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Comparison Of Mooring Line Length Against Fpso Ship Movement Characteristics Using Numerical Analysis

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Abstract

In analyzing moorings for FPSO (Floating Production Storage and Offloading), many things must be considered so that the mooring system can meet operability and safety standards. In this paper, we will discuss the stability of FPSO ships with varying mooring line lengths for FPSO ships with a capacity of 170218 DWT which will later be converted. The number of mooring ropes is limited to 4 with mooring rope lengths of 3100, 3200, 3300 m respectively. Variations in the length of the mooring line to clearly see the extent of the influence of changes in the length of the mooring line on the tension of each mooring line and the movement offset of the FPSO when moored and subjected to marine environmental loads (waves, wind, currents) using full dynamic analysis with the time method domain. From this study it can be seen that by increasing the length of the mooring line there will be a reduction in the maximum tension on the mooring line, but on the contrary there will be an increase in the offset of the ship's movement.

Keywords: FPSO, Mooring, Mooring line, Mooring tension

1. INTRODUCTION

The development of science and technological progress as well as the depletion of oil reserves on land means that the gas export area is increasingly expanding to reach deep waters. To deal with deeper water environments, the Floating Offshore that will be operated is a type that is considered cost-effective, such as a floating platform. Offshore platforms for floating offshore structures include TLP platforms, semi-submersible platforms, FPS, and SPAR platforms. One type of facility used in offshore mining is a floating production unit or FPU which is used as the initial unit for the natural gas or hydrocarbon production process which will then be distributed to refineries on land via undersea or oil pipelines. With resource exploitation reaching deep waters, floating structures combined with efficient and reliable mooring systems are becoming increasingly popular. Mooring systems are increasingly facing many challenges to ensure the reliability and safe operation of offshore platforms. In this case, the mooring system is an important element of the platform maintenance system developed for the exploration and production of offshore oil and gas resources. There are three types of arrangements for dispersed mooring systems, called anchor moorings, catenary moorings, and floating catenary moorings. Commonly used mooring ropes are heavy chains, steel cables and/or synthetic polyester ropes tied to anchors on the seabed. In this research, the focus will be on determining variations in mooring rope length. In theory, increasing the length of the mooring rope will cause a decrease in the maximum tension on the mooring rope, but on the contrary there will be an increase in ship movement [2].

Figure 1. FPSO Berge Helena

2. METHOD

The research was carried out using literature study methods and a numerical method approach using ANSYS AQWA software. This analysis was carried out to find out how the mooring line and the movement of the FPSO ship respond to the length of the mooring line. There are 3 variations in the length of the mooring line used in this research, namely 3100 meters, 3200 meters and 3300 meters. This model uses 4 mooring ropes with different rope lengths.
The tolerance limits given to the movement of floating structures are as follows:

Table 1. Criteria for tolerance of movement of floating structures.

Criteria	Well Production
Mean Hell Angel (deg)	2
Mean Roll Angel (deg)	2
Max Pitch (deg)	6
Lateral Acceleration (m/s^2)	0.20 x g =1.962
Surge Acceleration (m/s^2)	0.20 x g =1.962
Riser Stroke	+15 -10

The dimensions of the ship used are the Berge Helena ship, which is an FPSO type with dimensions:

Main Dimension		
LOA	:	250 m
B	:	46 m
H	:	24.6 m
T	:	16.5 m

The marine characteristics data used is environmental data from the Masela Block, namely:

Masela Block Environmental Data		
Wind	: 16.91	m/s
Current	: 0.5	m/s
Wave	: 2.5	m

The mooring lines are used in 3 rope length variations, namely:

Studless R4	
Mass / Unit Length	: 438.90 kg/m
Equivalent Diameter	: 0.1588 m
Section Length	: 140.208 m
Stiffness	: 1842397000 N
Maximum Tension	: 19563000 N

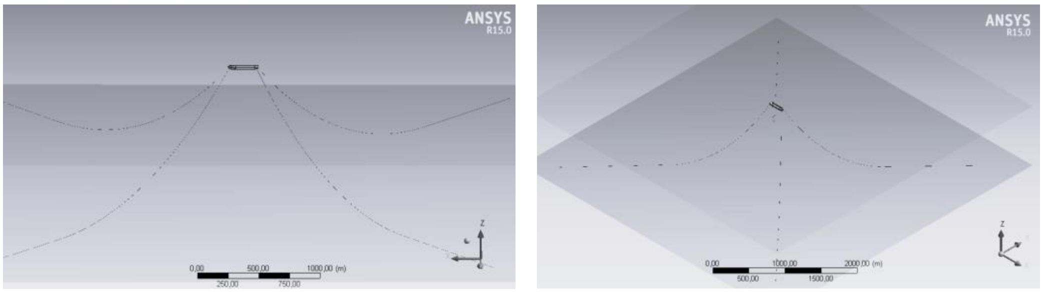


Figure 2. Mooring line configuration on FPSO

3. RESULT ANDA DISCUSSION

Response amplitude operator (RAO)

RAO) is a mathematical function to determine the results and response by floating production based on its amplitude as a result of wave excitation loads with a certain frequency range/period. RAO is information about the movement characteristics of the floating production building relative to the operator function wave. The RAO translational movement response is a direct comparison between the amplitude of the movement compared to the amplitude of the incident wave [3].

$$\text{RAO} = \left(\frac{amplitudorespongerakan}{amplitudogelombang}\right)^2 = \left(\frac{\emptyset_a}{S_\zeta}\right)^2$$

When :
Φa : Movement response amplitude [m] atau [deg]
ζa : Wave amplitude [m]

The following are the RAO values obtained from the Ansys AQWA software with loading directions at angles of 0 degrees, 45 degrees, 90 degrees, 135 degrees and 180 degrees, with respect to six degrees of freedom (Six Degrees of Freedom) including Surge (X), Sway (Y), Heave (Z), Roll (RX), Pitch (RY), and Yaw (RZ).

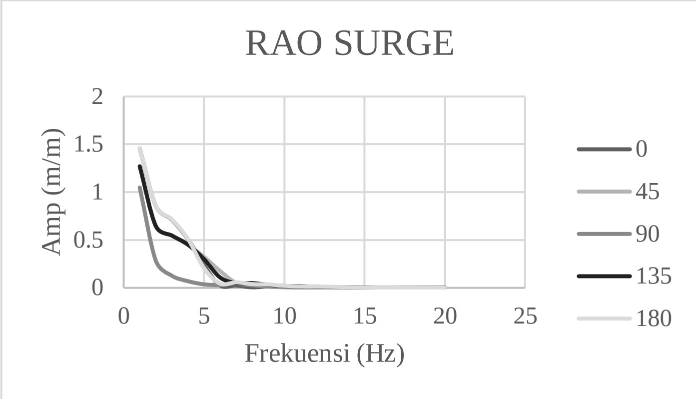


Figure 3. RAO on the X Axis (Surge)

The response graph of motion surge (X) with free floating conditions shows that at 180 degrees it experiences the largest significant value, namely 1.45 m/m, while the smallest value occurs at 90 degrees.

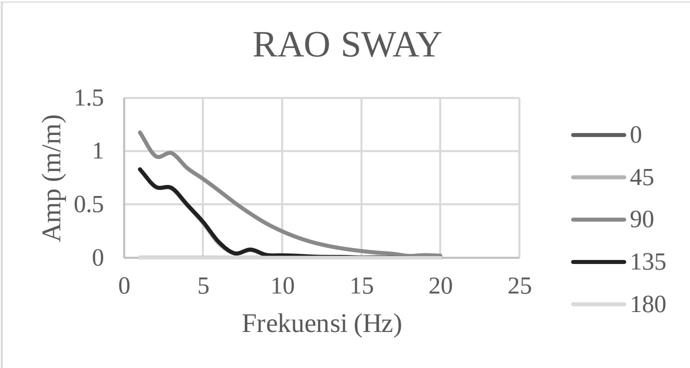


Figure 4. RAO on the Y Axis (Sway)

The response graph of motion sway (Y) with free floating conditions shows that at 90 degrees it experiences the largest significant value, namely 1.17 m/m, while the smallest value occurs at 135 degrees.

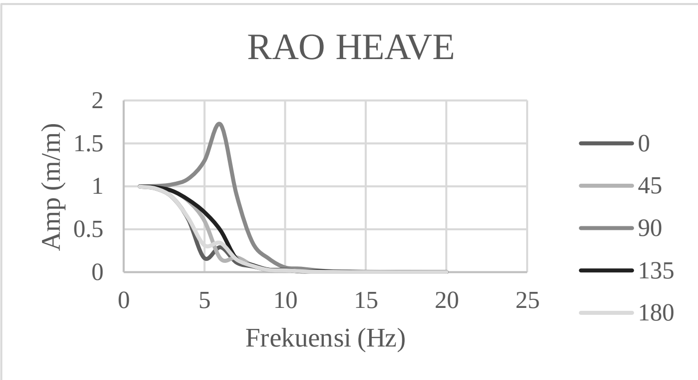


Figure 5. RAO Against the Z Axis (Heave)

Grafik respon dari motion heave (Z) dengan kondisi free floating menujukan pada derajat 90 mengalami nilai signifikan terbesar yakni 1,72 m/m sedangkan nilai terkecil terjadi pada derajat 0.

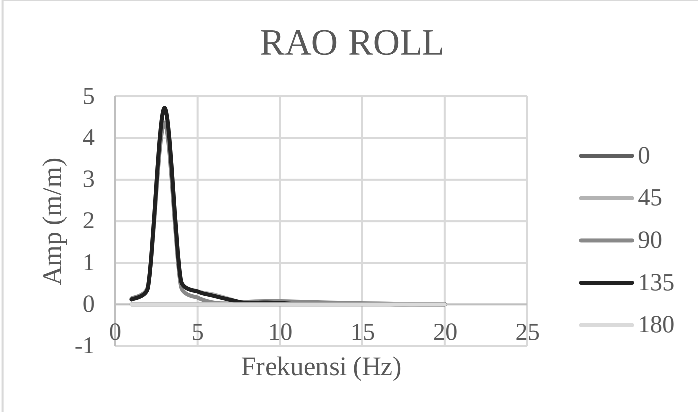


Figure 6. RAO Against the RX Axis (Roll)

The response graph of motion roll (RX) in free floating conditions shows that at 135 degrees it experienced the largest significant value, namely 4.71 m/m, while the smallest value occurred at 180 degrees.

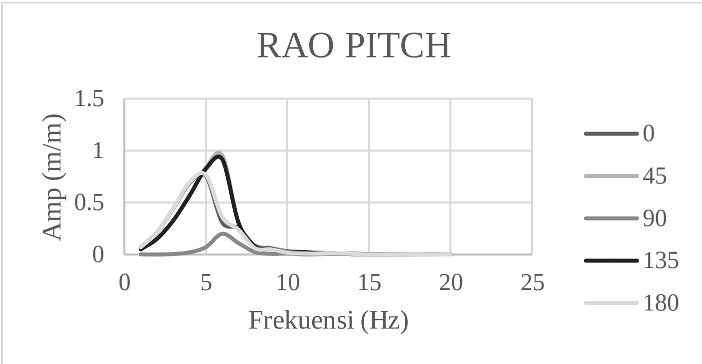


Figure 7. RAO to the RY Axis (Pitch)

The graph of the motion pitch (RY) response in free floating conditions shows that at 45 degrees it experiences the largest significant value, namely 0.95 m/m, while the smallest value occurs at 90 degrees..

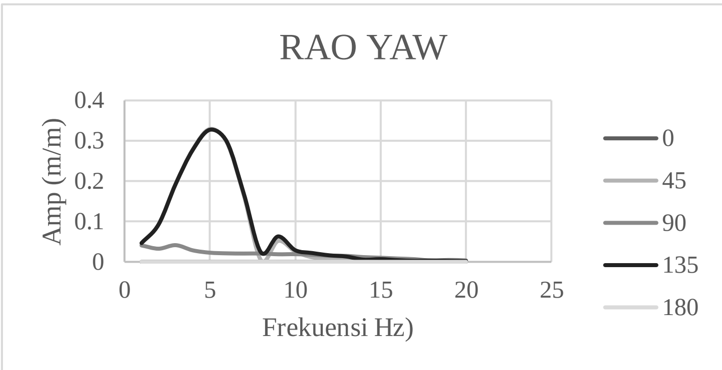


Figure 8. RAO to the RZ (Yaw) Axis

The motion sway (XZ) response graph with free floating conditions shows that at 45 degrees it experiences the largest significant value, namely 0.32 m/m, while the smallest value occurs at 90 degrees.
The graph above is the value of the Response Amplitude Operator (RAO) at each of the 6 degrees of freedom obtained using the Ansys AQWA software. From the graph above, we can see how the structure's movement responds to environmental loads in the Masela Block, various degrees of freedom axes with loading directions originating from angles of 0 degrees, 45 degrees, 90 degrees, 135 degrees and 180 degrees.

Surge Acceleration

Surge acceleration is the movement of a floating structure about the x-axis due to environmental loads. The criteria that have been determined for surge acceleration are 0.2 x 9.81 = 1,962 m/s^2. So we get graphs for 3 variations in mooring rope length, namely: 3100, 3200, and 3300 for 100 s.

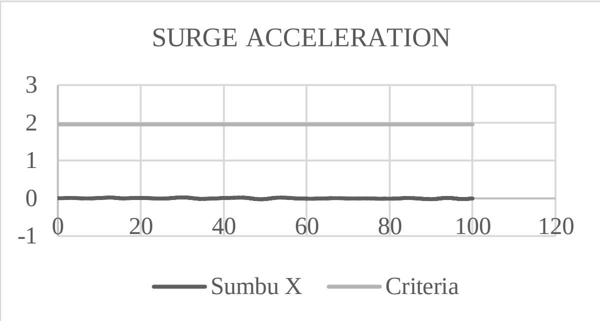


Figure 9. Surge on a string length of 3300

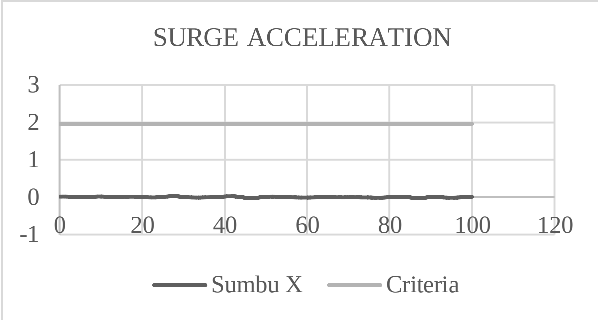


Figure 10. Surge on a string length of 3200

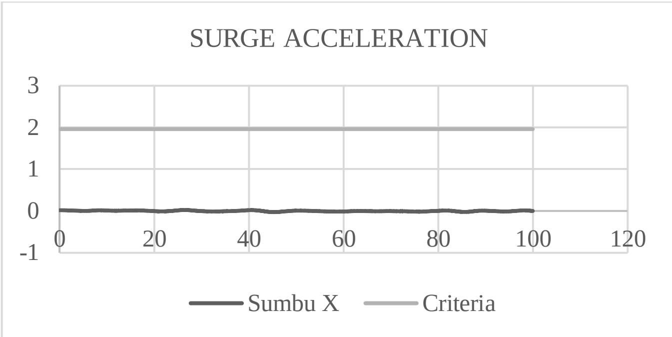


Figure 11. Surge on a string length of 3100

Based on the results obtained above, it can be seen how the FPSO ship moves about the X axis after being moored with various mooring line lengths.

Max Pitch Angel

Max pitch angel is the movement of a floating structure about the RY axis due to external forces, the criteria that has been set is 6 degrees. The following is a graph obtained from Ansys AQWA modeling of 3 variations in mooring line length, namely 3100, 3200, and 3300 for 100 s.

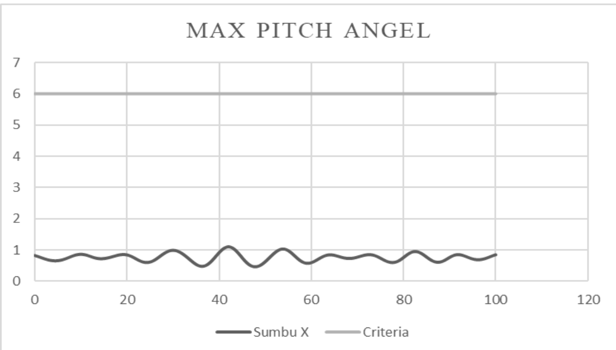


Figure 12. Max Pitch on a string length of 3300

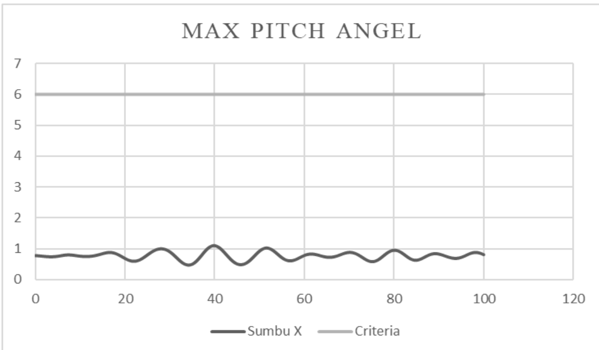


Figure 13. Max Pitch on a string length of 3200

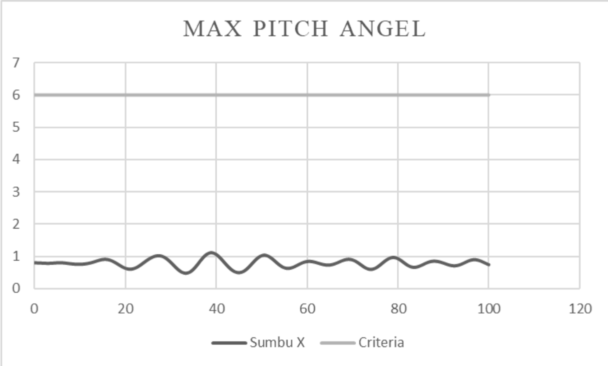
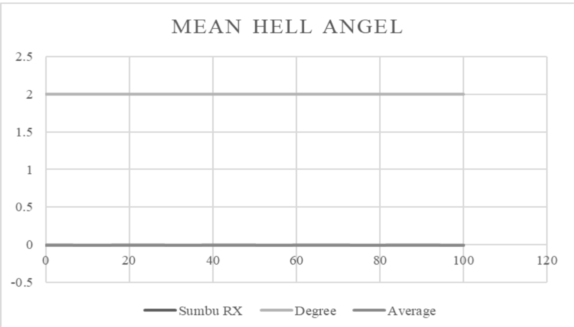


Figure 14. Max Pitch at string length 3100

Based on the results obtained above, it can be seen how the floating structure responds to the RY axis after being moored with various variations in the length of the mooring line.

Mean Hell Angel

Mean Hell angel is the movement of the floating structure regarding the RX axis (roll motion) caused by environmental loads, while the criteria that has been set is 2 degrees. The following is a graph obtained for 3 variations in the length of the mooring rope, namely 3100, 3200, and 3300 for 100 s.



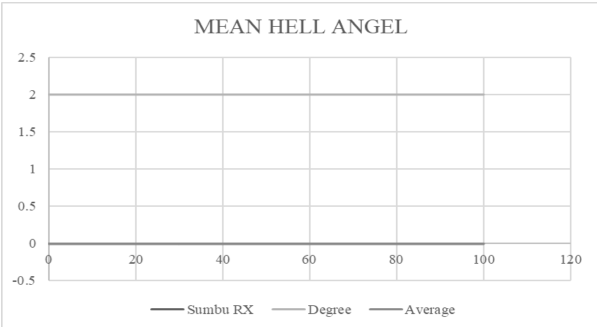


Figure 15. Mean Hell Angel at a rope length of 3300 Figure 16. Mean Hell Angel at a rope length of 3200

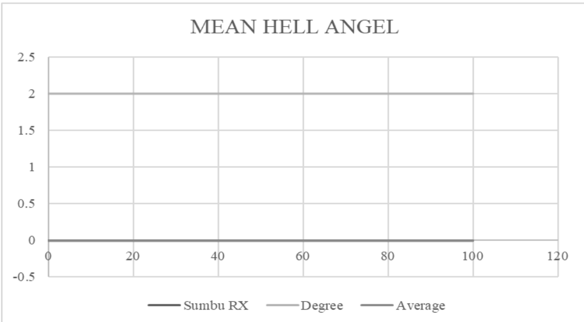


Figure 17. Mean Hell Angel at 3100 rope length

Based on the results obtained above, it can be seen how the structure moves in response to the RX axis (roll motion) after being moored with 3 variations in the length of the mooring line.

Riser Stroke

Riser stroke is the movement of a floating structure towards the z axis (heave motion) due to environmental loads. The criteria that have been determined for riser stroke are an upper limit of 15 and a lower limit of -10. The graphs obtained for 3 variations of mooring length, namely 3100, 3200, and 3300 for 100s are as follows.

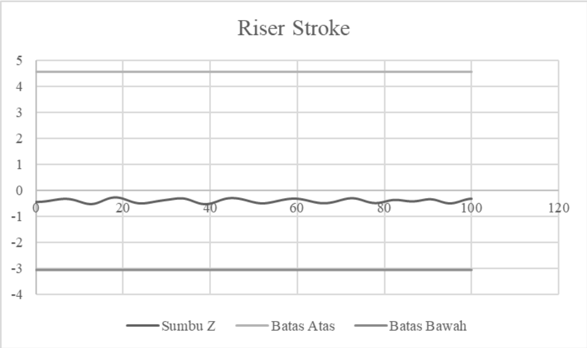


Figure 18. Riser Stroke on a string length of 3300

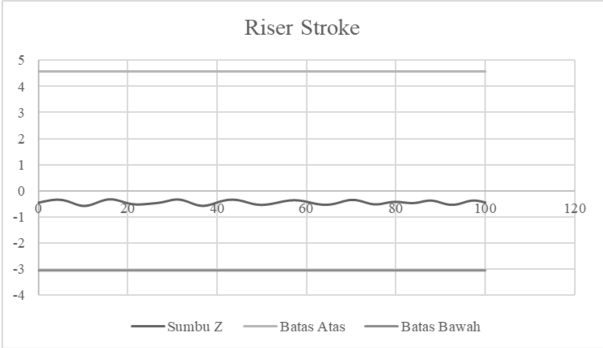


Figure 19. Riser Stroke on a string length of 3200

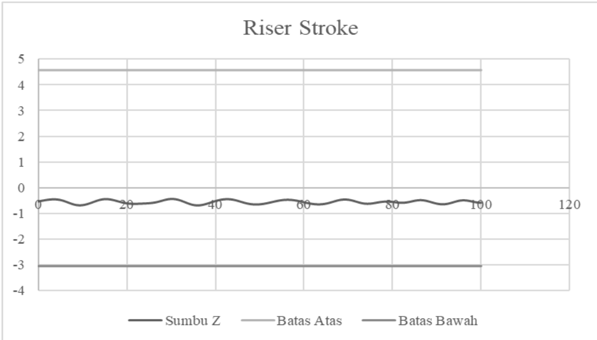


Figure 20. Riser Stroke on rope length 3100

Based on the results obtained above, it can be seen how the FPSO ship moves about the Z axis after being moored with various mooring line length variations.

Mooring Line Tension

Mooring line tension is the tension of the mooring lines which is very important to know how much pressure each mooring line receives. By knowing the tension of each mooring line we can find out how long the mooring line can last so that we can maximize the life of the mooring technology. The following is the mooring line tension obtained for each variation of mooring line length with a time span of 100s using Ansys AQWA software.

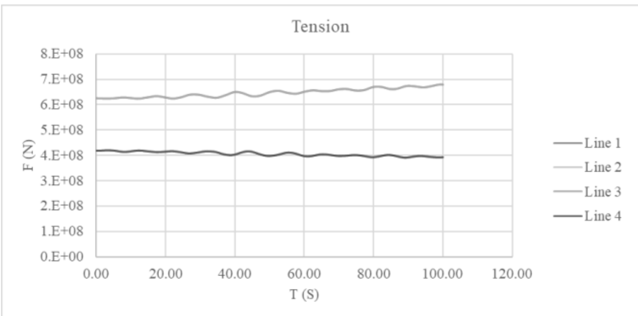


Figure 21. Tension on the length of the rope 3300

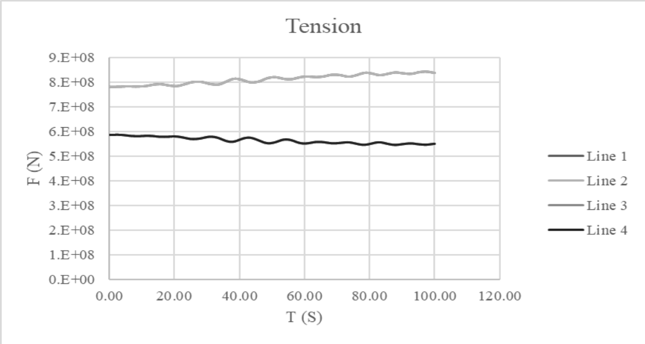


Figure 22. Tension on the length of the rope 3200

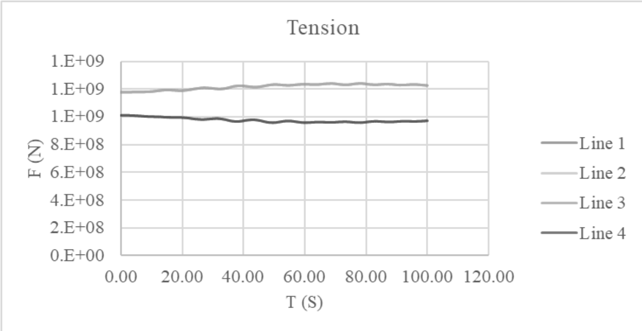


Figure 23. Tension on the length of the rope 3100

The results of the analysis of the third variation with a rope length of 3100 showed that the largest tension value occurred in line 2.
Tension analysis was carried out using 3 mooring line variation designs, namely (1) First model, with a rope length of 3300 using R4 Studless material with a diameter of 0.1588 m. (2) The second model, with a length of 3200, uses R4 Studless material with a diameter of 0.1588 m. (3) The third model, with a length of 3100, uses R4 Studless material with a diameter of 0.1588 m. Based on the analysis that has been carried out on the three designs for variations in the mooring system configuration, the maximum tension occurs in the mooring line 3 design with a rope length of 3100.

4. CONCLUSION

When designing a mooring system, the thing that needs to be considered is referring to the capability and capacity of the mooring rope. From the results of the analysis, it is clear that there are several ropes that have capacities below the standards permitted in the design, but from this research it appears that by increasing the length of the mooring rope, there will be a reduction in the maximum tension in the mooring rope, and conversely there will be a slight increase in the offset of the ship's movement. From the study above, it appears that the length of the mooring line will influence the choice of dimensions and type of chain and wire, as well as the anchors that will be used in the mooring system [4].

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