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Strength Analysis on Yoke Single Point Mooring with Finite Element Method

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KEYWORDS
deformation
finite element method
single point mooring
stressed
yoke

ABSTRACT

Analysis of stresses and deformations in the Single Point Mooring (SPM) yoke structure using the Finite Element Method (MEH) aims to determine and understand the stress distribution and deformation of the yoke, so that offloading activities comply with safety standards. The finite element method is a numerical modeling technique used to predict the behavior of a system by dividing an object into a number of elements that can be analyzed independently. This study uses 3 geometric models, namely single point mooring yoke geometry aged 0, 20, and 30 years. The results of the analysis will assist in understanding the stresses and deformations that occur in the SPM yoke structure. The towing load of 75, 100, and 125 tons is modeled to represent the towing load of the ship during offloading operations. The largest stress and deformation values obtained for each geometry are 89 MPa for the 0-year model, 89.2 MPa for the 20-year model, and 97.1 MPa for the 30-year model and 0.08 mm for the 0-year model, 0.10 mm for 20-year model, 0.11 mm for 30-year model. This study proves that the stress values and deformations that occur are in accordance with safety standard criteria.

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INTRODUCTION

SPM (Single Point Mooring) is a floating structure that is offshore with a function as an interconnection or mooring for tankers or ships that are unloading or operating cargo products in the form of gas or liquid. Ships that carry out operations for filling or emptying fuel, oil or gas use SPM, the use of SPM is usually used in sea areas where it is not possible to use traditional port systems. SPM has the advantage of handling various types of large and small ship sizes, such as even very large ships transporting oil, because alternative facilities are not available at sea, ships or tankers anchored at SPM can carry out operations quickly and efficiently, thereby reducing berthing time and operating costs. In addition, SPM is also used to improve the security and safety of ship navigation by providing safe and stable facilities for ships to dock.

Floating offshore structures must be able to maintain their installation, assisted by a suitable mooring system. Catenaries are the most popular mooring systems used for many floating offshore structures. The chain links form an increase in weight so that horizontal forces can be generated in floating offshore structures[3]. Offshore chain links mooring line components must be specified by offshore standards, where loads higher than the operational loads are applied to the mechanical components, resulting in high residual stress levels.[6]. It is therefore important to monitor the voltage response of the mooring lines to prevent potential damage[4]. Accidents due to failure of the mooring system shown in the accident diagram above explain that chain failures are dominated by corrosion (20%), followed by event-based failures due to corrosion fatigue (19%), fatigue (17%), then installation, manufacturing defects, mechanical, out of plane bending fatigue (8%), due to design (6%), multiple and unknown causes (3%)[2].

Belanak Oil Offloading Bouy (OOB) is an offshore building used for loading and unloading oil. OOB Belanak is designed to handle oil production from the field and facilitate the shipment of oil to tankers which will deliver the oil to various locations around the world, after operating for approximately 20 years, OOB Belanak requires analysis to evaluate the building and ensure that the building is still operational. operate safely and effectively. The studies that have been conducted related to*chains*on Single Point Mooring there is still little research evaluation on the Yoke Single Point Mooring.

The yoke is an important part of single point mooring which functions as a holding device. Yoke analysis is needed to determine the optimal operational conditions for the yoke system, such as the force received by the yoke, stress, factor of safety, and deformation when loading occurs. The stresses and deformations that occur in the yoke can cause damage to the yoke and create the risk of an accident. Therefore it is necessary to do a stress analysis on the yoke to find out the level of risk and take appropriate action to overcome it, and to be able to inform the value of the stressthat occurs during testing on a single point mooring yoke used to bind ships at sea, so as to evaluate the safety and load capacity of the system.

METHODS

The yoke structure is an object that has parts called check plates, main plates, stiffeners, sleeves and bushings. The yoke is usually used by FSOs or tankers, the yoke is at the top of the single point mooring, the yoke is used when the offloading process takes place, the hawser mooring system is linked to the pad eye to the offloading system so that it stays within reach, with this the yoke is intended so that the ship or FSO is doing offloading stay within reach. With the following research variables:

Table 1. Research variable

Variable		Variable Value
Load	1.	75 Tons
	2.	100 Tons
	3.	125 Tons
Structure Age	1.	Initial Structural Thickness
	2.	Thickness of the structure after the age of 20 years
	3.	Thickness of structure after 30 years of age

Research procedure

The yoke structure for single point mooring uses ASTM A36 material which is a type of structural carbon steel, this material has good mechanical properties and adequate strength, with the following yield stress.

Table 2. Yoke Structure Allowable Stress

Part	Yield Stress (MPa)	Safety Factor	Allowable Stress (MPa)
Stiffener, Main and Cheek Plate	250	1.43	175

Yoke structure modeling is done using Ansys Workbench software to create a 3D model of the yoke and analyze it using the finite element method (Finite Element Mothod) which isa numerical modeling technique used to predict the behavior of a system by dividing an object into a number of elements that can be analyzed independentlyto predict the structure under a given load, by creating a geometric design model with a space claim. The 0-year geometry is the initial size of the yoke structure (in figure 1).

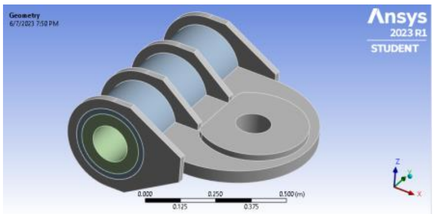

Figure 1. Geometry 0 Years

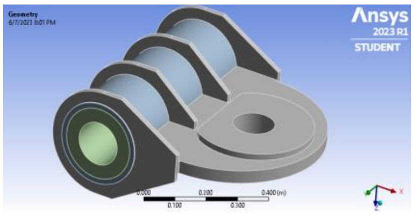

Figure 2. Geometry 20 Years

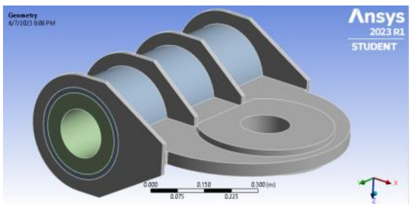

Figure 3. Geometry 30 Years

After the yoke structure has been operating for about 20 years, the yoke structure can change dimensions or sizes as a result of changes in load and operating environment, with a reduction in the size of the structure of about 0.2 mm per year, then it decreases by 4 mm for 20-year modeling (in figure 2) and 6 mm for 30-year modeling (in figure 3) on each side.

Mesh is used in the analysis of the finite element method (Finite Element Method). Meshing itself is the process of dividing a model or object into small elements, referred to as mesh elements, meshing is very important because it affects the accuracy and speed of analysis.

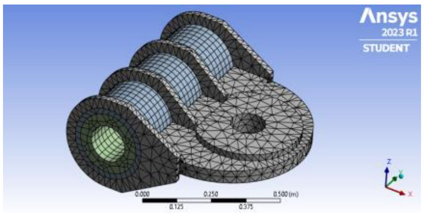

Figure 4. Meshing

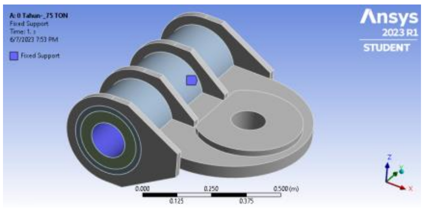

Figure 5. Fixed Support

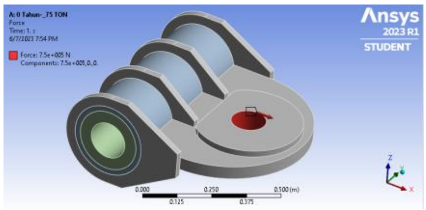

Figure 6. Forces

*Boundary conditions*used to limit movement or deformation of the structure, so as to determine the response of the structure to the applied load. In this analysis the boundary conditions used are Fixed Support/Fixed Boundary Conditions or cannot move or deform (in figure 5) and Force or the force or load exerted on the boundary (in figure 6), the force is given in the direction of the X axis with variations in loading 75, 100 and 125 Tons in 3 geometry models 0, 20 and 30 years.

After the analysis and results of the yoke model have been carried out, then stress and deformation are checked with the following standard criteria:

1. *ABS Safehull-Dynamic Loading Approach for FPSO Systems 2001*

   Max. Allowable Von Mises Stress ≤ 0.9
   Specified Minimum Yield Strength

2. *Modern Structural Analysis: Modeling Process and Guidance*

   Max. Deflection ≤ Plate Depth

RESULTS AND DISCUSSION

Result of Von Mises Loading 75 Tons

In Figure 7 is a diagram of the results of the von Mises stress loading of 75 Tons. This diagram is a comparison of the results of 3 geometry models, namely 0 year geometry, 20 year geometry, and 30 year geometry with a loading of 75 tons and has parts in the form of a stiffener, main plate, and cheek plate made of ASTM A53 material which has a yield stress value of 250 MPa, with the results obtained at this 75 Ton loading were 53.4 MPa for 0 year geometry, 53.5 MPa for 20 year geometry, and 58 MPa for 30 year geometry, with the largest values obtained in the 30 year geometry model where the reduced size or dimensions of the model can be produce a greater stress value than a design that is not reduced in dimension.

Table 3. Von Mises Loading 75 Tons

Part	Yield Stress (MPa)	Safety Factor	Allowable Stress (MPa)	Von-mises Stress (MPa)			UC		
				0 yrs	20 yrs	30 yrs	0 yrs	20 yrs	30 yrs
Stiffener, Main and Cheek Plate	250	1.43	175	53,4	53.5	58,2	0.31	0.31	0.33

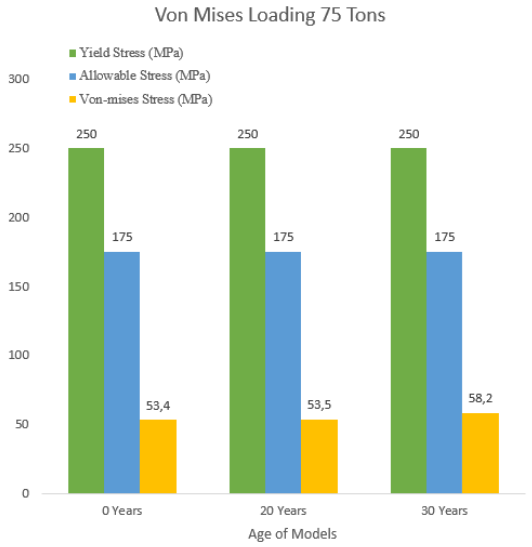

Figure 7. Von Mises Diagram of Loading 75 Tons

Result of Von Mises Loading 100 Tons

In Figure 8 is a diagram of the results of the von Mises stress of 100 tons of loading. This diagram is a comparison of the 3 geometry model results, namely 0 year geometry, 20 year geometry, and 30 year geometry with a loading of 100 tons and has parts in the form of a stiffener, main plate, and cheek plate made of ASTM A53 material which has a yield stress value of 250 MPa, with the results obtained at this 100 Ton loading were 71.2 MPa for 0 year geometry, 71.3 MPa for 20 year geometry, and 77.7 MPa for 30 year geometry, with the largest values obtained in the 30 year geometry model where the reduced size or dimensions of the model can be produce a greater stress value than a design that is not reduced in dimension.

Table 4. Von Mises Loading 100 Tons

Part	Yield Stress (MPa)	Safety Factor	Allowable Stress (MPa)	Von-mises Stress (MPa)			UC		
				0 yrs	20 yrs	30 yrs	0 yrs	20 yrs	30 yrs
Stiffener, Main and Cheek Plate	250	1.43	175	71,2	71.3	77,7	0.41	0.41	0.44

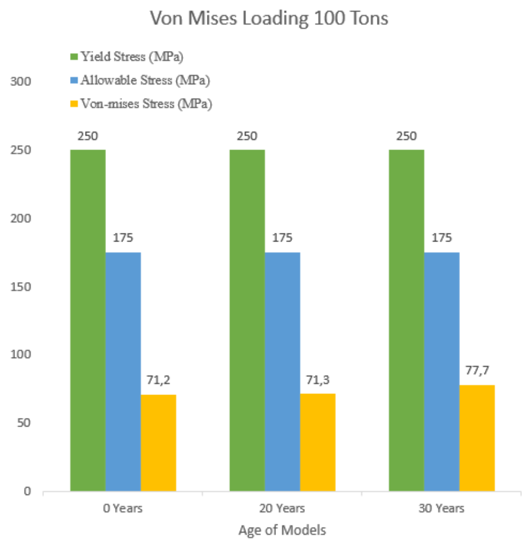

Figure 8. Von Mises Diagram of Loading 100 Tons

Result of Von Mises Loading 125 Tons

In Figure 9 is a diagram of the results of the von Mises stress of 125 Tons. This diagram is a comparison of the results of the 3 geometry models, namely 0 year geometry, 20 year geometry, and 30 year geometry with a loading of 125 tons and has parts in the form of a stiffener, main plate, and cheek plate made of ASTM A53 material which has a yield stress value of 250 MPa, with the results obtained at this 125 Ton loading were 89 MPa for 0 year geometry, 89.2 MPa for 20 year geometry, and 97.1 MPa for 30 year geometry, with the largest values obtained in the 30 year geometry model where the reduced size or dimensions of the model can be produce a greater stress value than a design that is not reduced in dimension.

Table 5. Von Mises Loading 125 Tons

Part	Yield Stress (MPa)	Safety Factor	Allowable Stress (MPa)	Von-mises Stress (MPa)			UC		
				0 yrs	20 yrs	30 yrs	0 yrs	20 yrs	30 yrs
Stiffener, Main and Cheek Plate	250	1.43	175	89	89.2	97.1	0.51	0.51	0.55

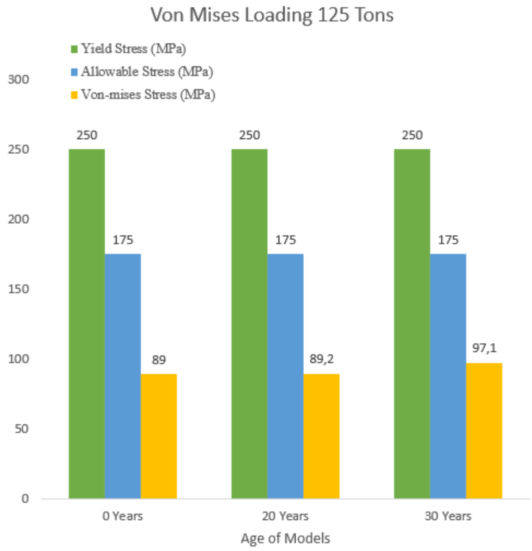

Figure 9. Von Mises Diagram of Loading 125 Tons

Result of Deformation Loading 75 Tons

Figure 10 is a diagram of the deformation results at a loading of 75 Tons. This diagram is a comparison of the deformation results of 3 geometry models, namely 0-year geometry, 20-year geometry, and 30-year geometry with a loading of 75 Tons, with the deformation results obtained at this 75 Ton loading of 0.05 mm for 0-year geometry, 0.06 mm for 0-year geometry 20-year, and 0.07 mm for the 30 years geometry, with the largest value obtained in the 30-year geometry model where the reduced size or dimensions of the model can produce larger deformation values. With the deformation value obtained is used to evaluate the reliability of the structure in the face of a given load,

Table 6. Deformation Loading 75 Tons

Part	Deformation(mm)			UC		
	0 yrs	20 yrs	30 yrs	0 yrs	20 yrs	30 yrs
Stiffener, Main and Cheek Plate	0.05	0.06	0.07	0.31	0.31	0.33

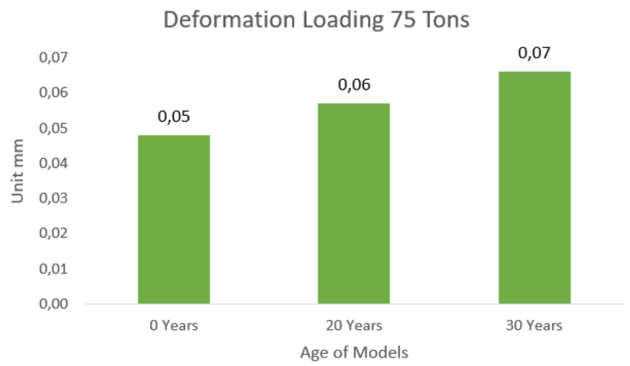

Figure 10. Deformation Diagram of Loading 75 Tons

Results of Deformation Loading 100 Tons

Figure 11 is a diagram of the deformation results at a loading of 100 tons. This diagram is a comparison of the deformation results of the 3 geometry models, namely 0 year geometry, 20 year geometry, and 30 year geometry with a loading of 100 Tons, with the deformation results obtained at this 100 Ton loading of 0.06 mm for 0 year geometry, 0.08 mm for 0 year geometry 20 years, and 0.09 mm for the 30 years geometry, with the largest value obtained in the 30 year geometry model where the reduced size or dimensions of the model can result in greater deformation values. With the deformation value obtained is used to evaluate the reliability of the structure in the face of a given load,

Table 7. Deformation Loading 100 Tons

Part	Deformation(mm)			UC		
	0 yrs	20 yrs	30 yrs	0 yrs	20 yrs	30 yrs
Stiffener, Main and Cheek Plate	0.06	0.08	0.09	0.41	0.41	0.44

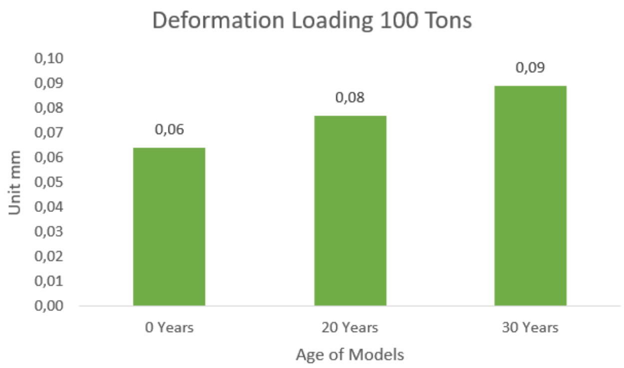

Figure 11. Deformation Diagram of Loading 100 Tons

Result of Loading Deformation 125 Tons

Figure 12 is a diagram of the deformation results at a loading of 125 tons. This diagram is a comparison of the deformation results of 3 geometry models, namely 0 year geometry, 20 year geometry, and 30 year geometry with a loading of 125 Tons, with the deformation results obtained at this 125 Ton loading of 0.08 mm for 0 year geometry, 0.10 mm for 0.10 mm geometry 20 years, and 0.11 mm for the 30 years geometry, with the largest value obtained in the 30 year geometry model where the reduced size or dimensions of the model can produce a larger deformation value. With the deformation value obtained is used to evaluate the reliability of the structure in the face of a given load,

Table 8. Deformation Loading 125 Tons

Part	Deformation(mm)			UC (Utilization Coefficient)		
	0 yrs	20 yrs	30 yrs	0 yrs	20 yrs	30 yrs
Stiffener, Main and Cheek Plate	0.08	0.10	0.11	0.51	0.51	0.55

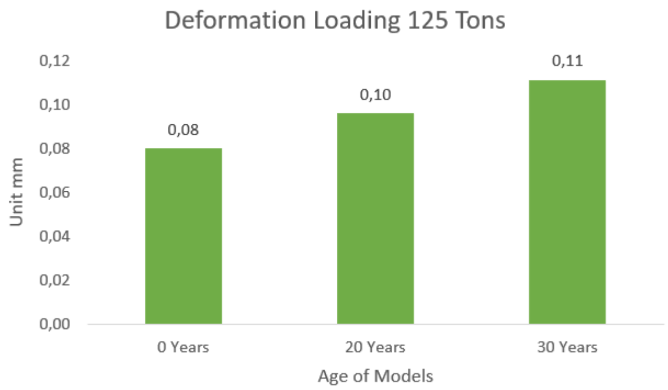

Figure 12. Deformation Diagram of Loading 125 Tons

CONCLUSION

This study uses 3 types of structural models, namely the 0 year geometry model, the 20 year geometry model, and the 30 year after geometry model, and each structural model uses 3 tested loads, namely 75, 100, and 125 Tons, with that the values obtained von-mises stress with a load of 75 Tons of 53.4, 53.5, and 58 MPa, with a load of 100 Tons of 71.2, 71.3, and 77.7 MPa, and with a load of 125 Tons of 89, 89.2, and 97.1 MPa for each geometry model 0 years, 20 years, and 30 years, with the results of the von-mises stress values of each model with the loads tested still meeting the criteria because there is no value that exceeds the allowable stress value of 175 MPa, the yoke structure is still safe to use until the age of 30 years. Obtained deformation values of each model with a tested load of 75, 100, and 125 tons. Deformation with a load of 75 Tons obtained values of 0.05, 0.06, and 0.07 mm, with a load of 100 Tons obtained values of 0.06, 0.08, and 0.09 mm, with a load of 125 Tons obtained values of 0.08, 0.10, and 0.11 mm for each 0-year geometry model, 20 years, and 30 years, the large deformation values obtained still meet safe standards because they do not exceed the plate thickness.

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