Numerical estimation of ultimate strength on double hull oil tanker cargo area

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ABSTRACT: Ship's hull consists of many elements located in deck, side shell and bottom structures. Those elements are unstiffened and stiffened plates and resist all the internal and external loads like cargos and waves. The primary element support the longitudinal strength is always to be investigated under loading conditions. The loads act perpendicular along the hull is resisted from these elements. The objective of the present study is to estimate the ultimate strength of Double Hull Oil Tanker cargo area using numerical analysis. Two Double Hull Oil Tankers are taken as the object in this study. The cargo tank is considered to be analyzed and the shell element is used to the entire model. The bending moment is connected to Multi-Point Constraint (MPC) at one side and the other side is constrained. The ultimate strength of chosen oil tanker is conducted under hogging and sagging conditions.

1 INSTRODUCTION

1.1 *Background*

Double hull oil tanker is a special ship due to its payload contains liquid which can be flammable. The fluid also moves and press inside cargo tank so that this would be internal force along cargo area. On the other hand, the external force such as waves also have influence to ultimate strength of ship global structure. So that the cargo area of double hull oil tanker should be assessed to the ultimate strength. The ultimate strength is always considered for ship design criteria. Some methods and tools are used and implemented to analyze the ultimate strength of ship such as beam theory, simplified approach and numerical method.

1.2 *Previous studies*

The ultimate strength analysis of ship has been carried out by numerous research analysts, particularly for tankers and bulk carriers. Li & Tang, (2019), stated that a structural reliability analysis model in accordance with a Bayesian belief network was recommended for the hull girder collapse risk after an accident. The Bayesian belief network was used to illustrate random variables of risk events after an accident, as well as their vulnerability. In addition, the structural reliability analysis was used to evaluate the failure probability of the hull girder after each possible undesirable condition. Subsequently, Campanile, et al (2018) carried out a study on the relative frequency of colli-sion damage models on an oil tanker and the reliabil-ity of bulk carriers in accordance with the IACS de-terministic pattern opposing the GOLADS/IMO database statistics for such events, as well as verify-ing the probabilistic model. In addition, the dependability of an oil tanker in intact condition was carried out to review the incidence of load combination methods on hull girder sagging or hogging time-variant failure probability Campanile, et al (2017). A simplified approach was used to analyze the ultimate strength of asymmetrically damaged ships following the critical elements subjected to sagging condition (Muis Alie, 2018).

The ultimate residual strength of ship hull plates, which are dependent on uniaxial cyclic load was also reviewed by carrying out numerical analysis using nonlinear finite element method (Xia, et al 2019). The local elements and their progressive collapse due to hogging and sagging condition were subjected to longitudinal bending moment using the nonlinear finite element method were conducted by Muis Alie & Latumahina (2019). (Wang, et al (2019) studied the maximum loading carrying capacity for Ultra-large container ship with an enormous deck opening and decreased torsional rigidity. The ultimate strength of the hull girder subjected to the three load components is carefully analyzed in this study.

In addition, Van, et al (2018) stated the effect of initial imperfection and corrosion wastage on the age-related strength degradation of bulk carriers. Parunov, et al (2017) reported that the residual strength of an Aframax-class double hull oil tanker damaged in the collision was assessed by consid ering the influence or effect of the rotation of the neutral axis. According to Guia, et al (2018) the probabilistic characteristics of the hull girder, tend to target the safety level of a Suesmax tanker derived from a cost-benefit analysis was also assessed. A simplified analytical method was used to examine the energy absorbed by double-hull ship structures subjected to a flat edge indenter (Liu, 2017). Furthermore, Xu, et al (2017) present a reliable and suitable FE modelling in the explicit dynamic method, which could keep the balance of the acceptable accurate results and computation resources.

Wang, et al (2020) present a similar scale model of a 10,000TEU container ship has been designed and manufactured first, in which both geometric similari-ty and strength similarity are taken into account. The ultimate and residual strength analyses of a double-hull tanker ship during biaxial bending moment con-ditions was presented by Kuznecovs, et al (2020). Wang, et al (2019a) presented the similarity between scale model and true ship in cross-section consider-ing the height of neutral axis, the section modulus, the inertia moment about neutral axis and the polar inertia moment should fit the geometrical similarity theory, and in strength considering buckling strength and shear ultimate strength of plates and stiffened panels should fit the strength similarity theory.

The previous studies show that the ultimate strength is very important especially for double hull oil tank-er. The present study focuses on the estimation of the ultimate strength on Double Hull Oil Tanker cargo area using numerical analysis. The section lo-cate in the mid of ship's length of scantling, L, while x/L is equal to 0.5, is called as the midship section. The midship section represents the characteristics of ship's hull under longitudinal bending. The ship's hull of Double Hull Oil Tanker is modeled by using numerical method. The cargo tank is considered to be analyzed and the shell element is used to the en-tire model. A cargo tank that locates nearly at the midship section of the ship (0.5 x/L) is chosen. The bending moment is connected to Multi-Point Con-straint (MPC) at one side and the other side is con-strained. The MPC is placed at the neutral axis posi-tion as reference point. It is assumed that the cargo tank of chosen oil tanker remained plane during pro-gressive collapse. The ultimate strength of chosen oil tanker is conducted under hogging and sagging conditions. The ultimate strength in term of moment-curvature curve is presented.

2 METHOD OF ANALYSIS

2.1 *Simple Formulation*

The ship's hull may be idealized as a simple beam which is floating on the water surface. The ship hull may experience hogging and sagging conditions due to internal loads and external loads such as payload acting inside cargo tank and waves. In this case, the total vertical bending   is the summation of still water bending moment   and waves bending moment.

So that the Equation should be (DNVGL, 2017):

$$M_T = M_{SW} + M_W \tag{1}$$

The section modulus   and section inertia   are calculated in advance to obtain the neutral axis posi-tion as follow,

$$z = \frac{I}{W} \tag{2}$$

This neutral axis position is base to place the Multi-Point Constrained (MPC). The total vertical bending moment is given in this MPC as a force rotation at one side of the cargo tank of the double hull oil tanker. In the present study, the longitudinal strength of double hull oil tanker is analyzed using numerical calculation. Two double hull oil tankers are taken to be investigated. One cargo tank of two double hull oil tankers is considered. The cross section of cargo tank is assumed remain plane during progressive collapse. It should be noted that the analysis is conducted under the axial force condition along the neutral axis to obtain the magnitude of stress occur on deck and bottom part.

In the present study, two models of double hull oil tankers have same dimensions, but different in case of types, numbers and dimensions of longitudinal stiffeners are located in cargo area. Therefore, these influences become motivation in this study to know its effect to ultimate strength. The numerical method is adopted to analyze the ultimate strength of cargo area under hogging and sagging conditions.

2.2 *Cross section model*

Figures 1 and 2 show the cross section of double hull oil tanker of Model-1 and Model-2. It is already mentioned that both two models are different for type and number of stiffeners on the cross section. Only one side of the model is figured, but the analysis is done by considering fully cross section. Both two models have longitudinal bulkheads located in the center line consisting longitudinal stiffeners on it.

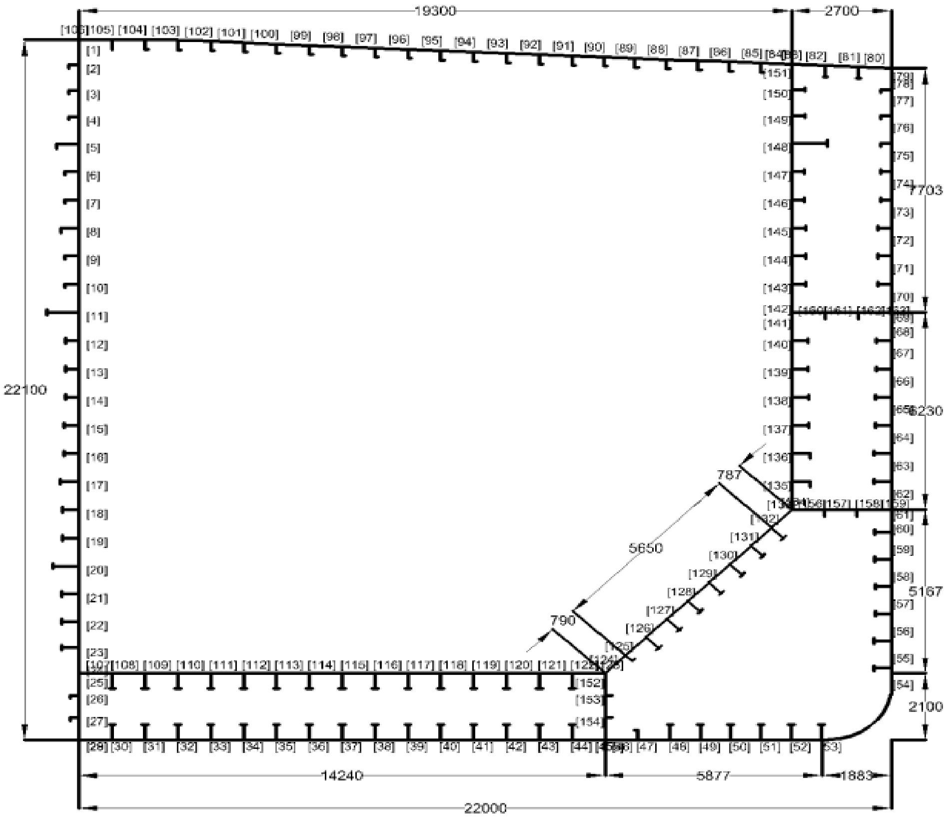

Figure 1. Double Hull Oil Tanker (Model 1)

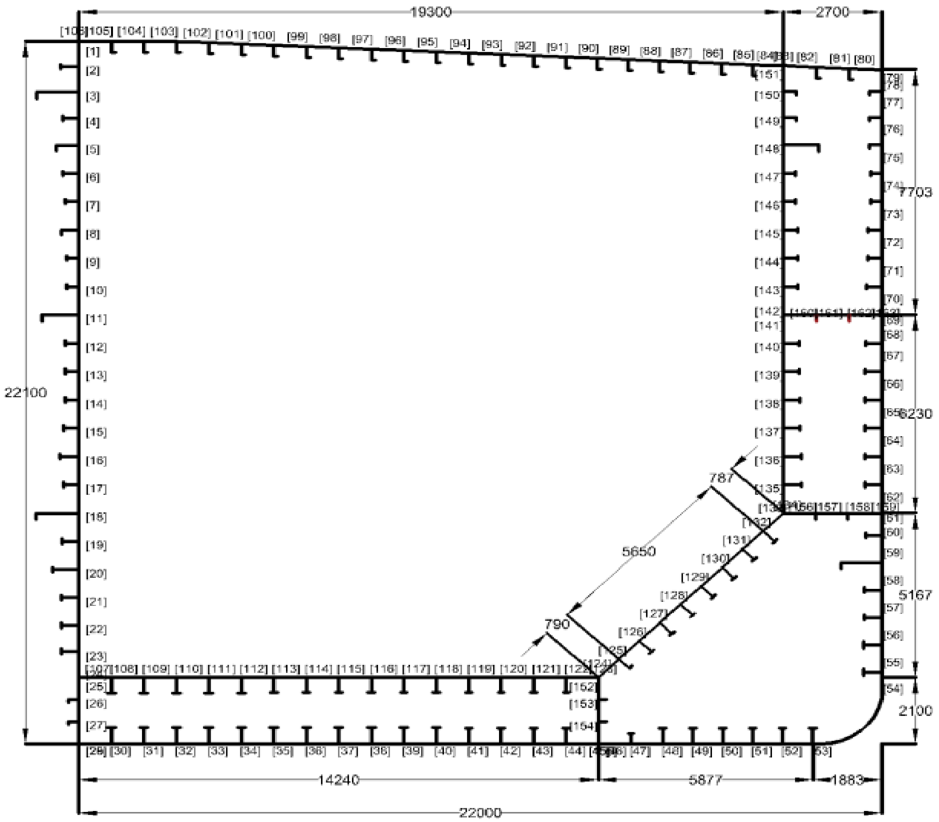

Figure 2. Double Hull Oil Tanker (Model 2)

The material properties of two models are constant. There are no cracks; damages, initial imperfection and so on are considered in the analysis. Table 1 shows the material properties for two models of Double Hull Oil Tankers.

Table 1. Materials properties

Items	Value
Type of material	AH37
Density (kg/m^3)	7850
Modulus Young (N/mm^2)	210000
Poisson’s Ratio	0,3
Yield Strength (N/mm^2)	370
Tangent Modulus (N/mm^2)	675

The shell element type is used and implemented to whole cross section models of Double Hull Oil Tanker. The models use the mesh size of 1000 mm so that the total numbers of the elements are 22940. The ANSYS software for academic/student version is adopted to estimate the ultimate strength of two Double Hull Oil Tankers on cargo area under hogging and sagging conditions.

The load and boundary conditions are applied by implementing the MPC place on the neutral axis position as reference point. The analysis conditions are determined by trial and error approach. Figure 3 shows the load and boundary condition of double hull oil tanker.

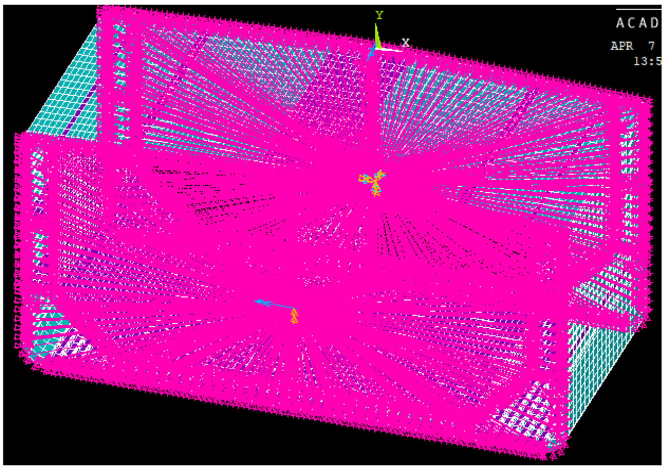

Figure 3. Load and boundary conditions

3 RESULT AND DISCUSSION

3.1 *Stress Distribution*

Figures 4 and 5 describe stress under hogging condition on Model-1 and Model-2 of double hull oil tanker, respectively.

According to figures 4 and 5 that the stress magnitude occurs under hogging due to tension at deck part. While the stress bottom part is under compression.

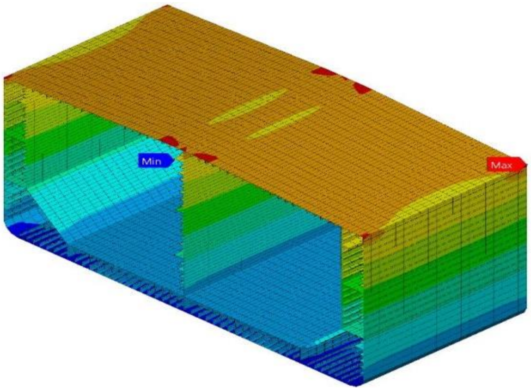

Figure 4. Stress Model-1 for hogging condition

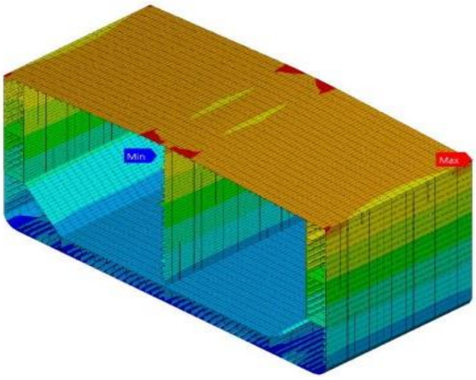

Figure 5. Stress Model-2 for hogging condition

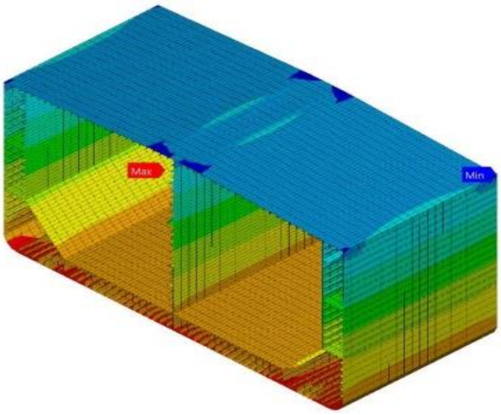

Figure 6. Stress Model-1 for sagging condition

Figures 6 and 7 express stress under sagging condition of double hull oil tanker on Model-1 and Model-2, respectively. In case of sagging condition, deck part is under compression, while bottom is under tension.

The ultimate strength of cargo area of two double hull oil tankers considering the influence of difference type and number of longitudinal stiffeners are conducted using numerical method. Figure 8 express the moment-curvature relationship of double hull oil tanker for Model-1 and Model-2 under hogging condition.

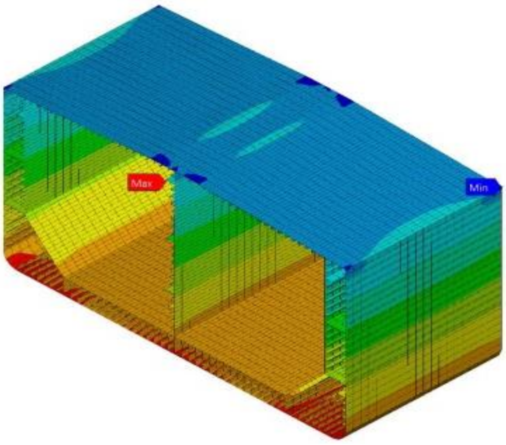

Figure 7. Stress Model-2 for sagging condition

There are two models of double hull oil tanker namely Model-1 and Model-2 to distinguish between both of them due to the differences of type and number of longitudinal stiffeners. Model-1 is represented with dashed line and Model-2 with solid line.

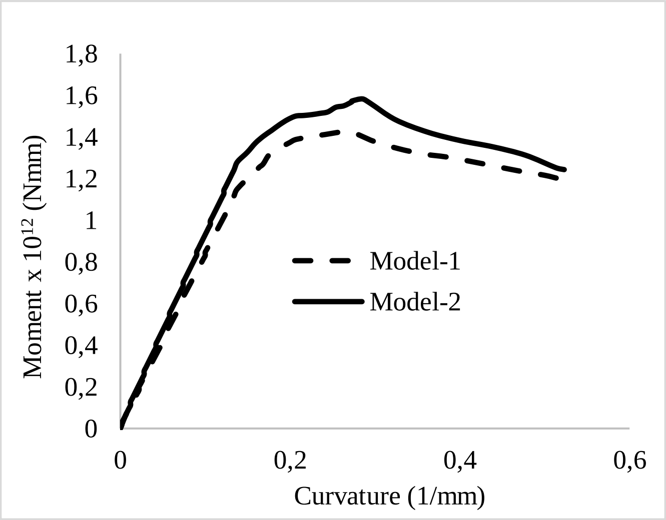

Figure 8. Moment-curvature for hogging condition

The ultimate strength under sagging condition for Model-1 and Model-2 of double hull oil tanker is shown in figure 9. The ultimate strength obtained by numerical method for Model-2 is larger than Model-1 both for hogging and sagging. Particularly in sagging condition, the ultimate strength of Model-2 is larger than Model-1. This is because the type and dimension of longitudinal stiffeners at the bottom part is completely different between Model-1 and Model-2 since the two model under sagging condition.

The section modulus and section inertia also influence to the ultimate strength since the ship is under tension or compression. In this regard, the neutral axis position determines the section modulus and section inertia above and under neutral axis. The second one, the section modulus and section inertia is also caused by the type, number and dimension of longitudinal stiffeners located at bottom, side shell and bottom part.

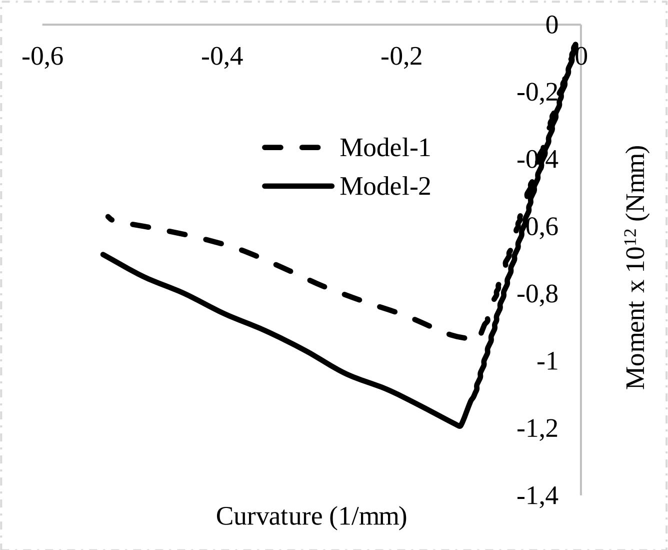

Figure 9. Moment-curvature for sagging condition

In addition, according to figures 8 and 9, the bending stiffenes are also different due to the effect of type, dimension and number of longitudinal stiffeners. It is found that the bending stiffenes of Model-1 is lower than Model-2 under hogging and sagging conditions.

4 CONCLUSIONS

The estimation of the ultimate strength on cargo area of two double hull oil tankers under hogging and sagging conditions has been conducted using numerical analysis. Two types of double hull oil tankers namely Model-1 and Model-2 are taken to be investigated. The ultimate strength on cargo area of Model-2 is larger than Model-1 both hogging and sagging conditions due to the influence of properties between two models such as types, numbers and dimensions of longitudinal stiffeners on the cargo area. The section modulus and section inertia also influence to the neutral axis position where the MPC is placed.

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