Ultimate strength analysis of stiffened plate variation on double bottom of Floating Production Storage Offloading (FPSO)

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Abstract. Double bottom is part of the ship that must be evaluated from the loads for instance wave load acts on side hull and pressure from the outer bottom. The loads must be evaluated and investigated the effect on the double bottom structure. The objective of the present study is to analyze the ultimate strength of stiffened plate variation on the double bottom of the floating production storage offloading. The small section of stiffened plate with attached plating at the double bottom is considered to be analyzed. The numerical analysis is adopted to analyze the model. The stiffened plate is varied with the distance in terms of model breadth. The boundary condition is applied to the model including axial compression load. The behavior of the model is represented by stress and deformation. For the simple analysis, the welding residual stress, crack, and initial imperfection are not taken. The result obtained by the numerical analysis is presented together with the behavior in terms of stress and deformation.

1. Introduction
Generally, the ship contains many structural elements connected with one another for local and global, particularly, the double bottom structure of the ship. The pressure load from the outer bottom and side shell, including inner bottom represented by cargo load acting together on the hull structure. The impact of these loads may hull girder becomes degrade and could collapse when the load acts extremely large. Therefore, all the component of the hull girder, especially the bottom area, must be analyzed and evaluated.

The ultimate strength analysis of ship hull girder has been presented by some papers. The residual strength of an Aframax-class double hull oil tanker damaged in the collision had been assessed by Parunov [1] by considering the influence of the rotation of the neutral axis. The influence of nonlinear finite element method models on the ultimate bending moment for hull girder was studied by Xu [2]. There was two analysis 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 [3] 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 events, 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 [4] considering the IACS deterministic model against
GOLADS/IMO database statistics for collision events, substantiating the probabilistic model. Reliability of an oil tanker in intact condition was performed by Campanile [5] to investigate the incidence of load combination methods on hull girder sagging/hogging time-variant failure probability. The simplified approach on the ultimate hull girder strength of asymmetrically damaged ships was conducted by Muis Alie [6] considering the critical element under sagging condition. The residual hull girder strength in intact and damage condition under longitudinal bending moment using nonlinear finite element was conducted by Muis Alie [7], and damages were modeled simply by removing the element on the damaged part. The ultimate hull girder strength considering section modulus under longitudinal bending was analyzed by Muis Alie and Latumahina [8] and the cross-section of Ro-Ro ship was taken to be analyzed.

The objective of the present study is to analyze the ultimate strength of stiffened plate variation on the double bottom of the floating production storage offloading. The small section of stiffened plate with attached plating at the double bottom is considered to the analyzed. The numerical analysis is adopted to analyze the model. The stiffened plate is variated with the distance in terms of model breadth. The boundary condition is applied to the model including axial compression load. The behavior of the model is represented by stress and deformation. For the simple analysis, the welding residual stress, crack, and initial imperfection are not taken. The result obtained by the numerical analysis is presented together with the behavior of the model in terms of stress and deformation.

2. Methodology

The midship section of floating production storage offloading is shown in figure 1. The target of the stiffened plate is located at the bottom part denoted by the red circle, including their dimension. The cross-section and model of the stiffened plate variation and boundary condition are presented in figure 2, 3, and 4, respectively.

![Figure 1. Half midship section of FPSO](image-url)
Figure 2. The cross-section of the stiffened plate

(a) Model 1  
(b) Model 2

Figure 3. The stiffened plate model

Figure 4. Boundary conditions of the stiffened plate model
3. Results and discussion

Figure 5 and 6 show the Von-Mises stress distribution and deformation of the stiffened plate model-1. The stiffened plate for model-1 deforms at the left and right side, while the stiffened plate at the center part does not have significant influence of the deformation as shown in figure 6. It is also found that the stress concentration takes place around the edge of the stiffened plate.

![Figure 5. Von-Mises stress distribution of the stiffened plate model-1](image1)

![Figure 6. Deformation of the stiffened plate model-1](image2)
Figure 7 and 8 show the Von-Mises stress distribution and deformation of the stiffened plate model-2. The stiffened plate for model-2 deforms at the left and right side, while the stiffened plate at the center...
part does not have significant influence of the deformation as shown in figure 7. It is also found that the stress concentration takes place around the edge of the stiffened plate, as shown in figure 8.

4. Conclusion
The ultimate strength of stiffened plate with some variations of distance using finite element analysis has been done. The following conclusion are; the stiffened plate at the center of the model does not have any significant influence to the deformation. The stress distribution takes place around the edge of the stiffened plate.

References
[1] Parunov J, Rudan S and Bužančić Primorac B 2017 Residual ultimate strength assessment of double hull oil tanker after collision Eng. Struct. 148 704–17
[2] Xu M C, Song Z J and Pan J 2017 Study on influence of nonlinear finite element method models on ultimate bending moment for hull girder Thin-Walled Struct. 119 282–95
[3] Li X and Tang W 2019 Structural risk analysis model of damaged membrane LNG carriers after grounding based on Bayesian belief networks Ocean Eng. 171 332–44
[4] Campanile A, Piscopo V and Scamardella A 2018 Conditional reliability of bulk carriers damaged by ship collisions Mar. Struct. 58 321–41
[5] Campanile A, Piscopo V and Scamardella A 2017 Incidence of load combination methods on time-variant oil tanker reliability in intact conditions Ocean Eng. 130 371–84
[6] Muis Alie M Z 2018 Simplified approach on the ultimate hull girder strength of asymmetrically damaged ships Int. J. Offshore Polar Eng. 28 200–5
[7] Muis Alie M Z, Sitepu G, Sade J, Mustafa W, Nugraha A M and Bin Muh. Saleh A 2016 Finite Element Analysis on the Hull Girder Ultimate Strength of Asymmetrically Damaged Ships V003T02A083
[8] Muis Alie M Z and Latumahina S I 2018 The Ultimate Hull Girder Strength Analysis Considering Section Modulus Under Longitudinal Bending 581–7