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MODIFICATION OF DOUBLE BOTTOM HEIGHT AND ITS EFFECT TO THE ULTIMATE STRENGTH

Muhammad Zubair Muis Alie
Department of Ocean Engineering, Engineering Faculty Hasanuddin University
Makassar, Indonesia

Indah Melati Suci
Department of Ocean Engineering, Engineering Faculty Hasanuddin University
Makassar, Indonesia

Andi Muhammad Alfian Arafat
Department of Ocean Engineering, Engineering Faculty Hasanuddin University
Makassar, Indonesia

Juswan
Department of Ocean Engineering, Engineering Faculty Hasanuddin University
Makassar, Indonesia

Wahyuddin Mustafa
Department of Naval Architecture, Engineering Faculty Hasanuddin University
Makassar, Indonesia

ABSTRACT

Double bottom is one part of the ship's construction which is located at the bottom and it functioned to overcome when the ship collides with the other object at the outer of ship's bottom. One of the parameters of the double bottom that must be considered is double bottom height. These would affects to the section inertia, section modulus and neutral axis position leads to the ultimate strength of ship.

The objective of the present study is to analyze the ultimate strength caused by the double bottom height before and after modification. The double bottom height is analyzed according to the existing condition, national and international classification. Those formulas are different so that it is very important to know those effects. The numerical method is adopted to analyze the tankers ship caused by changing the double bottom height before and after modification. The force rotation is given at the master node since it is placed after determined the position of neutral axis as reference point.

It is observed that the double bottom height gives significant influence to the ultimate strength according to existing condition, national and international classification before and after modification under hogging and sagging conditions. The ultimate strength in terms of the moment-curvature relationship including their behavior is presented in this study.

Keywords: Tankers, cross section, double bottom height, ultimate strength

1. INTRODUCTION

Almost seagoing steel ship has double bottom construction. Double bottom gives significant influence particularly for ship strength not only in transversal direction, but also in longitudinal. Double bottom also plays an important rule to overcome when the ship is under grounding accident. However, the double bottom construction must be analyzed due to its function to strengthen and protect from the accident.

The ultimate strength is widely used as one of the parameters in ship design. Many researchers have already introduced how to assess the ultimate strength of ship structure in many ways. Kuznecovs et al presented a methodology called SHARC developed for the simulation and analysis of a ship's damage stability and ULS conditions following a collision [1]. A novel method was proposed by Zhang et al to calculate strength loss based on stiffness loss [2]. A conceptual design framework for collision and grounding analysis was proposed by Liu et al to evaluate the crashworthiness of double-hull structures [3]. The incidence of collision damage models on oil tanker and bulk carrier reliability was investigated by Campanile et al by considering the IACS deterministic model against GOALDS/IMO database statistics for collision events, substantiating the probabilistic model [4]. The progressive collapse analysis was performed by Muis Alie and Latumahina for the local elements and the ultimate strength of a Ro-Ro ship [5]. Van et al focused on the effect of initial imperfections and corrosion related strength degradation of bulk carriers, the initial imperfections including initial distortions and residual stresses, are employed to assess the ultimate bending moment reduction [6].

In addition, Guia et al assessed the probabilistic characteristics of the hull girder target safety level of a Suezmax tanker derived from a cost-benefit analysis and the target safety level is obtained considering as risk control option the change in the cross section scantlings of the tanker and its effect on risk reduction expressed by the total expected cost of the hull girder failure [7]. Zhang et al addressed the experimental and finite-element simulation studies on scaled double-hull side structures quasi-statically punched at the mid-span by conical and knife edge indenters to examine their structure behaviors and energy dissipation mechanisms [8]. The ultimate strength of double hull oil tanker due to grounding and collision was conducted by Latumahina and Muis Alie, the collision damaged was modeled by removing the element at the side shell of the ship [9]. The ultimate hull girder strength was analyzed by Muis Alie and Latumahina by considering the section modulus under longitudinal bending, the ship cross section was different in number, type and dimension of the longitudinal stiffeners [10]. Reliability analysis of an oil tanker in intact conditions was performed by Campanile et al to investigate the incidence of load combination methods on hull girder sagging/hogging time-variant failure probability, particularly, Turkstra rule, Ferry Borges and Castanheta method and Poisson square wave model are applied to evaluate the statistical distribution of bending moment, with reference to both one voyage and 1-year period [11].

Xu et al presented a reliable and suitable FE modeling in the explicit dynamic method, which could keep the balance of the acceptable accurate results and computation resources, and several influential factors on the collapse behaviors of hull girder are discussed including boundary conditions, geometric ranges of finite element model, element types, loading methods and loading time. [12]. Parunov et al is the assessed the residual ultimate strength of an Aframax-class double hull oil tanker damaged in collision and the contribution to the research of the problem is given in a systematic investigation of the influence of the rotation of neutral axis (NA), which is performed by imposing appropriate boundary conditions. [13]. Downes et al presented a new procedure to determine LSE datum based on box girder Finite Element Analyses (FEAs) instead of using finite element model of stiffened panels, and to verify reliability of FEA results, the simple box girder collapse test results are compared with FEA results of same box girders. It reveals one frame-based box girder model is sufficiently accurate in terms of ultimate strengths of the box girders. [14].

Liu and Soares presented a simplified analytical method to examine the energy absorbing mechanisms of double-hull ship structures subjected to a flat edge indenter, and the method was validated with a numerical simulation was conducted on a structural module derived from an experimentally scaled stiffened panel [15]. The influence of superstructure on the longitudinal ultimate strength was analyzed by Muis Alie et al [16], the superstructure was include in the model in order to the effect of it. The influence of initial geometric imperfection modes on the ultimate strength of a ship's hull was studied by Estefen et al, with a focus on the buckling behavior of stiffened panels that initiates the structural hull failure [17]. The finite element analysis on the ship hull girder under longitudinal bending with bottom damaged was investigated by Muis Alie et al [18].

Among them, only few to investigate the effect of double bottom height construction to the longitudinal strength. Therefore, the ultimate strength by considering the effect of double bottom height must be taken into account and this should be a basis contribution to this research.

2. METHOD AND MODEL

In the present study, two double hull tankers are taken as the object to be analyzed and one frame space of 5 m is considered. The dimensions of two ships are identical, those are 44 m and 21.2 m of breadth and depth, respectively both two ships. However, the number, types and dimensions of the longitudinal stiffeners are different. The material properties namely elastic modulus, yield strength, density and poison ratio are constant both two types of double hull tankers. The ultimate strength of double hull tankers is analyzed by considering the double bottom height under hogging and sagging conditions. The analysis is performed with three stages, those are; the ultimate strength is calculated in the existing condition, then based on the IACS formula and finally based on the National Classification. The double bottom height is analyzed for the existing condition. In this existing condition, the double bottom height is 2.1 m as shown in Fig. 1. The height is similar both two types of double hull tankers.

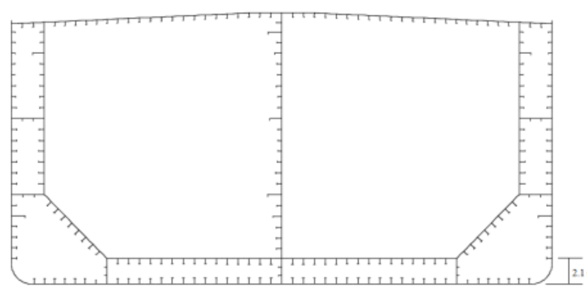

FIGURE 1: DOUBLE BOTTOM HEIGHT FOR EXISTING CONDITION

The double bottom height is calculated based on the National Classification [19] and IACS [20] regulation,

$$h_{db} = \frac{B}{20} \tag{1}$$

$$h_{db} = \frac{B}{15} \tag{2}$$

where h_{db} and B are double bottom height and ship breadth, respectively.
Then, double bottom heights according to those formulas are obtained 2.2 m for National Classification and 2.9 m for IACS. These double bottom heights are also same for two types of double hull tankers.

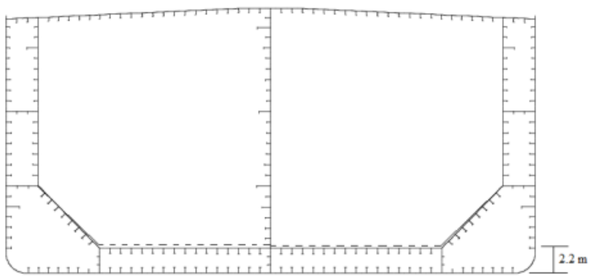

FIGURE 2: DOUBLE BOTTOM HEIGHT FOR NATIONAL CLASSIFICATION

Figure 2 shows the modification of double bottom height obtained by National Classification formula. Inner bottom panel moves up leading to side girder. However, the side stringer height is constant. This modification is also performed for IACS as shown in Fig. 3. The angle of bilge hopper panel also moves up depending on the change of the double bottom height starting from the side girder. Due to change of double bottom height, the section inertia, section modulus and neutral axis position are also changed.

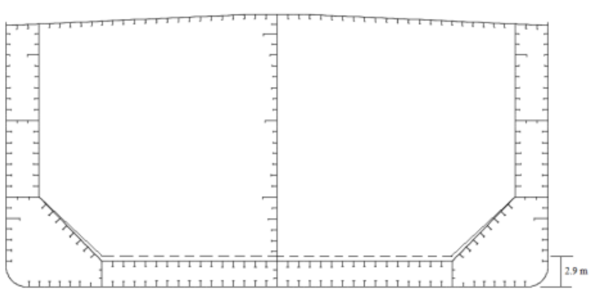

FIGURE 3: DOUBLE BOTTOM HEIGHT FOR IACS

The ultimate strength is calculated from the existing condition to the end due to modification of double bottom height obtained from National Classification and IACS regulation formula. These procedures are conducted by applying load as well as the boundary condition. The section modulus, section inertia and the position of the neutral axis are changed as already mentioned before and automatically obtained from the calculation. Once the neutral axis position is obtained, the Multiple Pont Constrained (MPC) can be placed where the applied load or rotational force or moment can be put.

The application of MPC is adopted to gain the maximum bending moment value under hogging and sagging condition including behaviors such as deformation at deck and bottom part as well as the side shell. The applied moment at the master node is then connected to all nodes at both sides of the cross section as shown in Fig. 4. The MPC is applied at the cross section of double hull tanker. It is connected automatically to all nodes. The MPC should be place at the neutral axis position not only for existing condition, but also due to changing the double bottom height. It should be noted that the cross section remained plane during progressive collapse. This procedure is similar for modification due to changing of double bottom height of National Classification and IACS regulation formula.

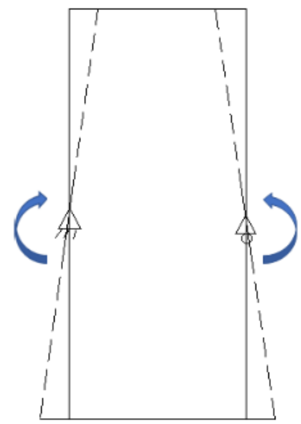

FIGURE 4: APPLIED LOAD

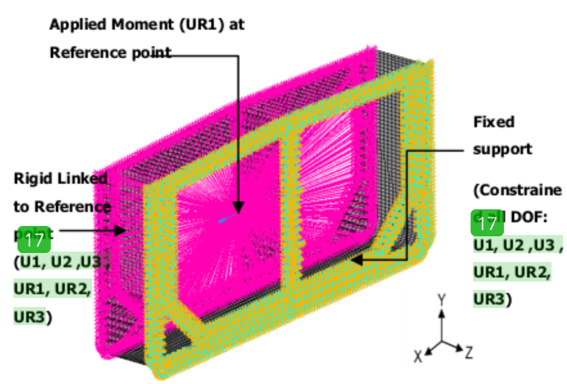

FIGURE 5: APPLIED MPC AND BOUNDARY CONDITION

3. RESULTS AND DISCUSSION

The ultimate strength two types of double hull tankers considering the effect of double bottom height in the existing condition, National Classification and IACS regulation under hogging and sagging are summarized. Table 1 shows the comparison of the ultimate bending moment in existing condition and due to modification of double bottom height according to National Classification and IACS regulation under hogging and sagging of double hull tanker Type-1.

Table 1. Comparison of bending moment of double hull tanker for Type-1

Conditions	Bending Moment Nmm	Description of Double Hull Tanker Type-1
$M_{u\ Hogging}$ x 10^{12}	13.9	Existing Condition
$M_{u\ Sagging}$ x 10^{12}	-11.6	
$M_{u\ Hogging}$ x 10^{12}	11.4	National Classification
$M_{u\ Sagging}$ x 10^{12}	-11.4	
$M_{u\ Hogging}$ x 10^{12}	10.1	IACS
$M_{u\ Sagging}$ x 10^{12}	-10.1	
$M_{u\ Hogging}$	1.22	Ratio between Existing Condition and National Classification
$M_{u\ Sagging}$	1.02	
$M_{u\ Hogging}$	1.38	Ratio between Existing Condition and IACS
$M_{u\ Sagging}$	1.15	
$M_{u\ Hogging}$	1.13	Ratio between National Classification and IACS
$M_{u\ Sagging}$	1.13	

According to Table 1, the positive sign means that the hull girder is under tension, while the negative sign means that the hull girder is under compression. The ultimate bending moment of double hull tanker for Type-1 increases from existing condition, then follow by National Classification and finally to IACS under hogging and sagging. The maximum ratio of the ultimate bending moment obtained by the relationship between existing condition and IACS regulation both hogging and sagging condition.

Table 2 expresses the ultimate bending moment of double hull tanker Type-2. It is found that the ultimate bending moment also increases from existing condition, then follow by National Classification and finally to IACS under hogging and sagging. It is also observed that the maximum ratio of the ultimate bending moment obtained by the relationship between existing condition and IACS regulation both hogging and sagging condition.

Table 3, 4 and 5 describe the ratio of ultimate bending moment of double hull tanker for Type-1 and Type-2 under hogging and sagging conditions. The ratios are for Existing Condition, National Classification and IACS regulation.

Table 2. Comparison of bending moment of double hull tanker for Type-2

Conditions	Bending Moment Nmm	Description of Double Hull Tanker Type-2
$M_{u\ Hogging}$ x 10^{12}	13.0	Existing Condition
$M_{u\ Sagging}$ x 10^{12}	-8.92	
$M_{u\ Hogging}$ x 10^{12}	10.3	National Classification
$M_{u\ Sagging}$ x 10^{12}	-8.20	
$M_{u\ Hogging}$ x 10^{12}	9.09	IACS
$M_{u\ Sagging}$ x 10^{12}	-7.33	
$M_{u\ Hogging}$	1.26	Ratio between Existing Condition and National Classification
$M_{u\ Sagging}$	1.09	
$M_{u\ Hogging}$	1.43	Ratio between Existing Condition and IACS
$M_{u\ Sagging}$	1.22	
$M_{u\ Hogging}$	1.13	Ratio between National Classification and IACS
$M_{u\ Sagging}$	1.12	

Table 3. Ratio of bending moment of Existing Condition for Type-1 and Type-2

Existing Condition	Bending Moment Nmm Type-1	Bending Moment Nmm Type-2	Ratio
$M_{u\ Hogging}$ x 10^{12}	13.9	13.0	1.07
$M_{u\ Sagging}$ x 10^{12}	-11.6	-8.92	1.30

Table 4. Ratio of bending moment of National Classification for Type-1 and Type-2

National Classification	Bending Moment Nmm Type-1	Bending Moment Nmm Type-2	Ratio
$M_{u\ Hogging}$ x 10^{12}	11.4	10.3	1.11
$M_{u\ Sagging}$ x 10^{12}	-11.4	-8.20	1.39

Table 5. Ratio of bending moment of IACS for Type-1 and Type-2

IACS	Bending Moment Nmm Type-1	Bending Moment Nmm Type-2	Ratio
$M_{u\ Hogging}$ x 10^{12}	10.1	9.09	1.11
$M_{u\ Sagging}$ x 10^{12}	-10.1	-7.33	1.38

According to tables 3, 4 and 5 that the maximum ratio of the ultimate bending moment is found in National Classification of double hull tanker between Type-1 and Type-2 under hogging and sagging conditions.

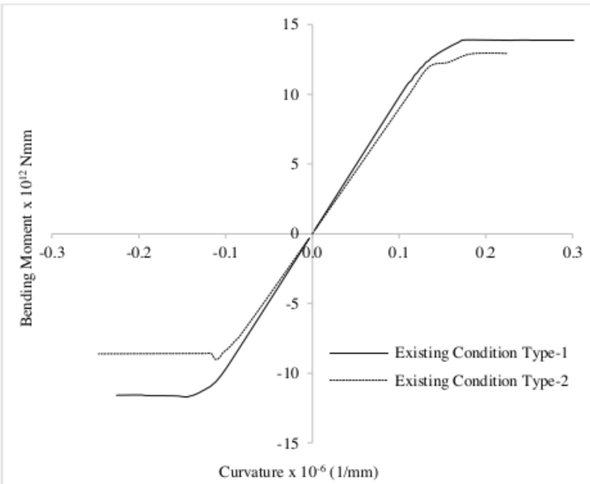

FIGURE 6: COMPARISON OF BENDING MOMENT BETWEEN TYPE-1 AND TYPE-2 FOR EXISTING CONDITION

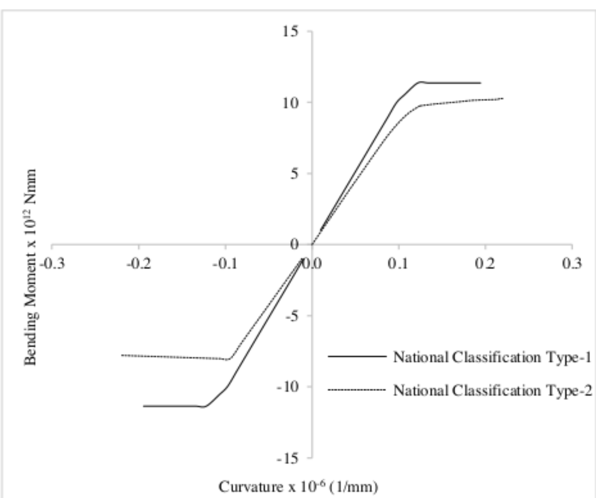

FIGURE 7: COMPARISON OF BENDING MOMENT BETWEEN TYPE-1 AND TYPE-2 FOR NATIONAL CLASSIFICATION

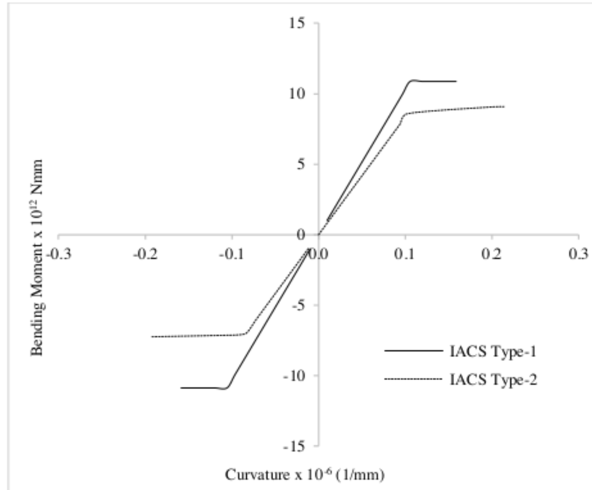

FIGURE 8: COMPARISON OF BENDING MOMENT BETWEEN TYPE-1 AND TYPE-2 FOR IACS

Figures 6, 7 and 8 express the comparison of ultimate bending moment of double hull tanker between for Type-1 and Type-2 in Existing Condition, National Classification and IACS under hogging and sagging. The solid line represents the ultimate bending moment of double hull tanker for Type-1 in Existing Condition, National Classification and IACS, while the dashed line for Type-2. It is observed that the ultimate bending moment for Type-1 of double hull tanker under hogging and sagging conditions in Existing Condition, National Classification and IACS is larger than Type-2.

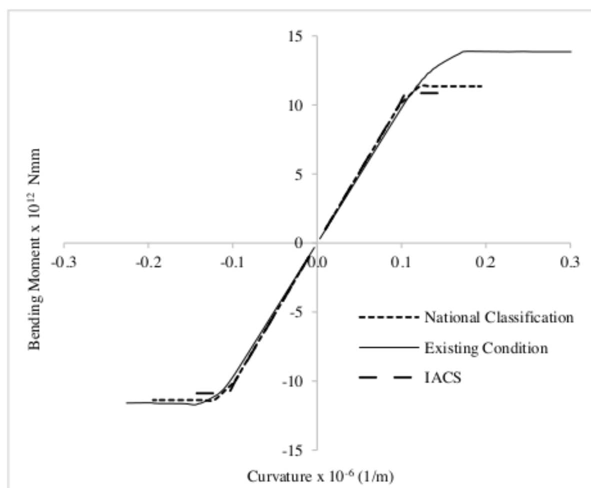

FIGURE 9: COMPARISON OF BENDING MOMENT FOR TYPE-1 OF DOUBLE HULL TANKER

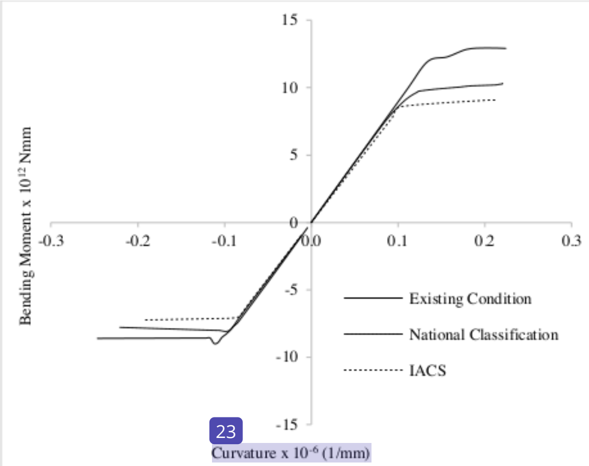

FIGURE 10: COMPARISON OF BENDING MOMENT FOR TYPE-2 OF DOUBLE HULL TANKER

Figures 9 and 10 describe the comparison of the ultimate bending moment between Existing Condition, National Classification and IACS of double hull tanker for Type-1 and Type-2 under hogging and sagging conditions. The solid line symbolizes the ultimate bending moment of double hull tanker for Type-1 and Type-2 for Existing Condition, then dashed line for National Classification and dot line for IACS. The maximum ultimate bending moment is found on the Existing Condition, then follow by National Classification and finally by IACS.

The modification of double bottom height according to National Classification and IACS regulation formula give significant influence to the ultimate strength. The modification of double bottom height also has the impact on the changes in the section modulus, section inertia and the position of the neutral axis. So that the bending stiffness caused by these parameters are also changed. The coefficient of the National Classification and IACS regulation formula gives effect to the double bottom construction and its ultimate strength.

The type, number and dimension of the longitudinal stiffeners also give contribution to the ultimate strength effect due to change of the double bottom height.

4. CONCLUSION

The analysis of the ultimate strength on the double hull tanker has been conducted. The following conclusions are; the effect of the double bottom height gives significant influence to the ultimate strength of double hull tanker for Type-1 and Type-2. The influence also effect to the section modulus, section inertia and neutral axis position where these parameters are the key points to analyze the ultimate strength. The ultimate strength obtained by National Classification is larger than IACS due to the differences of the double bottom height.

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