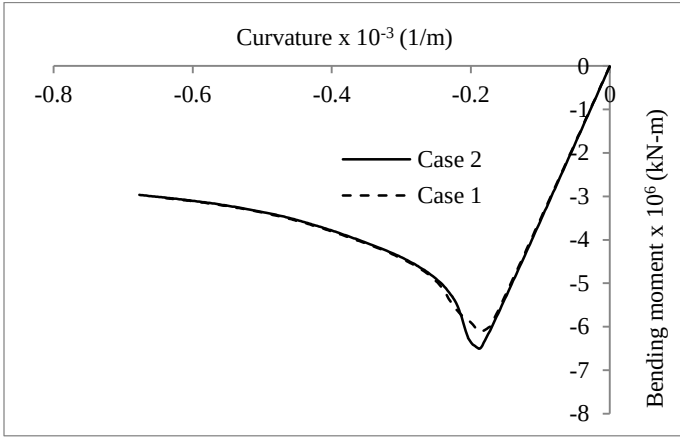


Fig. 8 Single hull bulk carrier (Ship B2) with 70% damage

Fig. 7 and Fig. 8 shows the results of the moment-curvature relationship obtained by progressive collapse analysis for single hull bulk carrier (B2). It is found that Case 2 generally gives larger ultimate strength than Case 1 because the horizontal curvature is constrained. The ultimate hull girder strength is attained even the horizontal curvature is constrained because of the horizontal bending moment is induced by the stiffened matrix interaction for horizontal and vertical and this makes the ultimate hull girder strength becomes higher. The effect is largest in Ship B1, smaller in Ship B2, and almost negligible in Ship T2. For Ship B1, Case 1 strength is 7.3% smaller than Case 2 in sagging condition. The difference between Ship B1 and Ship B2 may be related to that of the depth to breadth ratio, member scantlings etc. Fig. 9 and Fig. 10 represent the moment-curvature relationship under sagging condition for double hull oil tanker (T2) for 20% and 70% of damaged, respectively. According to the result obtained by progressive collapse analysis of double hull oil tanker (Ship T2), the effect of rotation of neural axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

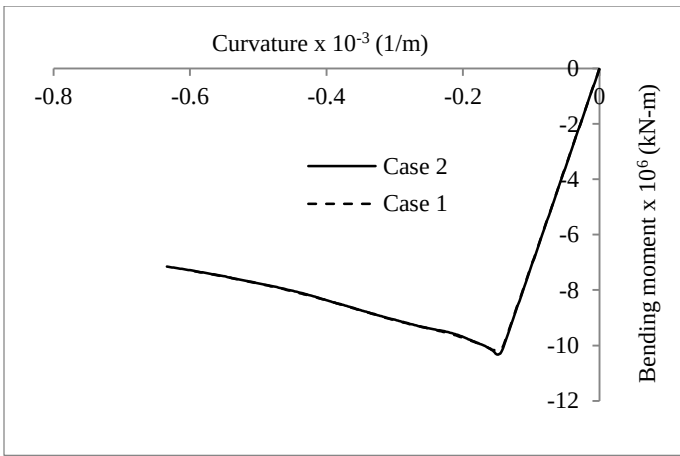


Fig. 9 Double hull oil tanker (Ship T2) with 20% damage

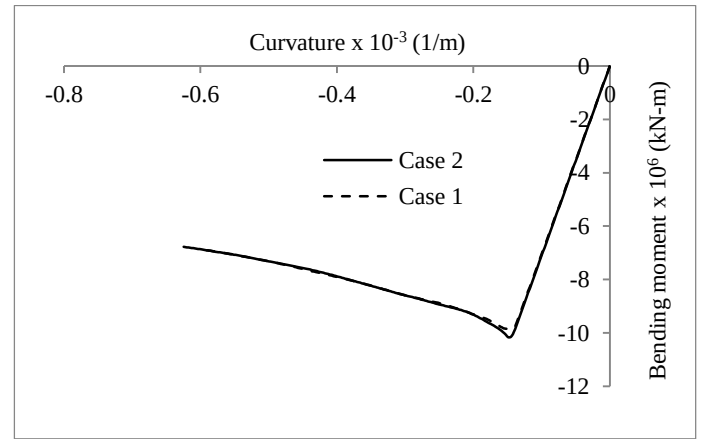


Fig. 10 Double hull oil tanker (T2) with 70% damage

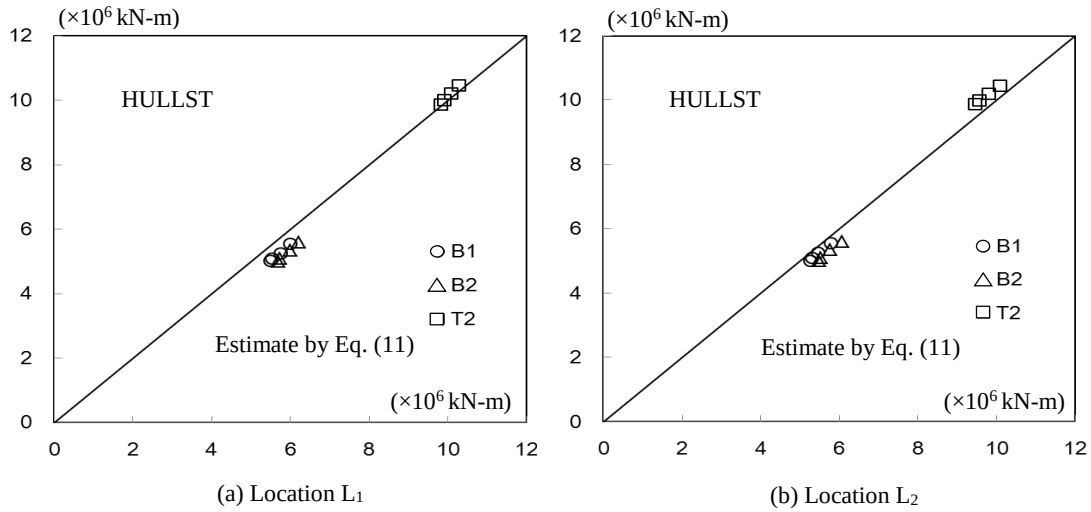


Fig. 11 Comparison of residual hull girder strength M_V between the simplified method and the progressive collapse analysis

The residual strengths of Ship B1, Ship B2 and Ship T2 obtained for the four different damage extents are summarized in Fig. 11. It is found that Eq. (11) gives an estimate of the residual strength which is in good agreement with the result of the progressive collapse analysis. For bulk carriers, the critical element at the location L_2 gives a better estimate of the residual strength. This is consistent with the observed collapse behavior in which the ultimate strength is attained when topside tank region of the damage side almost fully failed. The location L_1 cannot well take account of the effect of the horizontal curvature induced by M_V , resulting in the slight overestimate of the strength. In the case of tankers, the location L_1 gives better estimate of the residual strength than L_2 . This is also consistent with the failure behavior of T2 in which the ultimate strength is attained when the deck part almost fully failed.

The resultant of bending moment is induced by the accumulation of the horizontal and vertical bending moment based on the reference coordinate system. Fig. 12 shows the comparison the reduction rates of the residual strength due to rotation of the neutral axis obtained by Eq. (13) and progressive collapse analysis. The influence of the rotation of the neutral axis is larger for a larger damage extent in general. For the case of the subject ships and damages under consideration, the influence is larger in bulk carriers than in tankers. Eq. (13) gives a relatively good estimate of the reduction rate. It can be a good basis of a rational expression of the influence of the rotation of the neutral axis on the reserved hull girder strength, as required in ship structures. More systematic analyses are definitely needed to develop the formula having larger applicability in ship types and damaged cases.

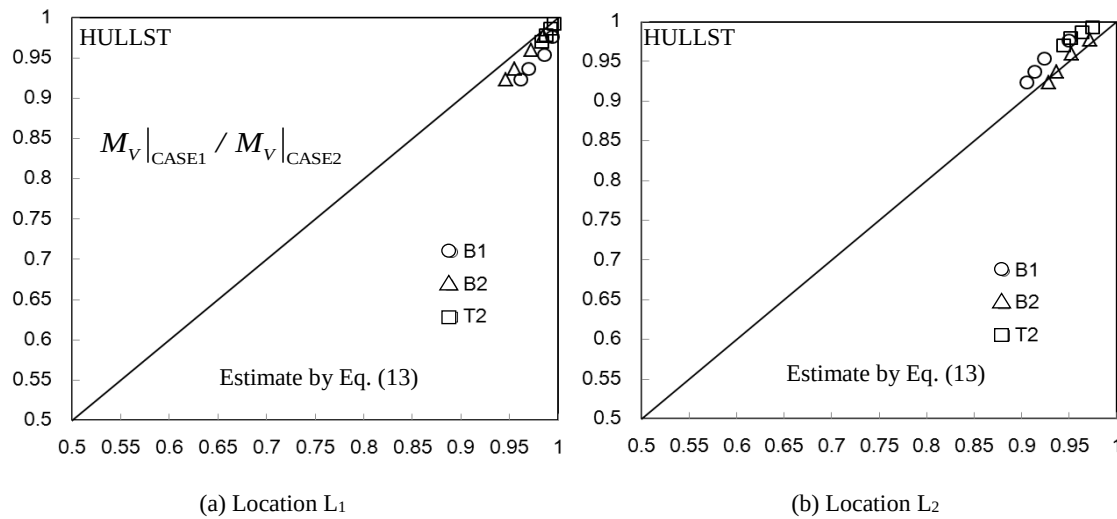


Fig. 12 Comparison of reduction ratio of residual hull girder due to rotation of neutral axis between the simplified method and the progressive collapse analysis (Case 1/Case 2)

CONCLUSIONS

The ultimate hull girder strength analysis of single hull bulk carriers and a double hull oil tanker with asymmetrically damaged cross section has been performed using the simplified approach under sagging condition by performing the elastic cross-sectional properties and critical member elements. A closed form formulae of residual strength and that of the reduction ratio of the residual strength due to the rotation of neutral axis are proposed. It is found through a comparison with the results obtained by the progressive collapse analysis that the residual hull girder strength of asymmetrically damaged ships under sagging bending moment can be predicted by the proposed formulae with a reasonable accuracy. The ultimate strength obtained with the horizontal curvature constrained is larger than without constrained one. The ultimate hull girder strength is attained even the horizontal curvature is constrained because of the horizontal bending moment is induced by the stiffened matrix interaction for horizontal and vertical and this makes the ultimate hull girder strength becomes higher. The effect is largest for single hull bulk carrier and almost negligible for double hull oil tanker. The difference characteristic for two single hull bulk carrier may be related to that of the depth to breadth ratio, member scantlings etc.

According to the result obtained by progressive collapse analysis of double hull oil tanker, the effect of rotation of neural axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

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Simplified Approach on the Ultimate Hull Girder Strength of Asymmetrically Damaged Ships

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ABSTRACT

The objective of the present study is to investigate the ultimate hull girder strength of asymmetrically damaged ship under sagging condition. Two kinds of ship are taken as the object of the analysis. The cross section of the ship is considered and assumed to be remained plane. The simply supported of boundary condition is applied to both sides of the cross section. The ultimate hull girder strength is attained when a plate and/or stiffened plate element at the specified location called “critical element” reach their ultimate strength. To investigate the ultimate hull girder strength, a simplified approach is proposed. The result obtained by simplified approach is compared to the progressive collapse analysis for the effectiveness and validation.

KEY WORDS: Single hull bulk carrier, double hull oil tanker, cross section, neutral axis, asymmetrically damaged, ultimate strength, simplified approach.

INTRODUCTION

The ability to predict accurately the ultimate strength of ship hull girder when subjected to longitudinal bending is one of the most important aspects of ship structural design. A collision and grounding damages may takes place on ship's hull, which may threaten safety ship and surrounding environment. In this regard, to enhance the safety of ship's structure and minimize the risks, the International Maritime Organization (IMO, 2009) has required in Goal Based Standard for New Ship Construction (GBS) to consider the residual strength of the hull girder in specified damage conditions as one of the functional requirements for the structural rules for bulk carriers and tankers.

Many studies have been conducted on the analyses of the residual hull girder strength due to collision and grounding damaged. Pedersen (1994) presented a mathematical modeling to estimate the contact pressure between the grounded ship and the sea bottom. The grounded contact force was compared to the force which would crush the forward bottom of the ship. The sectional bending moment due to grounding was determined and compared to the ultimate hull girder strengths. The model experiments and full-scale controlled grounding experiments were also performed to validate the mathematical model. Paik et al. (1998) developed a rapid procedure to identify the possibility of hull girder failure after collision and grounding damages

based on the closed-form formulae of the ultimate hull girder strength and section modulus after the damages. Soares et al. (2008) evaluated the ability of simplified structural analysis methods based on the Smith's formulation to predict the ultimate strength of damage ship's hull. Toh et al. (2012) developed simplified calculation program to calculate the ultimate strength in intact and damage condition and the reduction of hull girder ultimate strength is investigated. The calculation result of simplified method is compared to the FE result for both intact and damage condition. Muis Alie, M.Z et al. (2012) investigated the effect of neutral axis rotation on residual hull girder strength for asymmetrical damaged ships under longitudinal bending, performing the progressive collapse analysis and finding an explicit expression of rotation of neutral axis. After performing a series of progressive collapse analyses on two bulk carriers and a tanker, it was found that residual hull girder strength, considering the instantaneous neutral axis is generally lower than the relevant one, obtained by constraining the rotation, as it is commonly assumed in classical procedures. Ohtsubo et al. (1994) showed the experimental and numerical work on the ship structural damages due to collision and grounding. This was one of the first attempts to apply the explicit Finite Element Method codes, such as LS-DYNA and DYTRAN, to the collision and grounding problems of ships. Ozguc et al. (2005) investigated the collision resistance and residual strength of single skin and double skin bulk carriers subjected to damages. Lee et al. (2008) calculate the ultimate strength with collision damage using LS-DYNA and compared with the experiment results. It is found that the ultimate strength is reduced as a damage size increased as expected. Notaro et al. (2010) carried out full nonlinear FE assessments of hull girder capacity in intact and damage conditions. The effects of several

influences factors such as model extend and complexity, damage representations and model imperfections are investigated on the different vessels. It was found that the effect of damage extent in vertical direction is more critical than in longitudinal direction, and the damage varies the location of the neutral axes including higher stresses in proximity of the damage areas. The various probability levels are considered for the damage extent estimation.

When a hull-girder cross section is symmetric with respect to the centerline and subjected to pure vertical bending moment, the neutral axis for vertical bending is always horizontal and moves only vertically during the progressive collapse behavior. However, when the cross section is asymmetrically damaged due, for example, to a collision, the neutral axis rotates. Both rotation and translation need to be taken into account during the progressive collapse behavior even when only a vertical bending moment is applied, and the problem needs to be treated as a biaxial bending problem. Previous studies using the Smith's method on the ultimate strength of hull girders under biaxial thrust (Ozguc and Barltrop, 2008) and the residual strength of damaged hulls (Fang and Das, 2004; Hussein and Guedes Soares, 2009; Choung et al, 2011) consider the rotation and translation of neutral axis in a reasonable way. However, they employ a trial and error approach to detect the position of neutral axis. More easy approach to detect the position of neutral axis is demanded.

BASIC ASSUMPTION

The following assumption is made for the prediction of the residual hull girder strength under the sagging condition:

- (1) The ultimate sagging strength is attained when a stiffened panel element at the specified location (hereafter called 'critical element') reached the ultimate strength.
- (2) The hull girder cross section is elastic until the failure of the critical member.
- (3) The ultimate strength of the critical member is predicted from the average axial stress and average axial strain relationship calculated by HULLST (Yao and Nikolov, 1992).

ESTIMATION OF THE ULTIMATE HULL GIRDER STRENGTH NEUTRAL AXIS EFFECT

In the elastic cross section, the bending stress at the i -th element (see Fig.1), σ_i , is expressed as

$$\sigma_i = E \{ (y_i - y_G) \phi_H + (z_i - z_G) \phi_V \} \quad (1)$$

where E is Young's modulus, y_G and z_G the centroid coordinates, and ϕ_H and ϕ_V the horizontal and vertical curvatures, respectively. y_G and z_G are given by

$$y_G = \frac{\left(\sum_{i=1}^N y_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (2)$$

$$z_G = \frac{\left(\sum_{i=1}^N z_i D_i A_i \right)}{\left(\sum_{i=1}^N D_i A_i \right)} \quad (3)$$

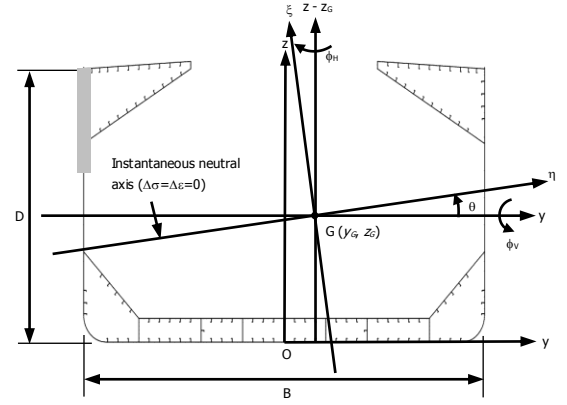


Fig. 1 Neutral axes of the elastic hull girder cross section with asymmetric damage

The biaxial moment and curvature relationship is given in the form

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (4)$$

where

$$\begin{aligned} I_{HV} &= I_{VH} = \sum_{i=1}^N (y_i - y_G)(z_i - z_G) A_i \\ I_{HH} &= \sum_{i=1}^N (y_i - y_G)^2 A_i \\ I_{VV} &= \sum_{i=1}^N (z_i - z_G)^2 A_i \end{aligned} \quad (5)$$

When the vertical bending moment is applied to the cross section with no constraint on the horizontal curvature (Case 1), the horizontal curvature as well as the vertical curvature is induced under the condition of $M_H = 0$. The incremental equation to be solved is

$$\begin{Bmatrix} 0 \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} \quad (6)$$

Therefore,

$$\begin{Bmatrix} \phi_H \\ \phi_V \end{Bmatrix} = \frac{1}{E(I_{HH} I_{VV} - I_{HV}^2)} \begin{Bmatrix} -I_{HV} M_V \\ I_{HH} M_V \end{Bmatrix} \quad (7)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{-(y_i - y_G) I_{HV} + (z_i - z_G) I_{HH}}{(I_{HH} I_{VV} - I_{HV}^2)} M_V \quad (8)$$

The terms including the moment of inertia, I_{HV} , represent the effect of the rotation of the neutral axis.

On the other hand, when the vertical bending moment is applied to the cross section with the horizontal curvature constrained (Case 2), the bending moment are induced under the condition of $\phi_H = 0$, that is,

$$\begin{Bmatrix} M_H \\ M_V \end{Bmatrix} = \begin{bmatrix} EI_{HH} & EI_{HV} \\ EI_{VH} & EI_{VV} \end{bmatrix} \begin{Bmatrix} 0 \\ \phi_V \end{Bmatrix} \quad (9)$$

Substituting Eq. (7) to Eq. (1), the bending stress σ_i is given by

$$\sigma_i = \frac{(z_i - z_G)}{I_{VV}} M_V \quad (10)$$

Here, it is assumed that the residual hull girder strength in the sagging condition M_V^u is attained when a critical member at the location of $(y_C - z_C)$ reached its ultimate strength, σ_C^u , namely for Case 1

$$M_V^u|_{CASE1} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \sigma_C^u \quad (11)$$

And for Case 2

$$M_V^u|_{CASE2} = \frac{I_{VV}}{(z_C - z_G)} \sigma_C^u \quad (12)$$

Therefore, the reduction rate of the residual strength due to the rotation of the neutral axis in the framework of the proposed approximate approach is given by ratio of Eq. (12) to Eq. (13) as

$$\frac{M_V^u|_{CASE1}}{M_V^u|_{CASE2}} = \frac{I_{HH} I_{VV} - I_{HH}^2}{-(y_C - y_G) I_{HV} + (z_C - z_G) I_{HH}} \frac{(z_C - z_G)}{I_{VV}} \quad (13)$$

CASE STUDY

Two single-hull bulk carriers, B1 and B4, and one double-hull oil tanker, T2, are taken as the subject ships as shown in Table 1. Ship B1 is designed according to Pre-UR rule and built in 1987 and Ship B4 according to CSR-B having larger cross section and scantling sizes. Ship T2 is designed according to CSR-T.

Ship	B1	B4	T2
L (mm)	217,000	219,000	234,000
B (mm)	32,236	32,240	44,000
D (mm)	18,300	19,900	21,200
Design criteria	Pre-IACS UR	IACS CSR-B	IACS CSR-T

Table 1 Subject ships

The damage of the upper part of side shell due to collision is assumed. The vertical damage extent is taken as 10%, 20%, 40% and 70% of the depth D for both bulk carrier and tanker. The horizontal damage extent is taken as $B/16$, and it is kept constant for all damaged cases. The damaged cross sections of Ship B1 are illustrated in Fig. 2 and those of Ship T2 in Fig. 3. The stiffness of the elements in the damaged area is completely removed. For the double hull tanker, only outer side shell is assumed to be damaged. The locations of the critical deck

element are presented in Fig. 4 for single hull bulk carrier and double hull oil tanker, respectively.

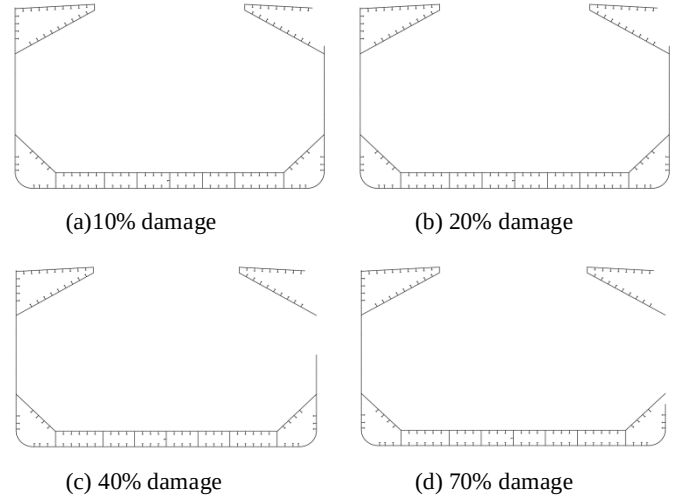


Fig. 2 Single hull bulk carrier (Ship B1)

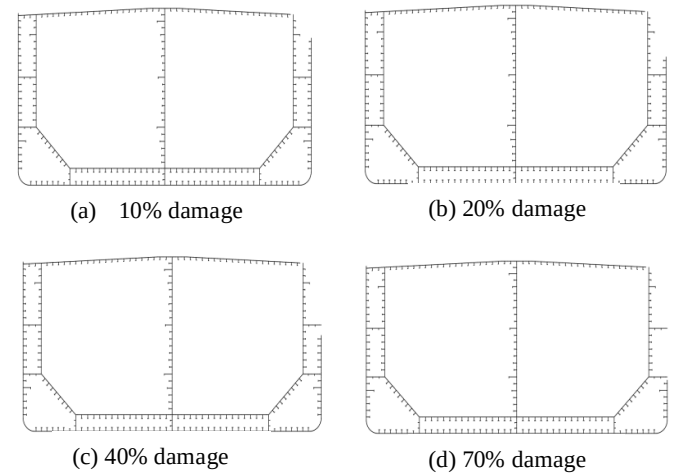
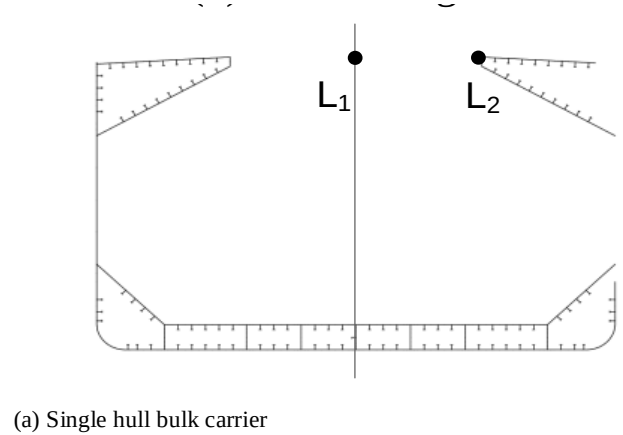
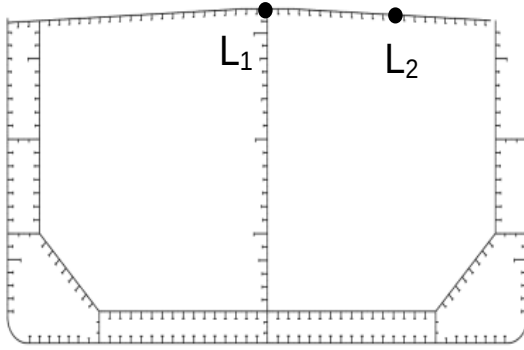


Fig. 3 Double hull oil tanker (Ship T2)





(b) Double hull oil tanker

Fig. 4 Locations of the critical deck elements

RESULT AND DISCUSSION

The results obtained by progressive collapse analysis under sagging condition for 20% and 70% damage are presented in Fig. 5 and Fig. 6, respectively. Case1 considers the rotation of neutral axis and Case 2 does not. The mome-nt-curvature relationship is given as follow,

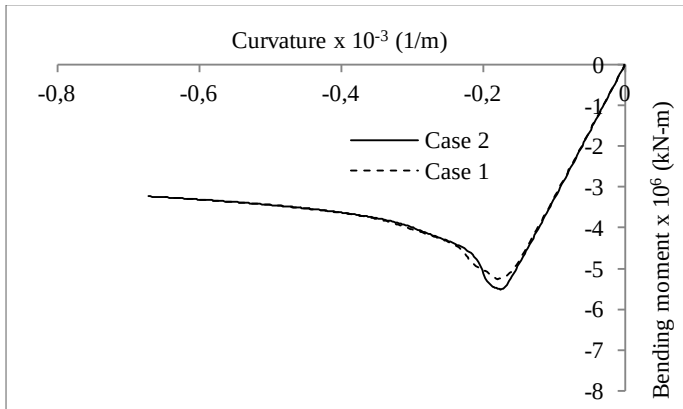


Fig. 5 Single hull bulk carrier (Ship B1) with 20% damage

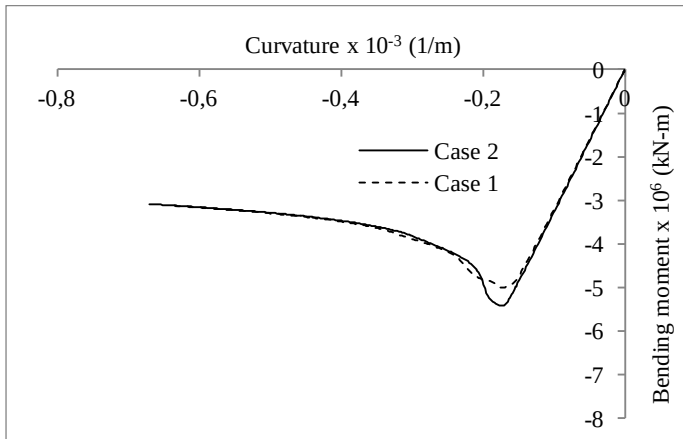


Fig. 6 Single hull bulk carrier (Ship B1) with 70% damage

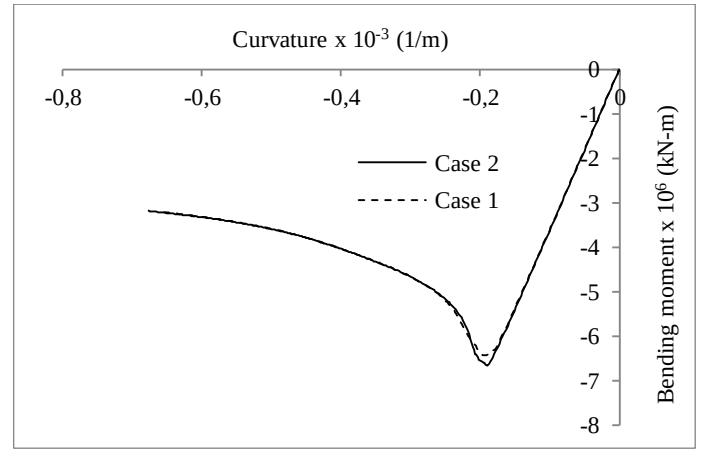


Fig. 7 Single hull bulk carrier (Ship B2) with 20% damage

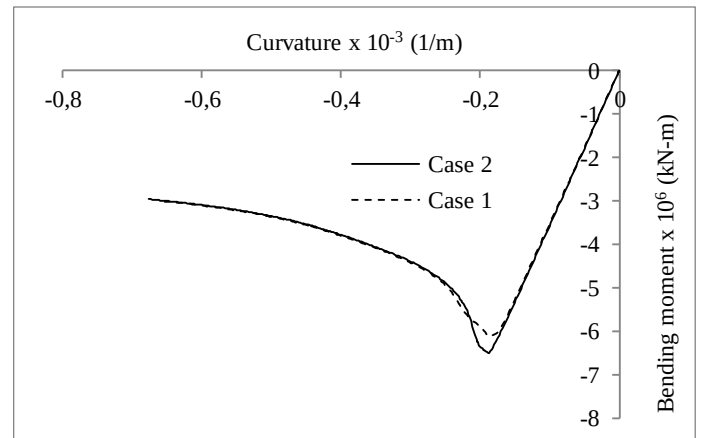


Fig. 8 Single hull bulk carrier (Ship B2) with 70% damage

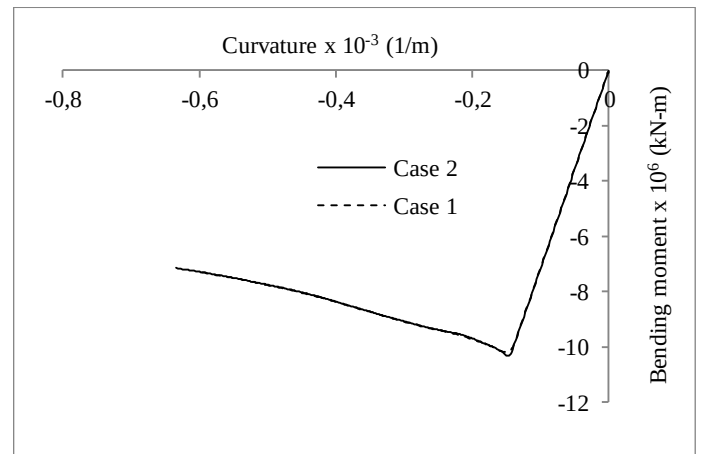


Fig. 9 Double hull oil tanker (Ship T2) with 20% damage

Fig. 7 and Fig. 8 shows the results of the mome-nt-curvature relationship obtained by progressive collapse analysis for single hull bulk carrier (B2). It is found that Case 2 generally gives larger ultimate strength than Case 1 because the horizontal curvature is

constrained. The effect is largest in Ship B1, smaller in Ship B4, and almost negligible in Ship T2. For Ship B1, Case 1 strength is 7.3% smaller than Case 2 in sagging condition. The difference between Ship B1 and Ship B4 may be related to that of the depth to breadth ratio, member scantlings etc. Fig. 9 and Fig. 10 represent the moment-curvature relationship under sagging condition for double hull oil tanker (T2) for 20% and 70% of damaged, respectively. According to the result obtained by progressive collapse analysis of double hull oil tanker (Ship T2), the effect of rotation of neural axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

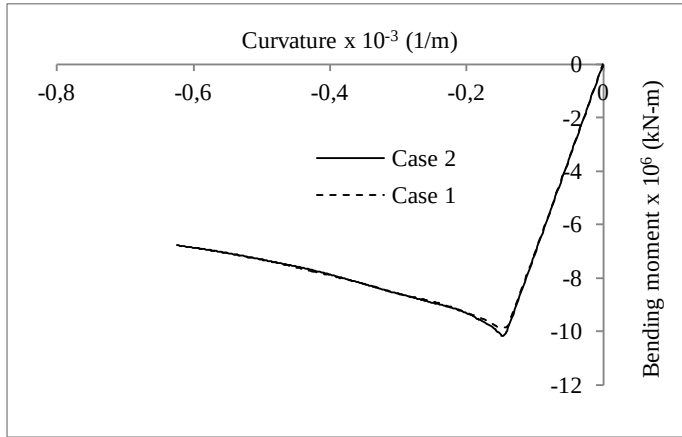


Fig. 10 Double hull oil tanker (T2) with 70% damage

The investigation of the residual hull girder strength under sagging condition is performed by taking two locations of the critical deck elements as shown in Fig. 4.

Single hull bulk carrier (B1 and B2), the locations of the critical element are L_1 and L_2 , L_1 is located at the center line and L_2 at the hatch coaming on the damage side. For the case of double hull oil tanker (T2), L_1 is located at the center line and L_2 at the distance of $B/4$ from the damage side shell.

The residual strengths of Ship B1, Ship B2 and Ship T2 obtained for the four different damage extents are summarized in Fig. 11. It is found that Eq. (11) gives an estimate of the residual strength which is in good agreement with the result of the progressive collapse analysis. For bulk carriers, the critical element at the location L_2 gives a better estimate of the residual strength. This is consistent with the observed collapse behavior in which the ultimate strength is attained when topside tank region of the damage side almost fully failed. The location L_1 cannot well take account of the effect of the horizontal curvature induce by M_V , resulting in the slight overestimate of the strength. In the case of tankers, the location L_1 gives better estimate of the residual strength than L_2 . This is also consistent with the failure behavior of T2 in which the ultimate strength is attained when the deck part almost fully failed.

Fig. 12 shows the comparison the reduction rates of the residual strength due to rotation of the neutral axis obtained by Eq. (13) and progressive collapse analysis. The influence of the rotation of the neutral axis is larger for a larger damage extent in general. For the case of the subject ships and damages under consideration, the influence is larger in bulk carriers than in tankers. Eq. (13) gives a relatively good estimate of the reduction rate. It can be a good basis of a rational expression of the influence of the rotation of the neutral axis on the reserved hull girder strength, as required in ship structural. More systematic analyses are definitely needed to develop the formula having larger applicability in ship types and damaged cases.

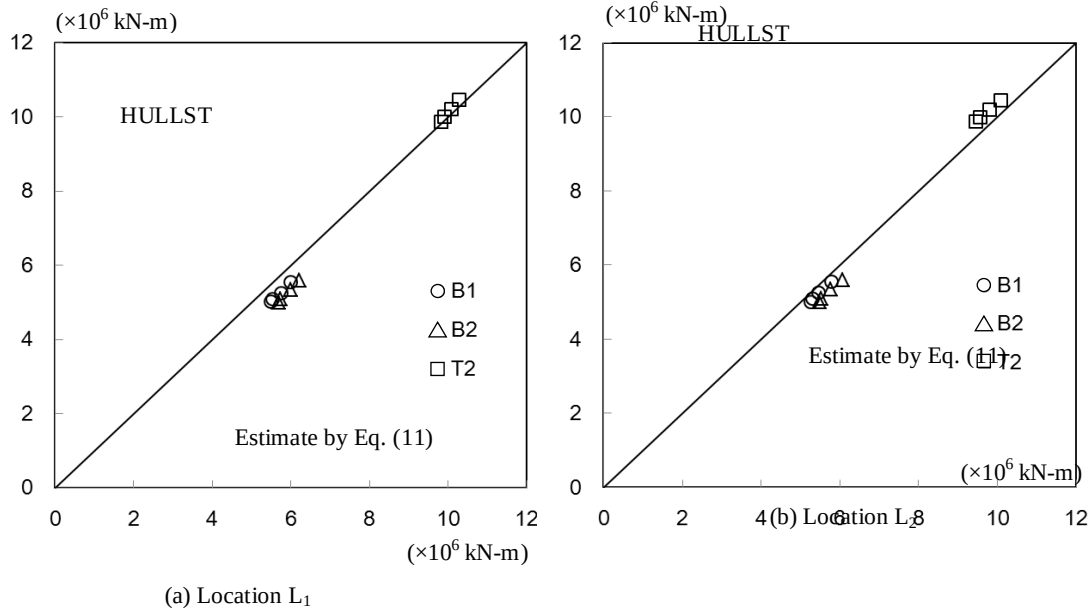


Fig. 11 Comparison of residual hull girder strength M_V between the simplified method and the progressive collapse analysis

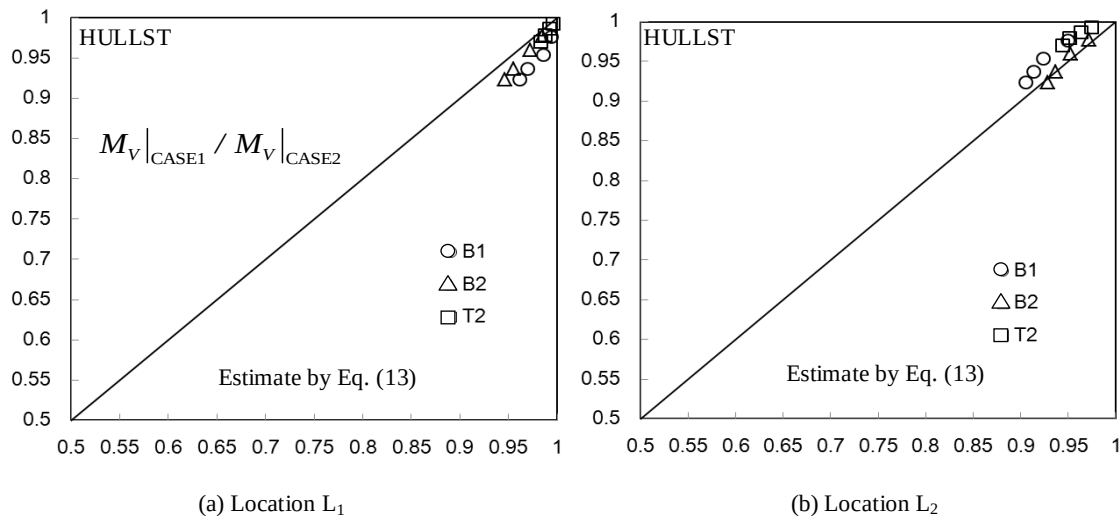


Fig. 12 Comparison of reduction ratio of residual hull girder due to rotation of neutral axis between the simplified method and the progressive collapse analysis (Case 1/Case 2)

CONCLUSIONS

The ultimate hull girder strength analysis of single hull bulk carriers and a double hull oil tanker with asymmetrically damaged has been performed using the simplified approach under sagging condition by performing the elastic cross-sectional properties and critical member elements. A closed form formulae of residual strength and that of the reduction ratio of the residual strength due to the rotation of neutral axis are proposed. It is found through a comparison with the results obtained by the progressive collapse analysis that the residual hull girder strength of asymmetrically damaged ships under sagging bending moment can be predicted by the proposed formulae with a reasonable accuracy.

The ultimate strength obtained by Case 2 generally gives larger ultimate strength than Case 1 because the horizontal curvature is constrained. The effect is largest in Ship B1, smaller in Ship B4, and almost negligible in Ship T2. The difference between Ship B1 and Ship B4 may be related to that of the depth to breadth ratio, member scantlings etc. According to the result obtained by progressive collapse analysis of double hull oil tanker (Ship T2), the effect of rotation of neutral axis on the ultimate longitudinal bending strength is small when only the outer side shell is damaged.

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