The Influence of Additional Equipment to the Ultimate Strength of FPSO

Muhammad Zubair Muis Alie[1], Juswan[1], Wahyuddin Mustafa[1], Kevin Gabriel Pangalinan[1]
and Nurul Inda Pratiwi[2]

[1]*Department of Ocean Engineering, Hasanuddin University, Jalan Poros Malino km. 6 Bontomarannu,
Makassar, Indonesia*
[2]*KTU Shipyard, Project Department, Riau, Indonesia*

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Abstract: Nowadays, there have many ship conversions, for example, from double hull tanker to Floating Production Storage Offloading (FPSO). The conversion is conducted due to the change function of the ship. On the other hand, due to the change function of the ship, some items of the ship, such as equipment, need to be evaluated because of those related to the ultimate strength of the ship. The objective of the present study is to analyze the influence of additional equipment to the ultimate strength of FPSO under vertical bending moment for hogging condition. The cross-section of FPSO is taken by considering one-frame space. The numerical method is used, and the Multi-Point Constraint (MPC) is applied to both sides of the cross-section, and it is assumed to have remained plane. The shell element type is used for modeling the cross-section. The material properties are set to be constant. As a simple calculation, the ship's cross-section is analyzed in intact. The additional equipment is calculated and included in the analysis to know the influence of it. The analysis of the ultimate strength, including their influence of additional equipment, is conducted under longitudinal bending. To compare the ultimate strength obtained by the numerical method, the analytical method is adopted. It is found that the ultimate strength gained by the numerical method is almost identical to the analytical method. The behavior of the ship's cross-section is also presented in terms of stress distribution and deformation.

1 INTRODUCTION

The conversion of a ship is implemented in recent years. This phenomenon is mostly conducted for an offshore structure such as from Double Hull Tanker to Floating Storage Offloading (FSO) or Floating Production Storage Offloading (FPSO). The conversion aims to change the ship function and operation, including ship payload. In some years, the conversion from tanker to FPSO is very significant. Time-consuming is shorter than a new design; that is one of the reasons. On the other hand, during conversion, some equipment must be added not only for the ship's function but also for the ship's construction. Due to this reason, the analysis of the ultimate strength of being converted considering the additional equipment must be taken into account.

The analysis of the ship's strength had been introduced by some papers like; The residual strength of an Aframax-class double hull oil tanker damaged in the collision had been assessed by (Parunov, Rudan, and Bužančić Primorac, 2017) considering the influence of the rotation of the neutral axis. The impact of nonlinear finite element method models on the ultimate bending moment for hull girder was studied by (Xu and Pan 2017). There were two analyses performed; those were implicit static analysis and explicit dynamic analysis. A structural reliability analysis model based on a Bayesian belief network was proposed by (Li and Tang, 2019) for the hull girder collapse risk after accidents. The Bayesian belief network was used to represent random states of variable risk events after accidents, as well as the dependencies between activities, and the structural reliability analysis was used to evaluate the failure probability hull girder for each possible accident conditions. The incidence of collision damage models on an oil tanker and bulk carrier reliability was investigated by (Campanile, Piscopo and Scamardella, 2018) considering the

IACS deterministic model against GOLADS/IMO database statistics for collision events, substantiating the probabilistic model. Safety of an oil tanker in intact condition was performed by (Campanile, Piscopo, and Scamardella, 2017) to investigate the incidence of load combination methods on hull girder sagging/hogging time-variant failure probability. The simplified approach to the ultimate hull girder strength of asymmetrically damaged ships was conducted by (Muis Alie, 2018), considering the critical element under sagging condition. The effect of symmetrical and unsymmetrical configuration shapes on buckling and fatigue strength analysis of fixed offshore nonlinear finite element was conducted by (Muis Alie, 2016), and damages were modeled simply by removing the element on the damaged part. The progressive collapse analysis of the local element was conducted by (Muis Alie and Latumahina, 2019) and the cross-section of the Ro-Ro under longitudinal bending.

In the present study, the hull girder strength analysis caused by additional equipment on FSO after being converted into FPSO under longitudinal bending is conducted. The ship's construction is not changed, but additional equipment after conversion is applied. For the simple calculation, the one-frame space of FPSO's cross-section is considered. The cross-section is assumed to have remained plane. The element type of shell 181 is used on the model. The initial imperfections, cracks, and residual welding stress are not taken into account. The ultimate strength obtained by the numerical method is compared with the analytical method, and the behavior of the ship in terms of stress distribution and deformation are also shown in this study.

2 FINITE ELEMENT MODEL

In the present study, the numerical method to analyze the hull girder strength due to load equipment of change function from FSO to FPSO before and after being converted is conducted. The ship has 172 m, 30 m, and 18.4 m of length, breadth, and depth of ship, respectively. The midship section consists of two kinds of longitudinal stiffeners those are flat-bar and angle-bar. The analysis of the ultimate strength is performed under the hogging condition. There is also the inner hull in the cross-section. The element type is shell-181. The shell-181 element applied to all of the cross-sections, as shown in figure 1.

Figure 1: Finite element model.

According to figure 1, there are two points located at the neutral axis. These two points are placed at both sides of the cross-section, and those are used to place the MPC (Multi-Point Constraint) for representing the behavior of the cross-section. The ultimate strength analysis, including the effect of change function from FSO to FPSO, is calculated using the numerical method under sagging condition. The rigidly linked corresponding with the boundary condition where MPC is applied to both sides of the cross-section, as shown in figure 2.
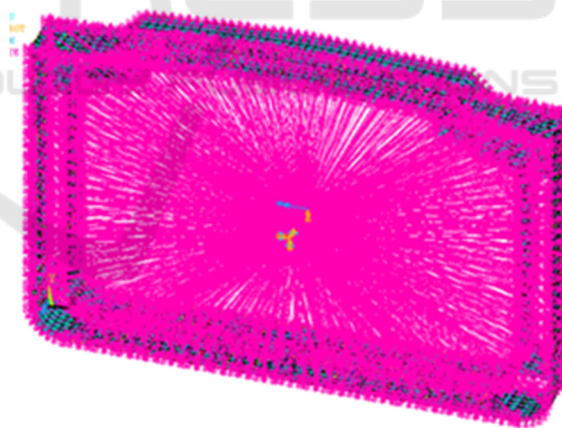

Figure 2: Rigid link and MPC.

According to figure 2, the applied MPC is placed at the fore and aft side of the cross-section. This is done to connect the MPC called master node and the points of the all side's cross-section. The applied moment is placed at this MPC.

3 RESULTS AND DISCUSSIONS

The behavior of the ultimate strength analysis is described in terms of working stress distribution. Figure 3 shows the working stress of FSO under the hogging condition. The deck and bottom part are under tension and compression since the hull cross-section is under hogging condition.
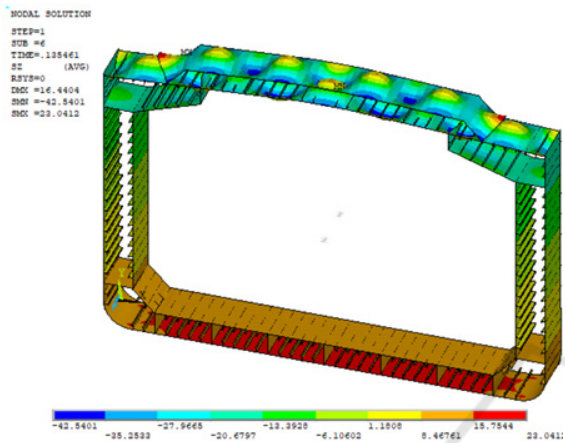

Figure 3: Working Stress of FSO in Hogging.

Figure 4 shows the working stress of FPSO under the hogging condition. It is observed that the characteristic of the working stress of FSO and FPSO is different from one another due to the additional equipment after being converted.
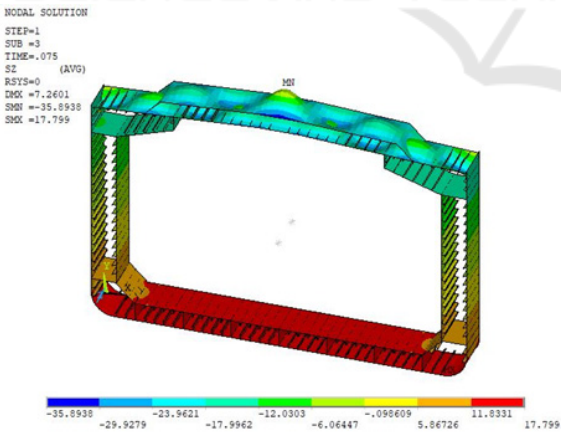
Figure 4: Working Stress of FPSO in Hogging.

Figure 5 shows the moment-curvature relationship of FSO under the hogging condition. The ultimate strength and collapse stages are represented by points A and B, respectively.
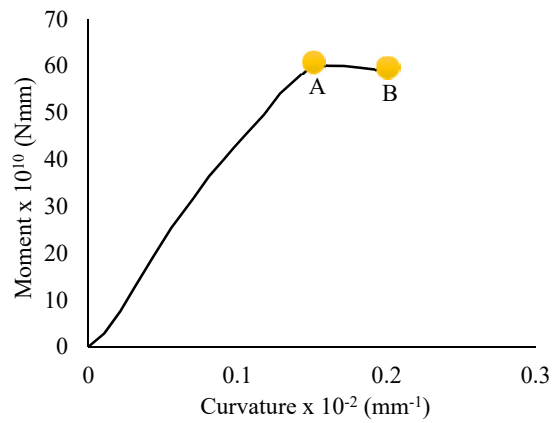

Figure 5: Moment-Curvature of FSO in Hogging.

Deformation of the FPSO at the ultimate strength and collapse stage at point A and B under hogging condition are shown in figures 6 and 7, respectively. Failure takes place at some elements at the deck part where tension happen under hogging condition.
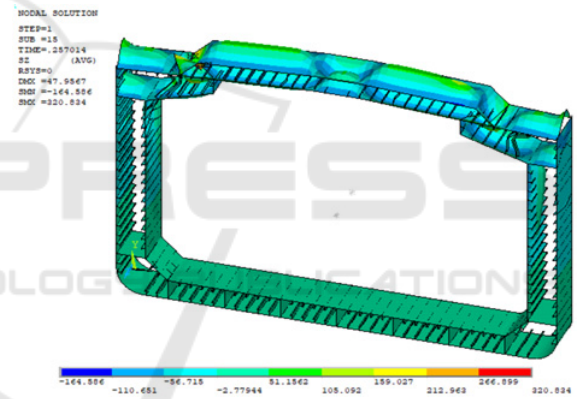

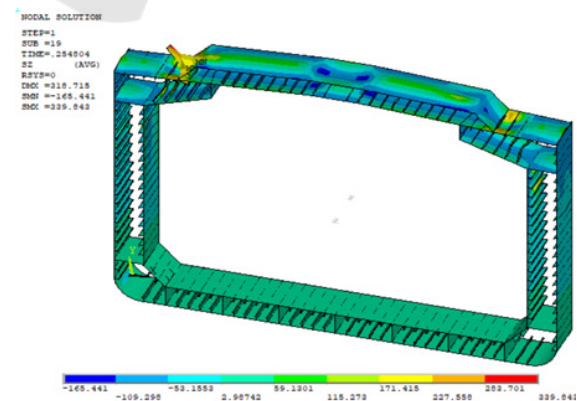Figure 6: Deformation of FSO at Ultimate Strength.

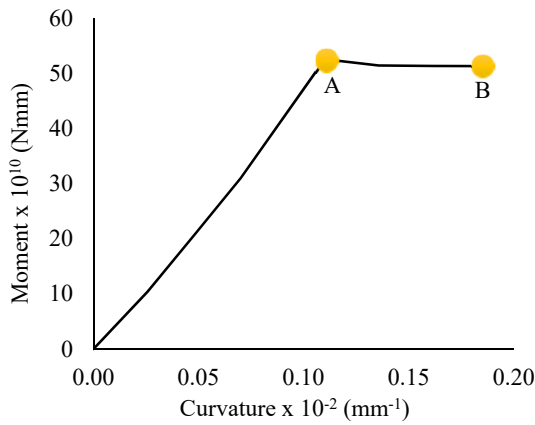Figure 7: Deformation of FSO at Collapse.
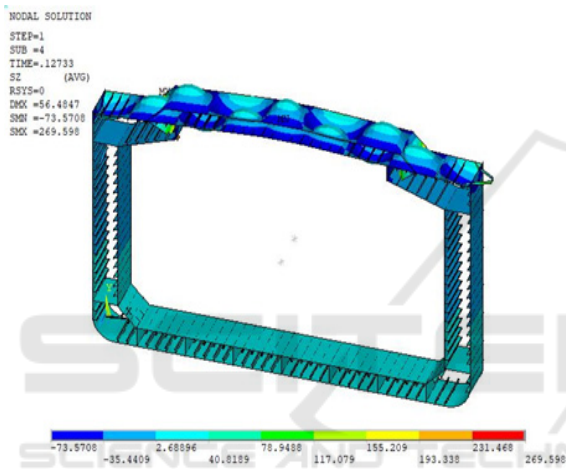
Figure 8: Moment-Curvature of FPSO in Hogging.

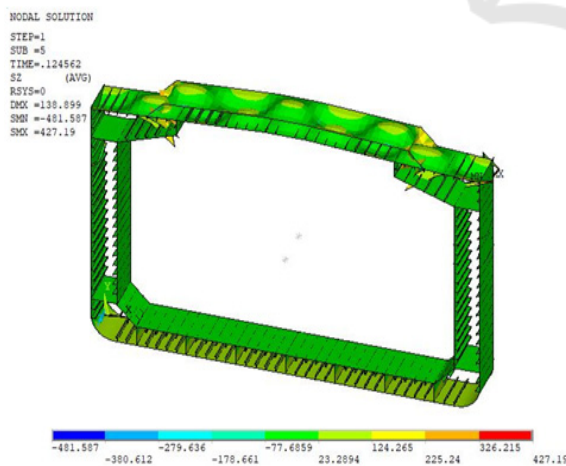Figure 9: Deformation of FPSO at Ultimate Strength.

Figure 10: Deformation of FPSO at Collapse.

Figure 8 shows the moment-curvature relationship of FPSO at point A and B in hogging conditions. Points A and B represent the ultimate strength and collapse regime, respectively. Figures 9 and 10 show

the deformation at the ultimate strength and collapse region of FPSO under hogging condition.
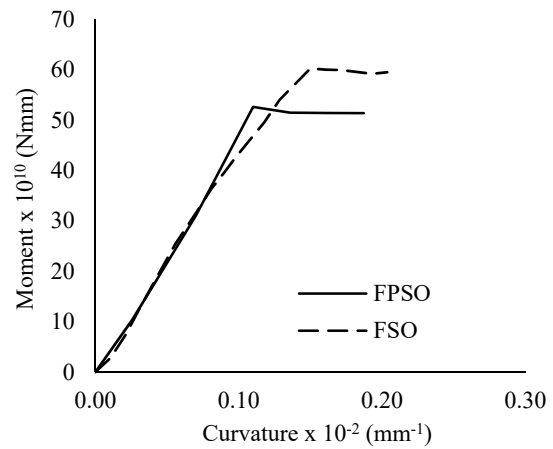

Figure 11: Moment-Curvature Relationship.

Figure 11 expresses the comparison of the moment-curvature relationship after being converted from FSO to FPSO under the hogging condition.

According to figure 11, the bending moment capacity of FSO is larger than FPSO. This is because the additional equipment is applied from FSO to FPSO so that the capacity bending moment after being converted is decreased.
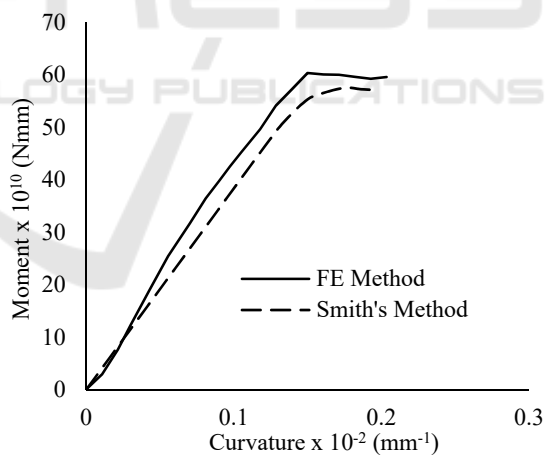

Figure 12: Comparison of Moment-Curvature Relationship.

For the comparison purpose for the ultimate strength analysis, the analytical method is adopted. Figure 12 shows the comparison of the ultimate strength obtained by the numerical method and analytical method. The numerical method is represented by the solid line and the dashed line for the analytical method. It is found that the ultimate strength obtained by the numerical method is larger than the analytical method. This phenomenon happens due to

the redistribution of the stress concentration takes place since the three-dimensional analysis is considered. The bending stiffness is also changed due to the additional equipment after being converted from FSO to FPSO.

4 CONCLUSIONS

The ultimate strength analysis has been conducted by using the numerical method under longitudinal bending in hogging condition. The following conclusions are; the additional equipment has a significant influence on the ultimate strength after being converted from FSO to FPSO. The bending stiffness is different due to additional equipment before conversion from FSO to FPSO. The ultimate strength obtained by the numerical method for FPSO is larger than FSO.

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