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Effect Of Mooring Line Radius On Fpso Mooring Using A Numerical Approach

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Abstract

Floating Production Storage and Offloading (FPSO) is a floating facility in the form of a ship that is used to produce as well as a temporary storage of petroleum taken in the middle of the ocean, in its operation the FPSO is moored using mooring ropes to limit the motion of the facility. This mooring system is needed to reduce dynamic movements due to environmental loads received by the FPSO. This study was conducted to analyze the motion characteristics of FPSO that have been moored using a Spread Mooring System with a certain mooring radius and the stresses received by each mooring line using a time domain based numerical approach. The method used is a literature study and a numerical approach with the Boundary Element Method (BEM), it is concluded that the further the radius of the mooring line, the smaller the tension received by each mooring rope so that the structure becomes more stable.

Keywords : Floating Production Storage and Offloading (FPSO), Mooring Line, Tension

1. INTRODUCTION

In the world of oil and gas exploration on the high seas, the use of Floating Production Storage and Offloading (FPSO) has become one of the main solutions for producing and temporarily storing petroleum in the middle of the ocean. FPSO is a ship-shaped floating facility that plays a vital role in this industry, requiring an effective mooring system to reduce dynamic movements due to environmental loads received.

The importance of research on the influence of mooring line radius on FPSO mooring cannot be ignored. By understanding how variations in mooring line radius affect the tension in the mooring lines and the response of the FPSO structure to the surrounding environment, we can improve the efficiency, safety and operational stability of FPSOs in open waters.

In this context, this research aims to analyze the movement characteristics of FPSOs that have been moored using a spread mooring mooring system with certain radius variations. Through a numerical approach based on the Boundary Element Method (BEM), this research will provide in-depth insight into how determining the mooring line radius can influence the dynamics of the moored FPSO structure and the stress received by each mooring rope.

By deepening understanding of the influence of mooring line radius on FPSO mooring, it is hoped that this research can make a significant contribution to the development of FPSO mooring technology, improve operational safety, and expand knowledge in this field. Thus, this research has high relevance in supporting the progress of the marine and petroleum industry in the future.

Figure 1. FPSO Armada Perkasa.

2. RESEARCH METHODS

This research was carried out using the literature study method and using a numerical approach using Boundary Element Method (BEM) software. This analysis was carried out to find out how the mooring line and the movement of the FPSO ship respond to the mooring system radius. Basically, floating structures have six degrees of freedom which are divided into two groups, namely translational motion (surge: transverse direction of the X axis, sway: transversal direction of the Y axis, and heave: direction of the Z axis) and rotational motion (roll: rotation of the X axis, pitch: Y-axis rotation, and yaw: Z-axis rotation). In this study, 3 variations of mooring radius were used in this study, namely 2000 meters, 2200 meters and 2400 meters. This modeling uses 4 mooring ropes with a certain radius.
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 Heel Angle (deg)	2
Max Pitch (deg)	6
Lateral Acceleration (m/s^2)	0.20 x g =1.962
Raser Stroke	+15 -10

The dimensions of the ship used are the Armada Perkasa ship, which is an FPSO type with dimensions:

Main Dimension		
LOA	:	300 m
B	:	46.2 m
H	:	26.2 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 radius variations, namely:

#1 Mooring Data Radius 2000 m

Mass / Unit Length : 264.5 kg/m
Equivalent Diameter : 0.115 m
Section Length : 2100 m
Stiffness : 1060000000 N
Maximum Tension : 10300000

#2 Mooring Data Radius 220 m

Mass / Unit Length : 264.5 kg/m
Equivalent Diameter : 0.115 m
Section Length : 2300 m
Stiffness : 1060000000 N
Maximum Tension : 10300000

#3 Mooring Data Radius 240 m

Mass / Unit Length : 264.5 kg/m
Equivalent Diameter : 0.115 m
Section Length : 2500 m
Stiffness : 1060000000 N
Maximum Tension : 10300000

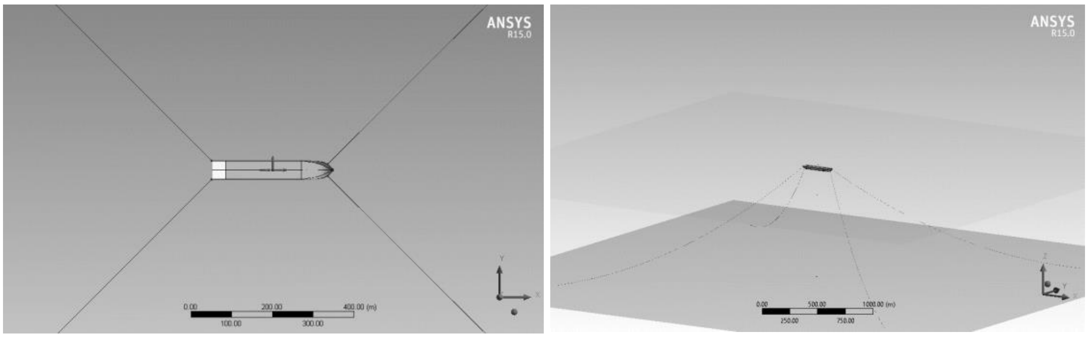


Figure 2. Mooring line configuration on FPSO.

3. RESULT AND DISCUSSION

From the data obtained above, data processing is required using Ansys AQWA software based on Boundary Element Method (BEM) to be able to find out how the structure responds to environmental loads and the response of each mooring rope to several predetermined radius variations. What will be analyzed is the response of the moored FPSO to external loads as well as the stress and tension of each mooring rope in several variations.

3.1. Response Amplitude Operator (RAO)

Response Amplitude Operator (RAO) is a function used to determine the response that a floating structure will experience due to wave forces in the frequency range hitting the structure's hull. RAO can also be interpreted as the relationship between the amplitude of the structure's response to the wave amplitude. The general form of the RAO equation in frequency functions includes:

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

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

The following are the Response Amplitude Operator 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).

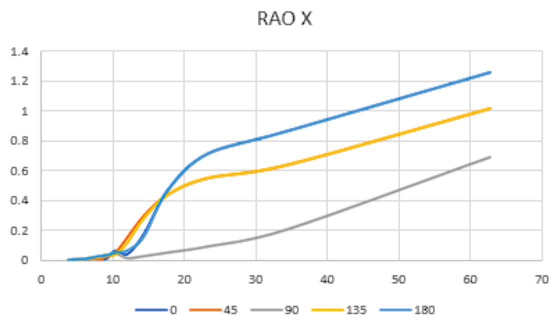


Figure 3. RAO Against the X Axis (Surge).

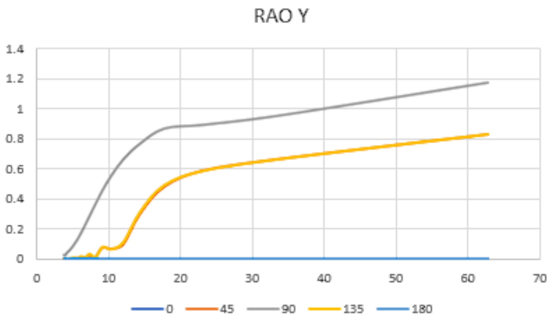


Figure 4. RAO Against the Y Axis (Sway).

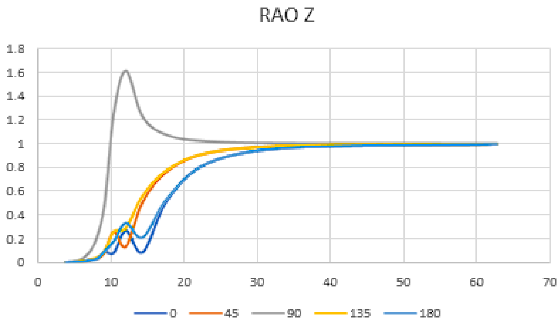


Figure 5. RAO Against the Z Axis (Heave).

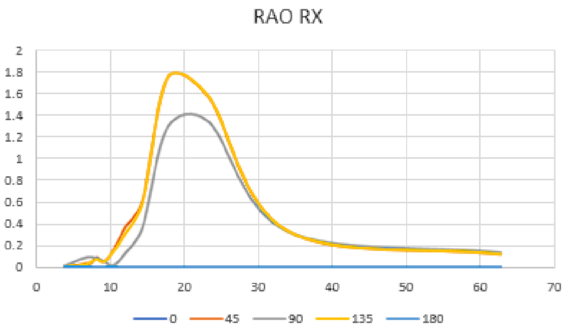


Figure 6. RAO Against RX Axis (Roll).

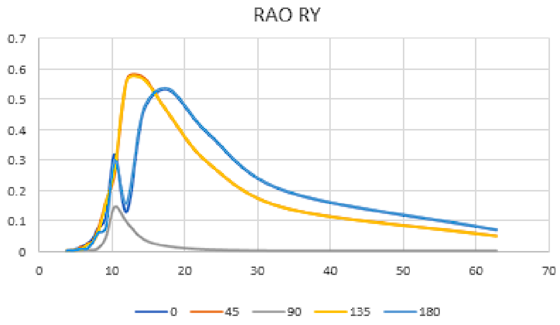


Figure 7. RAO Against the RY Axis (Pitch).

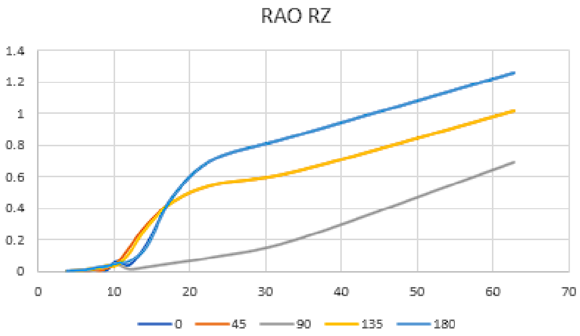
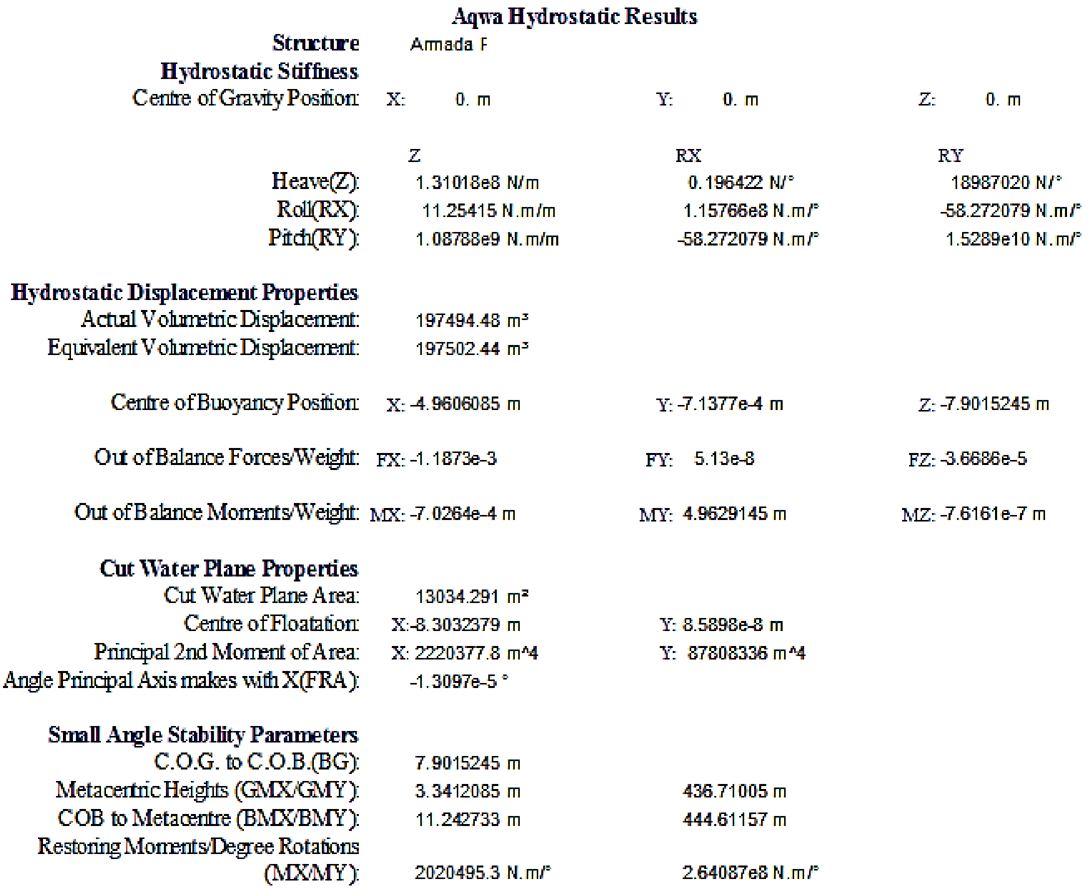


Figure 8. RAO Against the RZ (Yaw) Axis.

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.

3.2. Hydrostatic Data

Hydrostatic data is a value that shows the characteristics of a floating structure immersed in water. The calculation results obtained from the Ansys AQWA software are as follows.



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                                         Aqwa Hydrostatic Results
                          Structure      Armada F
                Hydrostatic Stiffness
           Centre of Gravity Position:  X:      0. m              Y:      0. m              Z:      0. m

                                         Z                         RX                         RY
                           Heave(Z):     1.31018e8 N/m             0.196422 N/°               18987020 N/°
                            Roll(RX):    11.25415 N.m/m            1.15766e8 N.m/°            -58.272079 N.m/°
                           Pitch(RY):    1.08788e9 N.m/m           -58.272079 N.m/°           1.5289e10 N.m/°

  Hydrostatic Displacement Properties
         Actual Volumetric Displacement:   197494.48 m³
     Equivalent Volumetric Displacement:   197502.44 m³

           Centre of Buoyancy Position:  X: -4.9606085 m            Y: -7.1377e-4 m            Z: -7.9015245 m

         Out of Balance Forces/Weight:  FX: -1.1873e-3             FY:   5.13e-8               FZ: -3.6686e-5

        Out of Balance Moments/Weight:  MX: -7.0264e-4 m           MY:  4.9629145 m            MZ: -7.6161e-7 m

            Cut Water Plane Properties
                 Cut Water Plane Area:     13034.291 m²
                  Centre of Floatation:  X:-8.3032379 m             Y: 8.5898e-8 m
           Principal 2nd Moment of Area:  X: 2220377.8 m^4          Y:  87808336 m^4
  Angle Principal Axis makes with X(FRA):  -1.3097e-5 °

       Small Angle Stability Parameters
                   C.O.G. to C.O.B.(BG):   7.9015245 m
          Metacentric Heights (GMX/GMY):   3.3412085 m              436.71005 m
         COB to Metacentre (BMX/BMY):      11.242733 m              444.61157 m
     Restoring Moments/Degree Rotations
                            (MX/MY):       2020495.3 N.m/°          2.64087e8 N.m/°
```

3.3. 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 of mooring radius, namely: 2000m radius, 2200m radius, and 2400m for 100 s.

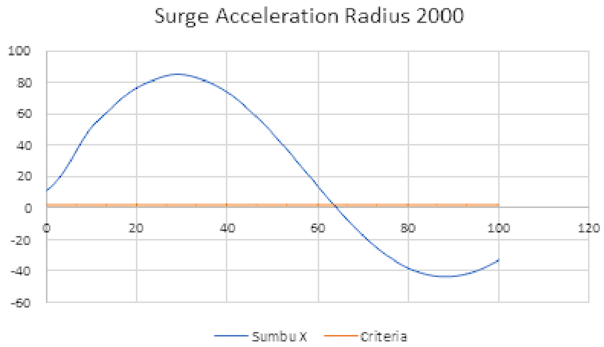

Figure 9. Surge at a mooring radius of 2000m.

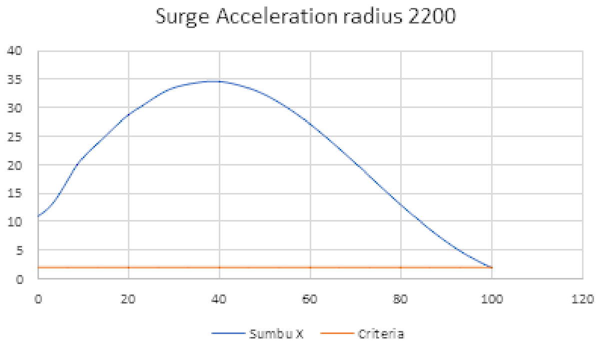

Figure 10. Surge at a mooring radius of 2200m.

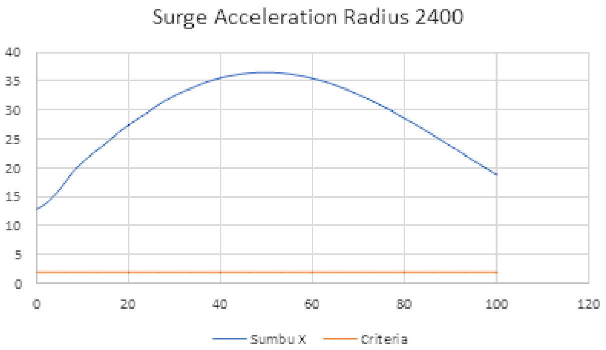

Figure 11. Surge at a mooring radius of 2400m.

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

3.4 Max Pitch Angle

Max pitch angle is the movement of the 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 of mooring radius for 100 s.

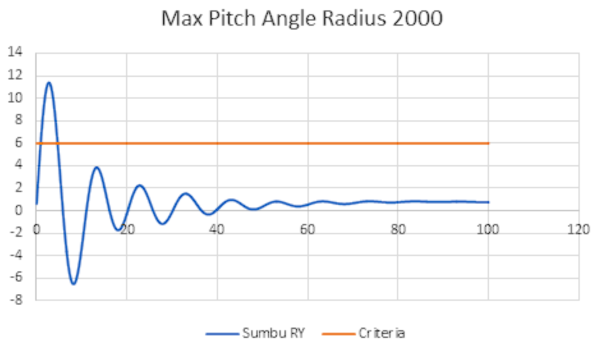

Figure 12. Max Pitch at mooring radius 2000m.

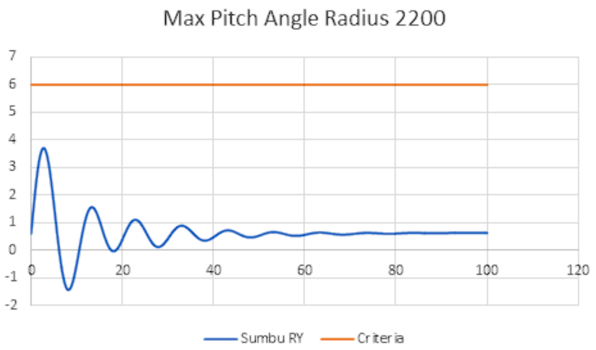

Figure 13. Max Pitch at mooring radius 2200m

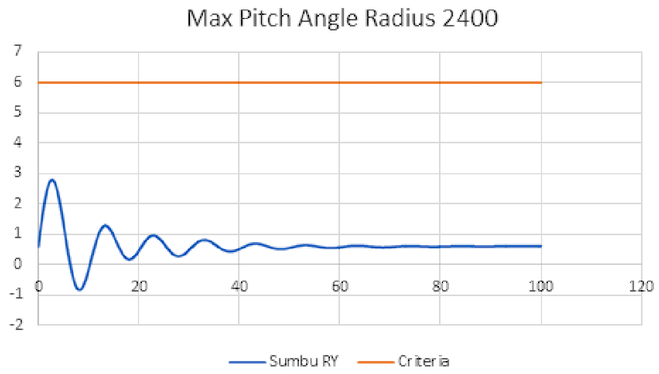

Figure 14. Max Pitch at mooring radius 2400m.

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 mooring line radius.

3.5 Mean Heel Angle

Mean Heel angle is the movement of the floating structure regarding the RX axis (roll motion) which is caused by environmental loads, while the criteria that has been set is 2 degrees. The following is a graph obtained for 3 variations of mooring radius for 100 s.

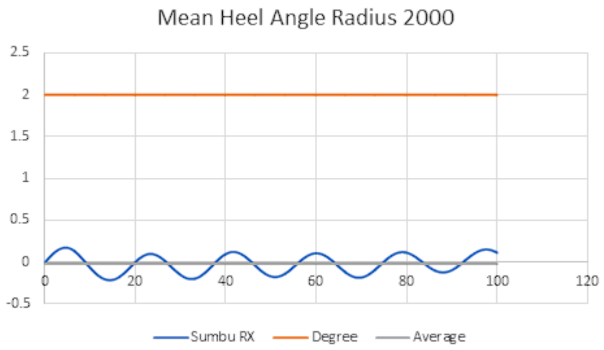

Figure 15. Mean Heel at mooring radius 2000m. `

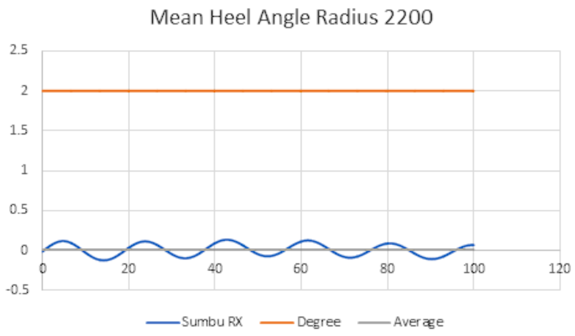

Figure 16. Mean Heel at mooring radius 2200m.

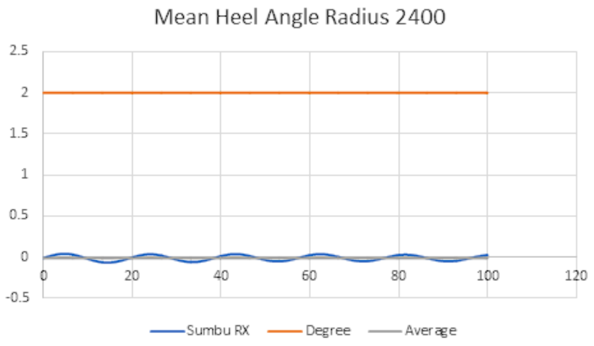

Figure 17. Mean Heel at a mooring radius of 2400m

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 of the mooring line radius.

3.6 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 graph obtained for 3 variations of mooring radius for 100s is as follows.

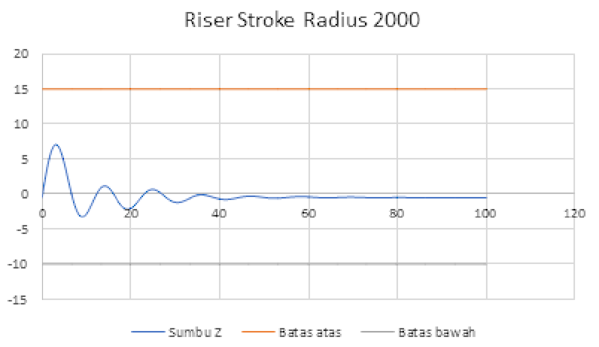

Figure 18. Riser Stroke at mooring radius 2000m.

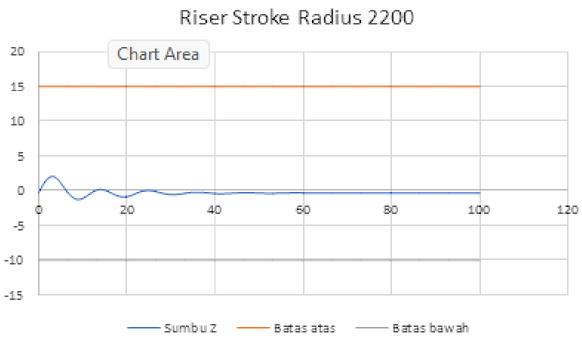

Figure 19. Riser Stroke at mooring radius 2200m.

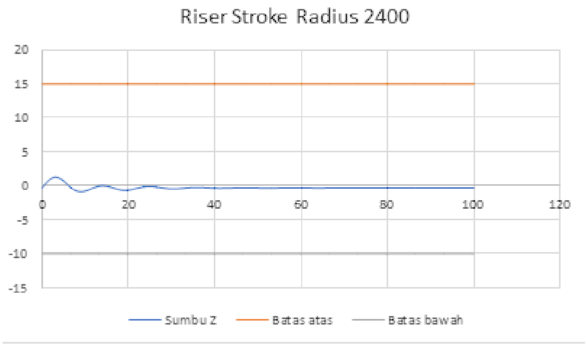

Figure 20. Riser Stroke at a mooring radius of 2400m.

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

3.7 Mooring Line Tension

Mooring line tension or mooring line tension is a very important thing to know the amount of pressure received by each mooring line. 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 radius with a time span of 100s using Ansys AQWA software.

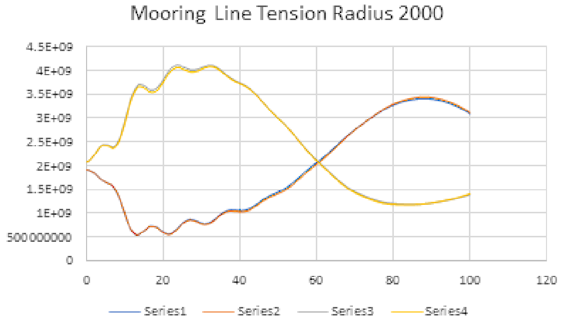

Figure 21. Tension at mooring radius 2000m.

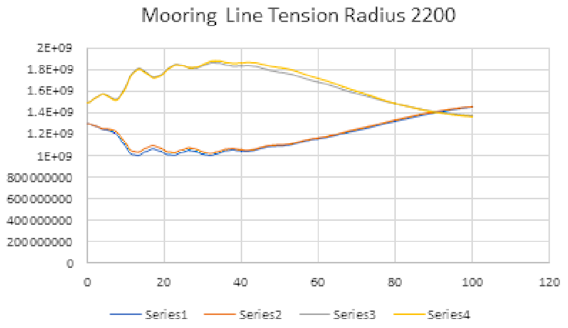

Figure 22. Tension on mooring radius 2200m.

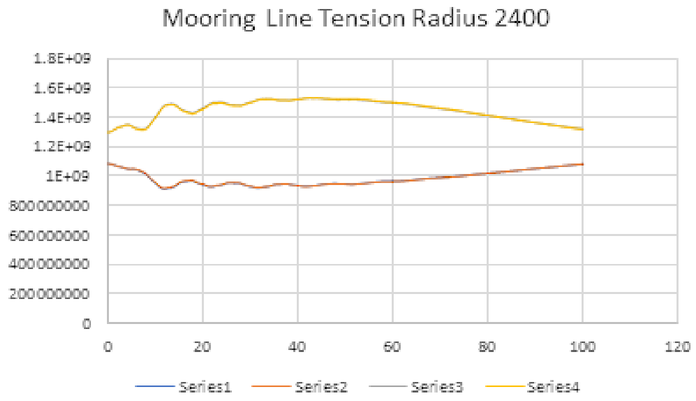

Figure 23. Tension at a mooring radius of 2400m

From the graph produced above using Ansys AQWA software, we can find out the pressure received by each mooring line at several different radius variations, so that we can know the characteristics received by the mooring line at each different radius.

4. CONCLUSION

Based on the results of the analysis that has been carried out using a numerical approach with Boundary Element Method (BEM) based software on 3 different mooring radius variations, we can conclude that determining the mooring line radius can influence the dynamics of the moored floating building structure and also influence the tension of each rope. mooring. From several graphs that have been obtained, we can see that the farther the mooring radius we use, the more stable the movement of the floating structure will be, as well as the tension received by each mooring line, the further the mooring radius, the smaller the pressure received by each mooring line. so that we can extend the life of the mooring technology, so that we can plan the appropriate radius for the floating structure to be operated according to the characteristics of the installation location.

Based on research conducted regarding the effect of mooring line radius on FPSO mooring using a numerical approach, several conclusions can be drawn:

1. Determining the mooring line radius affects the dynamics of the floating structure being moored and the tension of each mooring rope. The farther the radius of the mooring line, the lower the tension received by each mooring rope, so the structure becomes more stable.
2. Numerical analysis using the Boundary Element Method (BEM) approach provides a deeper understanding of the response of the mooring line and FPSO ship motion to the mooring system radius.
3. The graph of the analysis results shows that the farther the mooring radius used, the more stable the movement of the floating building structure. The pressure received by each mooring line also tends to be lower, extending the life of the mooring technology.
4. This conclusion provides important insights for planning the operation of floating structures, where selecting an appropriate mooring line radius can increase the stability of the structure and minimize the stress received by the mooring lines.

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