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Fpso Motion Analysis (Floating Production Storage And Offloading) Using Mooring Radius Variations Based On Time Domain Simulation

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Abstract

Along with the development of technology, oil and gas exploration has begun to be carried out in the deep sea. One technology that can be used is FPSO (Floating Production Storage and Offloading). In order for the FPSO to be damped due to environmental loads during the production process, a mooring system is needed that meets standards according to the needs and environmental characteristics of the oil field. The mooring system used is a spread mooring system whichis limited to 12 mooring lines. The research uses variations in the mooring line radius so that the length of the mooring line and the anchor position are different. This research is intended to analyze the effect of the mooring line radius on FPSO movement and the tension of the mooring line itself using a numerical approach with ANSYS AQWA software. From this study it can be seen that by increasing the length of the mooring line there will be a reduction in maximum tension on the mooring line, but the opposite is true there is an additional offset to the ship's movement. However, becausethe anchor position is further away in each radius, the tension value on the mooring line does not have a significant difference

Keyword: FPSO, Tension, Mooring line

1. INTRODUCTION

Looking at the last few years, the price of petroleum has always increased every year. This is directly proportional to the high birth rate which causes the human population to increase. Therefore, this requires a large supply of petroleum. Along with the development of technology, oil and gas exploration is starting to be carried out in the deep sea. Therefore, supporting technology is needed in the form of offshore building construction that can carry out oil and gas exploration in these situations. From that

There are many existing technologies, namely FPSO. FPSO is a construction that functions to carry out the drilling process and then produce oil and gas which is placed in oil and gas fields off the coast.

FPSO is a type of floating building that has a large size, because of its size, environmental loads (currents, wind and waves) around the FPSO can influence the movement of the FPSO during the production process. To keep the FPSO position stable and reduce dynamic forces, a restraining system is needed, namely a mooring system. The forces that arise in the installation system are very dependent on the motion characteristics of the FPSO and vice versa.

In analyzing moorings for FPSO (Floating Production Storage and Offloading), many factors need to be considered so that the mooring system can meet regulatory and safety standards. In this research, we will discuss the ideal length for a spread type mooring system and the number of mooring lines is limited to 12 spread mooring lines. In this analysis, the variations used are variations in the radius of the mooring line, so that the length of the mooring line and the location of the anchor are also different to see how the length of the mooring line and the location of the anchor affect the tension of each mooring line and its impact on the movement of the FPSO when moored at place and accept marine environmental loads (waves, wind, currents) with comprehensive dynamic analysis using time domain methods.

2. METHOD

This research was carried out by taking references from literature, text books and previously published research experiences.

2.1. Ship Data

The research was carried out by reviewing literature and supporting FPSO data. From these references, the FPSO design was made by validating the actual size. This is the FPSO design measurement data that will be used in the analysis.

Table 1. Data Geometry FPSO ALVHEIM

Item	Unit	Mark
LoA	m	285
LBP	m	274,09
Displacement	ton	210048
Breadth	m	63
Depth	m	16,93
Draught	m	13
Coefficient Block		0.884

For more details, the three-dimensional model that the author has created can be seen in Figure 1 below.

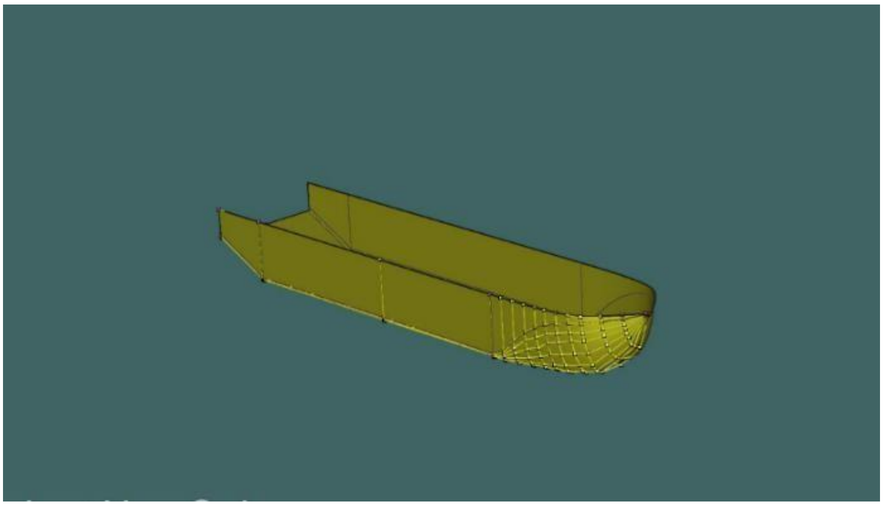

Figure 1. 3D FPSO model on maxsurf

2.2. Mooring Line Data

Analyzing the FPSO motion response using Ansys AQWA, the tension range for each mooring rope was obtained. The tension range for each mooring rope is obtained from time domain analysis of the mooring system based on the FPU motion response in the direction of 0 to 180 degrees, which is caused by tension due to different rope radii, namely, 3000, 3250, 3500. The following is a picture and size data of the mooring line design that will be used for analysis.

Tabel 2. Data Mooring Line tiap radius:

Radius 3000

Mooring Properties	
Mass / Unit Length	264,5 kg/m
Outer Diameter	0,115 m
Section Length	3000 m
Stiffness, EA	1060000000 N
Maximum Tension	10300000 N

Radius 3250

Mooring Properties	
Mass / Unit Length	264,5 kg/m
Outer Diameter	0,115 m
Section Length	3250 m
Stiffness, EA	1060000000 N
Maximum Tension	10300000 N

Radius 3500

Mooring Properties	
Mass / Unit Length	264,5 kg/m
Outer Diameter	0,115 m
Section Length	3500 m
Stiffness, EA	1060000000 N
Maximum Tension	10300000 N

2.3. Operational Criteria

This voltage analysis was carried out for 100 seconds. This simulation will produce the amount of tension that appears on the mooring line as a function of time. There are also operational criteria that a floating building structure must go through so that the mooring used can be said to be safe, namely as follows:

Table 3. Safe limits of operating criteria

Kriteria	Well Production
Lateral Acceleration	1,962 m/s^2
Mean Hell Angel	2 Derajat
Max Pitch Angel	6 Derajat
Riser Stroke	4.572 -3.048

3. RESULT AND DISCUSSION

After going through the design and data processing stages, results and discussion will be obtained. The following are the results and discussion of this research:

3.1. Operator Amplitude Response Analysis

The response amplitude operator (RAO) is also known as the transfer function. According to Chakrabarti (1987), RAO is usually defined as the response amplitude per unit wave height. In calculating RAO, waves are considered regular waves. Then it is explained in the movements of surge, sway, heave, roll, pitch and yaw. The assessed angle is 00, 450, 900, 1350 and 1800. Here is the graph.

$$RAO(\omega) = \frac{\zeta_k(\omega)}{\zeta_w(\omega)}$$

Dimana :

ζ_k = Amplitudo struktur

ζ_w = Amplitudo gelombang

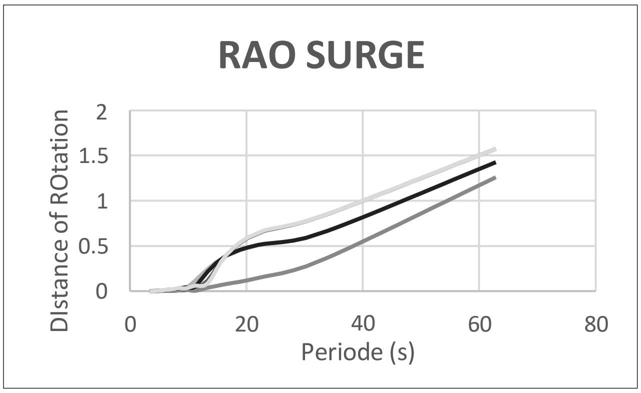

Figure 2. RAO Against the X Axis (Surge).

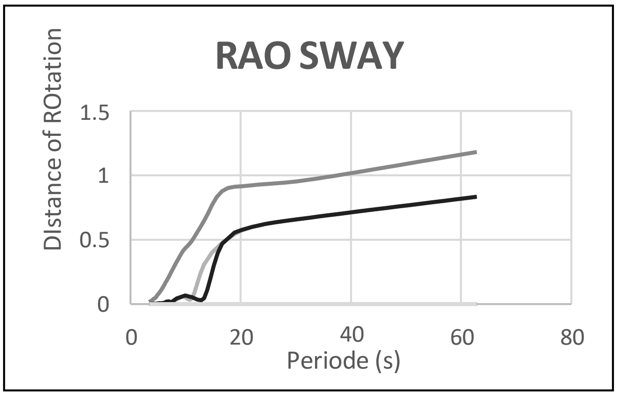

Figure 3. RAO Against the Y Axis (Sway).

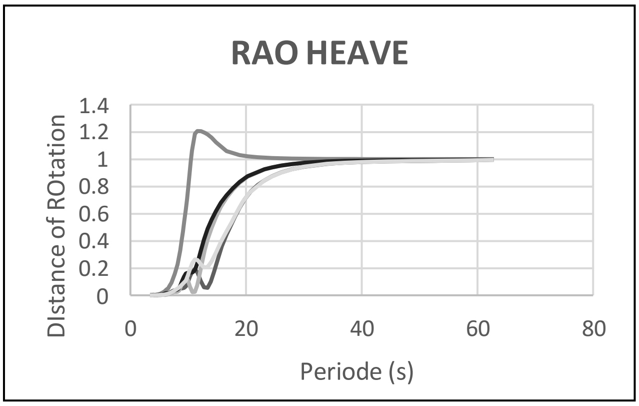

Figure 4. RAO Against the Z Axis (Heave).

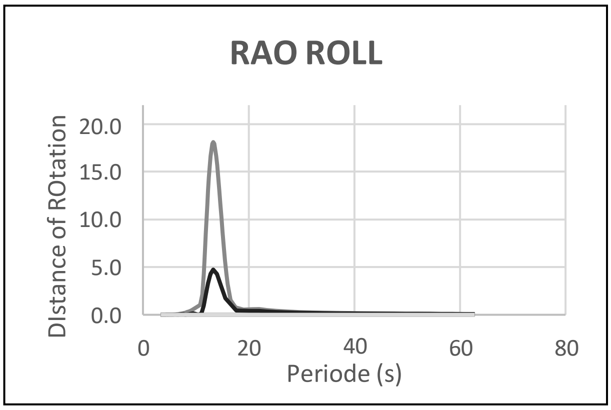

Figure 5. RAO Against RX Axis (Roll).

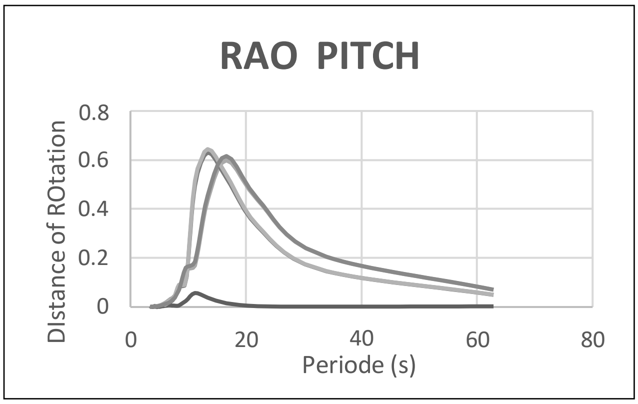

Figure 6. RAO Against the RY Axis (Pitch).

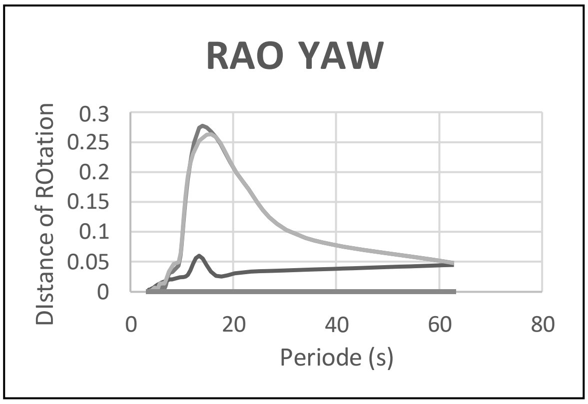

Figure 7. RAO Against the RZ Axis (Yawl).

3.2. Hydrostatic analysis of geometric characteristics

The results of the FPSO hydrostatic analysis were obtained from running Hydrodynamic Difraction using time domain simulation by looking at the values of surge, roll and pitch motion as well as displacement values and others listed below:

Aqwa Hydrostatic Results

Structure	Alvheim		
Hydrostatic Stiffness			
Centre of Gravity Position:	X: 0. m	Y: 0. m	Z: 0. m
	Z	RX	RY
Heave(Z):	1.70851e8 N/m	45.81123 N/°	21277416 N/°
Roll(RX):	2624.79 N.m/m	7.22935e8 N.m/°	236.28795 N.m/°
Pitch(RY):	1.21911e9 N.m/m	236.28795 N.m/°	1.8261e10 N.m/°
Hydrostatic Displacement Properties			
Actual Volumetric Displacement:	204877.61 m³		
Equivalent Volumetric Displacement:	204924.88 m³		
Centre of Buoyancy Position:	X: -5.2433958 m	Y: -2.6853e-4 m	Z: -6.2294173 m
Out of Balance Forces/Weight:	FX: -2.9579e-3	FY: -3.2409e-8	FZ: -2.3222e-4
Out of Balance Moments/Weight:	MX: -2.6642e-4 m	MY: 5.2508621 m	MZ: 1.1741e-6 m
Cut Water Plane Properties			
Cut Water Plane Area:	16997.021 m²		
Centre of Floatation:	X:-7.1354957 m	Y: 1.5363e-5 m	
Principal 2nd Moment of Area:	X: 5397028. m^4	Y: 1.04501e8 m^4	
Angle Principal Axis makes with X(FRA):	-1.7106e-5 °		
Small Angle Stability Parameters			
C.O.G. to C.O.B.(BG):	6.2294173 m		
Metacentric Heights (GMX/GMY):	20.113276 m	503.83841 m	
COB to Metacentre (BMX/BMY):	26.342693 m	510.06784 m	
Restoring Moments/Degree Rotations (MX/MY):	12617594 N.m/°	3.16071e8 N.m/°	

3.3. Lateral Acceleration

By using 3 types of mooring radius we can see that the FPSO movement value on the X axis (surge) does not exceed the criteria, namely 1,962 m/s^2

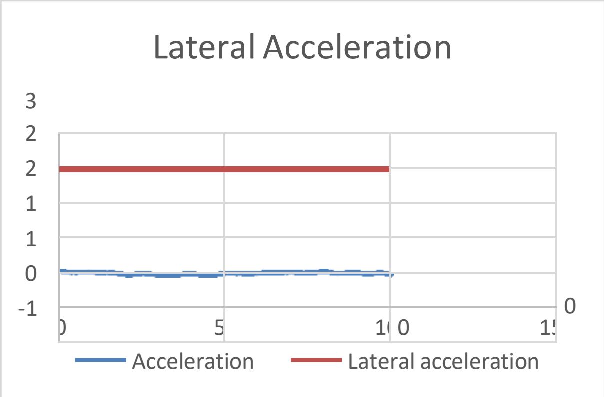

Figure 8. Lateral acceleration pada radius 3000.

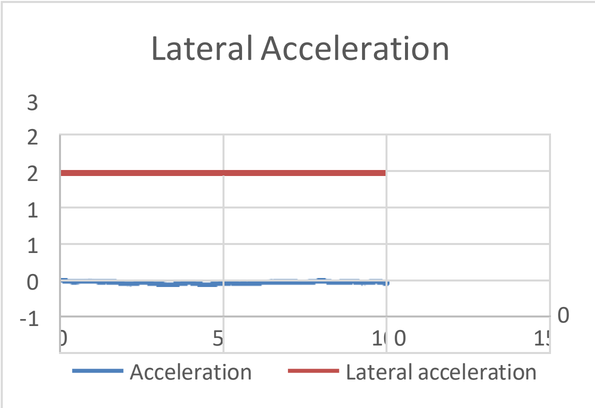

Figure 9. Lateral acceleration pada radius 3250.

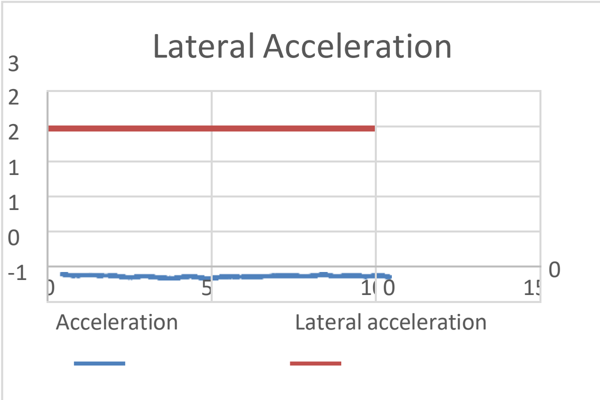

Figure 10. Lateral acceleration pada radius 3500.

3.4. Mean Heel Angle

This graph shows the movement of the structure on the RX (Roll) axis using 3 types of mooring radius. From the analysis results, it can be seen that the value does not exceed the tolerance limit of the criteria, namely 2 degrees.

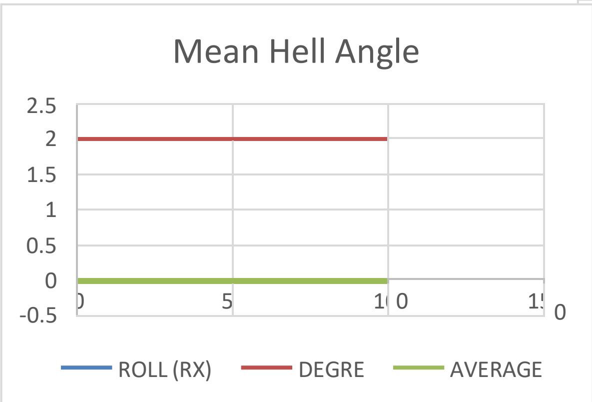

Figure 11. Mean Hell Angle pada radius 3000.

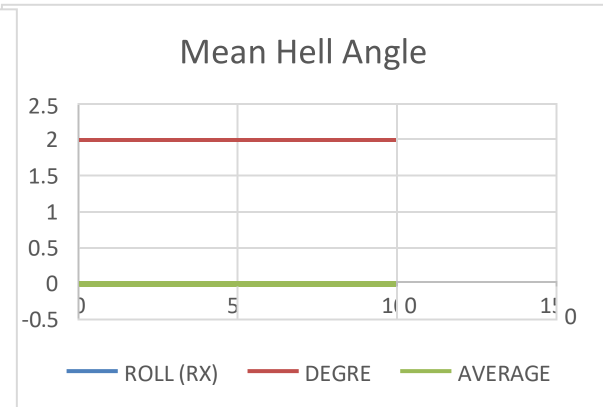

Figure 12. Mean Hell Angle pada radius 3250

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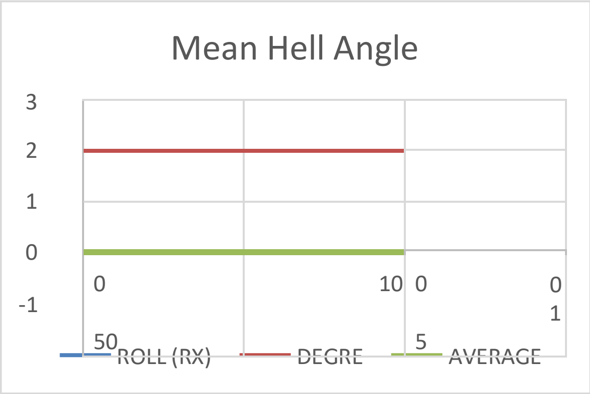
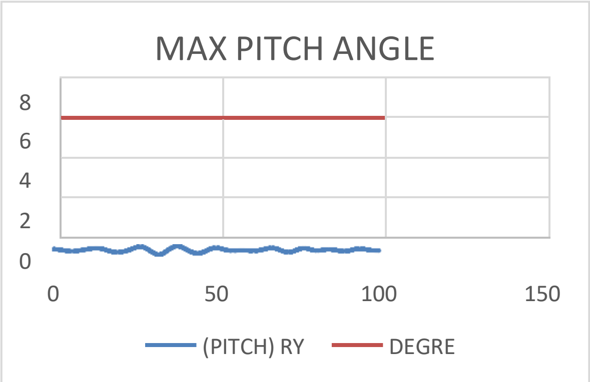


Figure 13. Mean Hell Angle pada radius 3500

3.5. Max Pitch Angel

This graph shows the movement of the structure on the RY (Pitch) axis using 3 types of mooring radius. From the analysis results, it can be seen that the value does not exceed the tolerance limit of the criteria, namely 6 degrees.



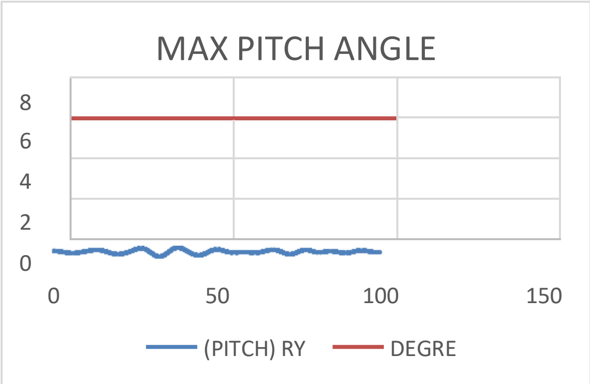


Figure 14. Max Pitch Angle at radius 3000.

Figure 15. Max Pitch Angle at radius 3250.

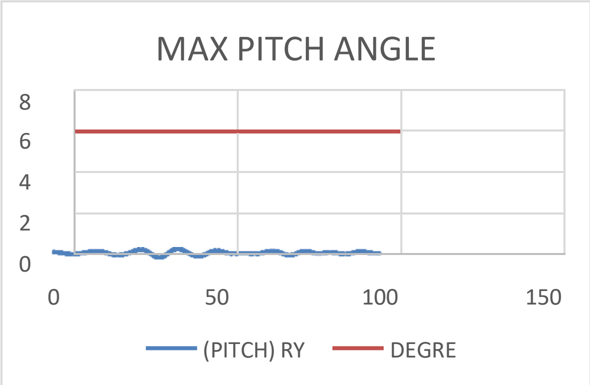


Figure 16. Max Pitch Angle at radius 3500.

3.6. Riser Stroke

By using 3 types of mooring radius we can see that the FPSO movement value on the Z axis (Heave) does not exceed the criteria, namely the upper limit of 15 meters and the lower limit of -10 meters

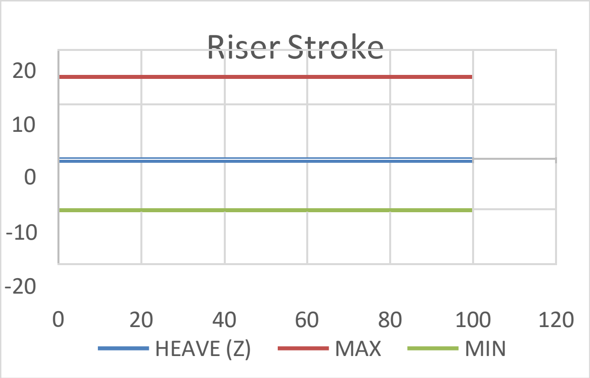


Figure 17. Rising Storke at radius 3000.

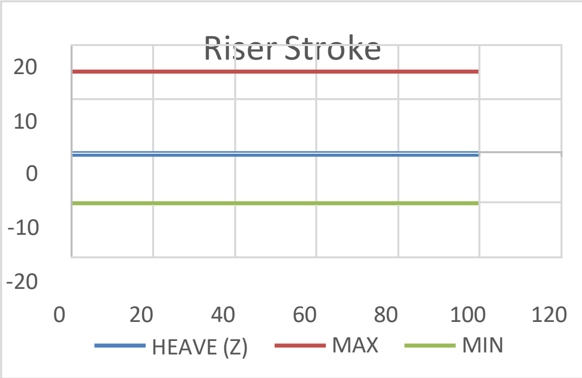


Figure 18. Rising Storke at radius 3250.

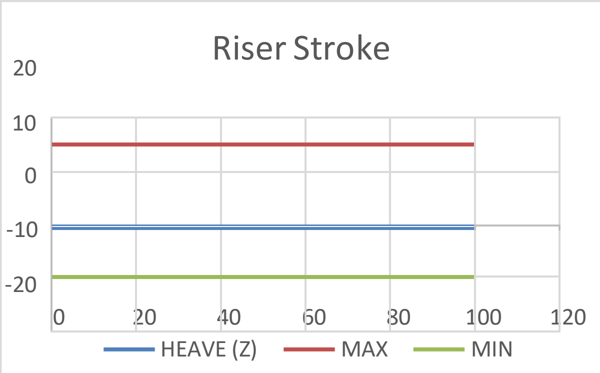


Figure 19. Rising Storke at radius 3500

3.7. Tegangan Gaya Kabel

Mooring ropes that experience maximum tension have a minimum safety factor. It should be noted that the higher the tension value that appears compared to the limit value of tension capacity (breaking strength) of the mooring rope received, the more easily the mooring rope will break. In the time domain, the analysis is performed in 100 seconds. The ULS condition is a load that occurs in operating conditions, where the mooring ropes that function as a mooring system on FPSO vessels operate optimally, intact, with no broken mooring ropes. Based on the results of historical data processing which contains the tension that appears every second, it can be seen that the tension value is important for each mooring rope.

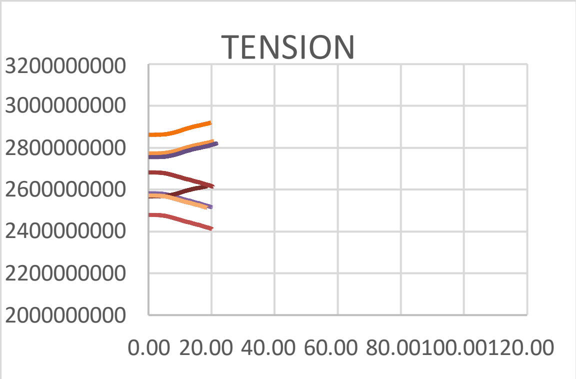


Figure 20. Tension at radius 3000.

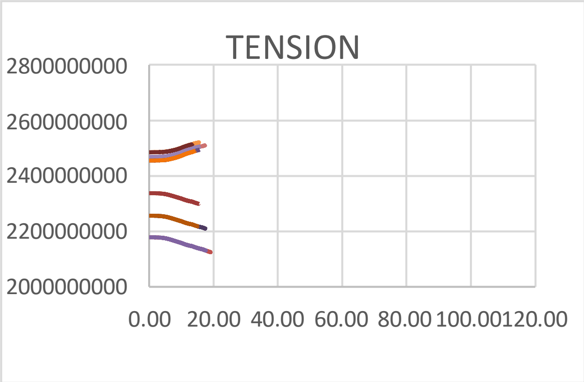


Figure 21. Tension at radius 3250.

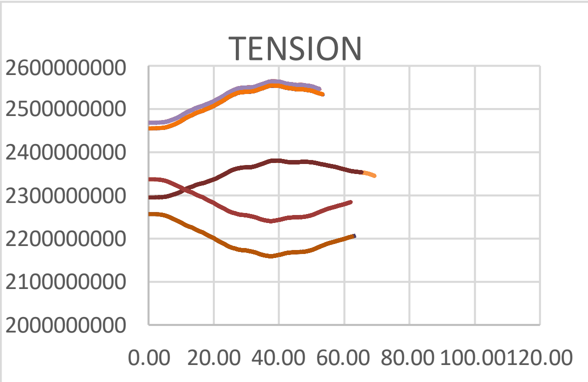


Figure 22. Tension at radius 3500.

4. CONCLUSION

Based on the results of the analysis in the discussion section, the author draws several conclusions including:

1) The spread mooring model with the first variation with a radius of 3000 has the largest tension value, namely 2968293 kN. The spread mooring model with the second variation with a radius of 3250 has the largest tension value, namely 2577983 KN. The spread mooring model with the third variation with a radius of 3250 has the largest tension value, namely 2564024 kN

2) Of the three models that use 3 different radii, all meet the specified criteria

3) The farther the radius from the mooring line, the smaller the value for the mooring line tension. This is due to the longer length of the rope. Although the difference in stress values is not very significant, this is the result of changes in the anchor point with each change of radius

4) Of the three spread mooring designs analyzed, the third design is the optimal design in terms of operational probability because the ship's movement is not significant when exposed to environmental loads.

5) Among the three mooring models analyzed, the third model is the optimal model in terms of operating probability because the ship's movement is smaller when exposed to environmental loads, but from an economic perspective more costs will have to be incurred due to the increase in rope length.

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