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Ultimate Strength Investigation of Ro-Ro Ship

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Ultimate Strength Investigation of Ro-Ro Ship

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Abstract. Ro-Ro ship has special characteristic for cargo handling because the cargo is transferred in horizontal direction. For example, cars can move by using ramp door which is located in front and/or aft of the ship. In conjunction with this, car passenger and other decks such as top including bottom part need to be investigated for local and global of Ro-Ro ship structure. In the present study, the ultimate strength investigation of Ro-Ro ship is conducted. There are three types of Ro-Ro ships are taken as the ship's subject. The cross section of Ro-Ro is considered in the analysis and it is modelled having plate and stiffened plate. The one-frame is represented in longitudinal direction. The simply supported of boundary condition is applied and the cross section is assumed to be remained plane. The calculation of the ultimate strength using in-house integrated program. The ultimate strength of Ro-Ro ship is investigated under hogging and sagging conditions. The vertical bending moment is imposed to the cross section to obtain the ultimate strength including their progressive collapse. The result obtained by in-house program for three types of Ro-Ro ships are summarized and the collapse behaviour for local and global of the decks to the ultimate strength of Ro-Ro ship are also presented in this study.

1. Introduction

Generally, a Ro-Ro ship functioned to move cargo in horizontal direction. The ship has passenger and car decks. One of the deck on Ro-Ro ship is car deck where it is very important to be assessed when the ship is under voyage. The ship's hull resists applied loads such as internal and external. Loading and unloading process may have an impact to structural damage of the ship. Therefore, the ultimate strength of ship hull is one of the most important aspects in the ship design criteria and must be taken into account.

Many studies have been conducted to assess and/or evaluate the ultimate strength of ship structure. The researcher [2] assessed the ultimate hull girder strength of Ro-Ro ship after damage. The cross section of Ro-Ro ship is considered to be analysed. Another researcher [1] focused on the ultimate strength of typical bottom structure in container ships under both longitudinal and transversal loads in corrosive environment. Muis Alie, M.Z et al [3] analysed the hull girder ultimate strength of asymmetrically damaged ships using Finite Element Method. The collision damage was modelled by removing the plate and stiffened plate elements. Muis Alie, M.Z [4] analysed the residual strength of ship hull girder with bottom damage. The nonlinear finite element method was used and the fully cross section was considered in the calculation. Shu, Z [5] investigated the ultimate strength of a capsize bulk carrier hull girder under combined global and local load in the hogging and alternate hold loading (AHL) condition using nonlinear finite element (FE) analysis with ABAQUS. Amlashi, H.K.K [6] contributed to establish rational ultimate longitudinal strength criteria for the hull girder under combined loading. An important issue was the significant double bottom bending in empty holds in AHL due to combined global hull girder bending moment and local loads. Paik, J.K [7] investigated the ultimate strength

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characteristics of ship hulls with large hatch opening under torsion. Axial (warping) as well as shear stress is normally developed for thin-walled beams with open cross sections subjected to torsion.
In this study, the investigation of Ro-Ro ship to the ultimate strength is conducted. There are three types of Ro-Ro ships are analysed. The cross section for each type of Ro-Ro ship is considered. The vertical bending moment is given both left and right sides of the cross section. For the simple calculation, one-frame space represents the length of ship is taken. The ultimate strength calculation is done by considering hogging and sagging condition.

2. Method of Analysis

The ultimate strength of ship hull is performed using the Smith's method considering the cross sectional approach. The Smith's method is adopted and implemented in-house program developed by [8] is used with some modification in the process. The moment-curvature relationship for the ultimate hull girder strength calculation is expressed by,

$$\begin{Bmatrix} \Delta P \\ \Delta M_H \\ \Delta M_V \end{Bmatrix} = \begin{bmatrix} \overline{D}_{AA} & \overline{D}_{AV} & \overline{D}_{AH} \\ \overline{D}_{HA} & \overline{D}_{HH} & \overline{D}_{HV} \\ \overline{D}_{VA} & \overline{D}_{VH} & \overline{D}_{VV} \end{bmatrix} \begin{Bmatrix} \Delta\varepsilon_0 \\ \Delta\varphi_H \\ \Delta\varphi_V \end{Bmatrix} \tag{1}$$

Where

$$\begin{aligned} \overline{D}_{AA} &= \sum_{i=1}^{N} D_i A_i \\ \overline{D}_{HH} &= \sum_{i=1}^{N} D_i y_i^2 A_i \\ \overline{D}_{VV} &= \sum_{i=1}^{N} D_i z_i^2 A_i \\ \overline{D}_{AH} = \overline{D}_{HA} &= \sum_{i=1}^{N} D_i y_i A_i \\ \overline{D}_{AV} = \overline{D}_{VA} &= \sum_{i=1}^{N} D_i z_i A_i \\ \overline{D}_{HV} = \overline{D}_{VH} &= \sum_{i=1}^{N} D_i y_i z_i A_i \end{aligned} \tag{2}$$

To obtain the ultimate hull girder moment capacity, the above expression can be simply expressed by,

$$\begin{Bmatrix} 0 \\ \Delta M_H \\ \Delta M_V \end{Bmatrix} = \begin{bmatrix} \overline{D}_{AA} & 0 & 0 \\ 0 & \overline{D}_{HH} & \overline{D}_{HV} \\ 0 & \overline{D}_{VH} & \overline{D}_{VV} \end{bmatrix} \begin{Bmatrix} \Delta\varepsilon_0 \\ \Delta\phi_H \\ \Delta\phi_V \end{Bmatrix} \tag{3}$$

Where

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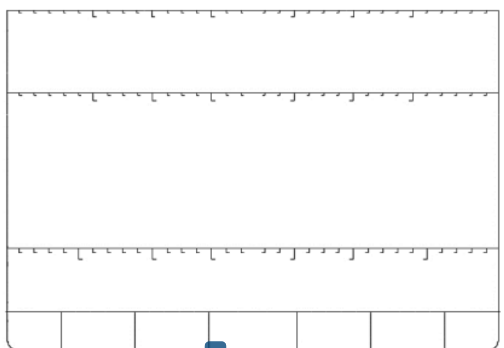
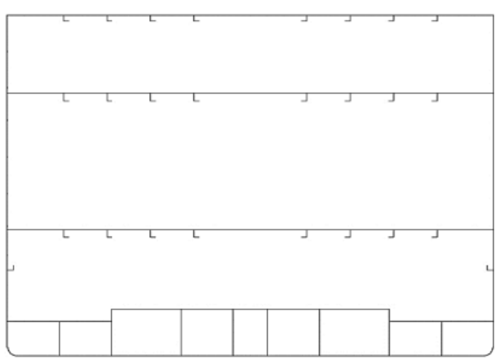
$$\begin{aligned} D_{AA} &= \sum_{i=1}^{N} D_i A_i \\ \overline{D}_{HH} &= \sum_{i=1}^{N} D_i \left(y_i - y_G\right)^2 A_i \\ \overline{D}_{HV} = \overline{D}_{VH} &= \sum_{i=1}^{N} D_i \left(y_i - y_G\right)\left(z_i - z_G\right) A_i \\ \overline{D}_{VV} &= \sum_{i=1}^{N} D_i \left(z_i - z_G\right)^2 A_i \end{aligned} \tag{4}$$

There are three types of Ro-Ro ships as shown in Figure 1. The investigation of Ro-Ro ship to the ultimate strength is conducted by considering cross section. Welding residual stress, crack and initial deflection are not included in the calculation.



(a) Type-1



(b) Type-2

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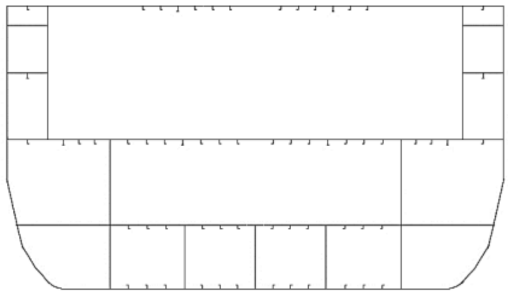

(c) Type-3

Figure 1 Cross sections of Ro-Ro types

The ultimate strength calculation is done under vertical bending moment in hogging and sagging conditions. All the types of Ro-Ro ships are calculated for intact only. Damages such as collision, grounding and so on are not considered in the analysis. The vertical bending moment is given on the cross section in right and left sides. The one-frame space represents the length of ship is taken as a fundamental calculation. The calculation of the ultimate strength of Ro-Ro ship considers two frame-spaces under hogging and sagging conditions.

3. Results and Discussions

The bending moment-curvature relationships for three types of Ro-Ro ship are shown in Figures 2-5 for two frame-spaces under hogging and sagging conditions, respectively. The larger ultimate strength of Ro-Ro ship is found on type-3 than followed by type-1 and type-2. These differences may be caused by dimension of scantling, configuration shapes, section properties of the hull girders and so on of the Ro-Ro ships.

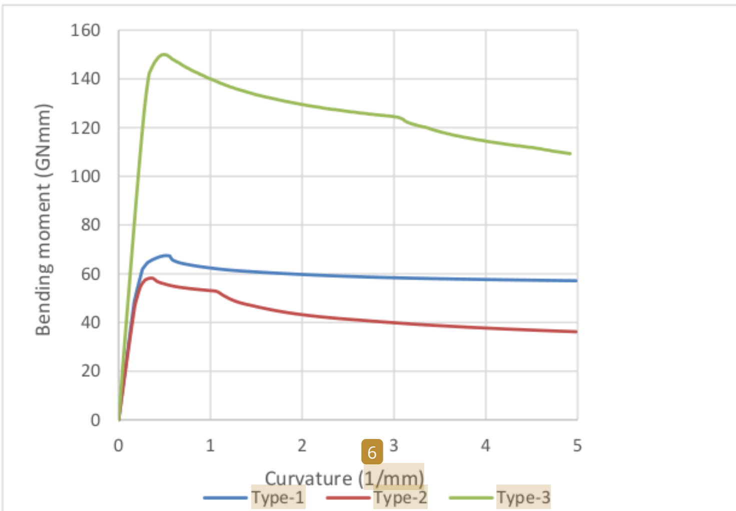

Figure 2 Bending moment-curvature relationship of 550 mm frame-space in hogging

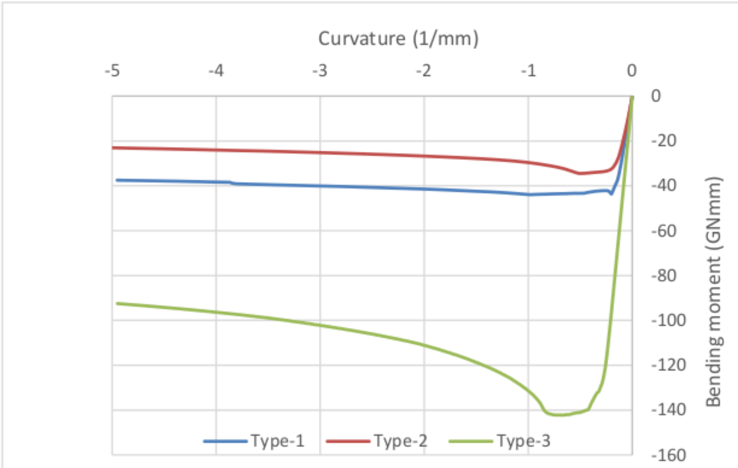

Figure 3 Bending moment-curvature relationship of 550 mm frame-space in sagging

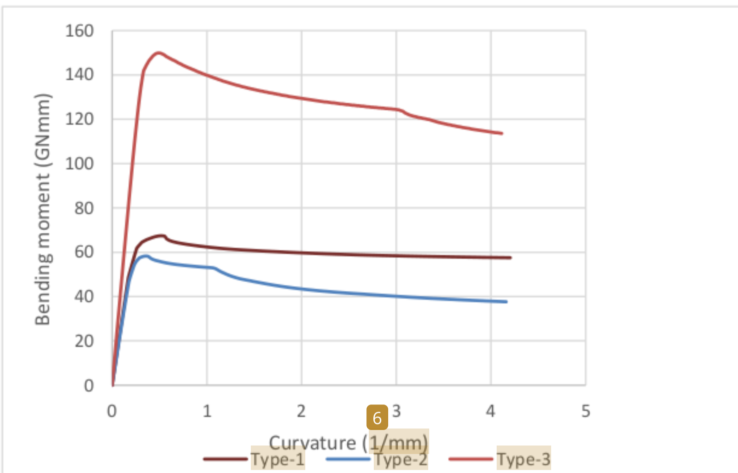

Figure 4 Bending moment-curvature relationship of 650 mm frame-space in hogging

It is also observed that the bending stiffness for type-3 is different with type-1 and type-2 for hogging and sagging. The tendency of the bending stiffness for type-3 tends to coincide to the vertical axis. This behavior may be influenced by the shape of bilge. It should be noted that the cross section of Ro-Ro ship for type-1 and type-2 is almost identic for the case of bilge. Perhaps, it is also affected by the shape of side shell for type-3, because there is a little different for the bottom part near to the bilge shell. This part is generally contributed to the effect of the ultimate strength including their tendency of the stiffness.

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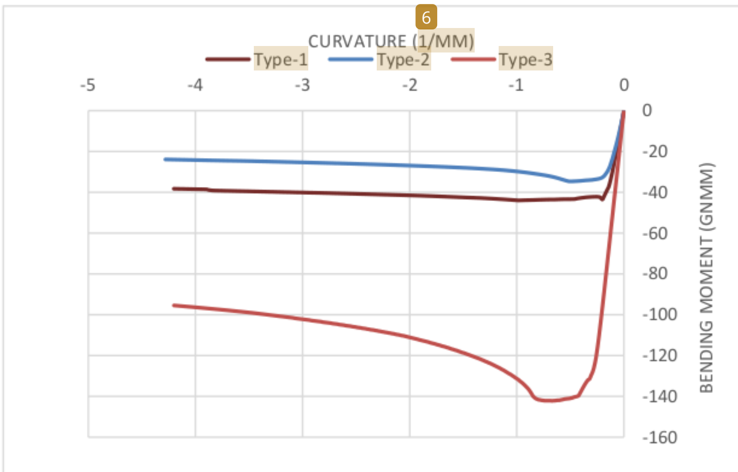

Figure 5 Bending moment-curvature relationship of 650 mm frame-space in sagging

4. Conclusions

The investigation of the ultimate strength on Ro-Ro ships has been done using Smith's method. The following conclusions may be summarized as; the ultimate strength of Ro-Ro ship for type-3 gives significant influence toward type-1 and type-2. This effect cause by the shape of cross sectional including their dimensions and hull girders. For the case of the influence of the frame-space, the effect is not so significant. The percentage of the biggest one is only about 0.5%.

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