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Analysis Of The Influence Of Position Fairlead On The Ratio Of Damage Due To Fatigue In Type Moring Rope Structures Catenary Fpso Aka Mizu

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Abstract

This research discusses the effect of fairlead position on the fatigue damage ratio of the Aoka Mizu Floating Production Storage and Offloading (FPSO) catenary structure during moored conditions. The FPSO is subject to the influence of ocean waves, ocean currents, and wind that can cause significant movement, jeopardize the catenary mooring system, and disrupt the production process. This study utilizes a numerical method based on the Boundary Element Method and uses environmental data from the Masela Block, which includes wave, wind, and current data. Three variations of fairlead position (0.3T, 0.5T, and 0.9T), each referring to the fairlead distance from the laden to the ship's keel, were tested with a rope length of 3100 m and a sea depth of 1000 m. The results showed that a fairlead position of 0.3T resulted in low stress and damage levels, while fairlead positions of 0.5T and 0.9T resulted in higher stress and damage. The fairlead position plays an important role in determining the stability and performance of the FPSO catenary structure. A fairlead position of 0.3T appears to be the most favorable option to reduce the risk of damage and stress to the FPSO Aoka Mizu catenary mooring system during moored conditions.

Keyword: Catenary, Fairlead, Fatigue Damage Ratio, FPSO, Fatigue, Stress

1. INTRODUCTION

During the oil and gas production phase at sea, Floating Production Storage and Offloading (FPSO) will certainly not be separated from the influence of sea waves, ocean currents and wind. These environmental variables can induce fluctuating movements and exert dynamic stress on the mooring system, resulting in the gradual accumulation of fatigue damage. This problem has received considerable attention recently, with increasing cases recorded of fatigue-related damage in real projects.

Waves and high current speeds can result in the offset distance of the moored FPSO being large enough to cause a high voltage response in the mooring system. This can also disrupt the production process and even damage the structure and other operational load factors [1]. Tension on the mooring rope can affect the safety and stability of the ship, and can affect the service life of the mooring rope itself [2]. In designing a ship's mooring system, stress analysis in the mooring rope is very important to ensure that the mooring rope does not experience damage due to fatigue [3].

The successful operation of an FPSO vessel relies heavily on careful design and analysis of the mooring system. This research will discuss the influence of the fairlead position on the ratio of fatigue damage to the catenary structure of the Aoka Mizu FPSO when moored.

2. METHOD

This research was carried out using the literature study method, namely based on supporting data that has been obtained as shown in Table 1, Table 2, Table 3 and Table 4. using environmental data from the Masela Block (09 07' 51” S / 130 28' 00” E) which includes wave data, wind data and current data. FPSO is simulated with three position variations fairlead namely: 0.3T, 0.5T and 0.9T of water draft and then compare how it affects the ratio of damage due to fatigue in the mooring system. Because the mooring system is designed symmetrically, in the analysis of stress calculations and fatigue damage this is used mooring line 1, 5, and 6, as samples mooring line in part fore FPSO and mooring line 4, 11 and 12 as samples for section aft FPSO.

The length of the rope used in the simulation for each mooring line is 3,100 meters with a sea depth of 1,000 meters, corner mooring line in this design it is 34^o, 45^o, and 56^o. The mooring pattern used is a 4x3 pattern with a radius mooring 3,000 meters, numbering each mooring line can be seen in Fig. 1, the properties of the mooring ropes [4] are shown in more detail in Table 2, and the main dimensions of the Aoka Mizu FPSO ship can be seen in Table 1.

Table 1. Aoka Mizu FPSO Dimensions

Barge Hull Gas FPSO	
Length	206.75 m
Breadth	38.4 m
Height	30.08 m
Draft	21.75 m

Table 2. Properties of FPSO Aoka Mizu mooring lines

Mooring Properties	
Description	Studdles R4
Diameter (m)	0.1588
Wet Weight (kg/m)	438.90
Maximum Breaking Load, MBL (kN)	19,563.30
Axial Stiffness, EA (kN)	1,842,397.80

Table 3. Masela Block wind and current data

Parameter	Speed (m/s)
Angin	16.91
Arus	0.50

Table 4. Masela Block wave distribution data

		Hs (m)					Total
		0.1 - 1	**1.1 - 2**	**2.1 - 3**	**3.1 - 4**	**4.1 - 5**	
Tp (s)	**0.1 - 2**	0	0	0	0	0	0
	2.1 - 4	0.58	0	0	0	0	0.58
	4.1 - 6	9.51	4.43	0	0	0	13.94
	6.1 - 8	5.12	6.9	4.74	0.03	0	16.79
	8.1 - 10	8.2	3.5	5.6	0.78	0.04	18.12
	10.1 - 12	10.8	20.8	0.15	0.01	0.01	31.77
	12.1 - 14	9.3	2.68	0.02	0	0	12
	14.1 - 16	2.93	2.46	0.04	0	0	5.43
	16.1 - 18	0.42	0.77	0.03	0	0	1.22
	18.1 - 20	0.05	0.096	0	0	0	0.146

Total	46.91	41.636	10.58	0.82	0.05	**100**
Cumulative	46.9	88.5	99.1	99.9	**100**	

Based on Table 3. above, the input wind speed and current are 16.91 m/s and 0.5 m/s respectively at software Ansys AQWA, and from Table 4. the wave probability (Pi) used is the highest, namely 20.8 with a significant wave height (Hs) of 2 meters and wave period (Tp) of 12 seconds.

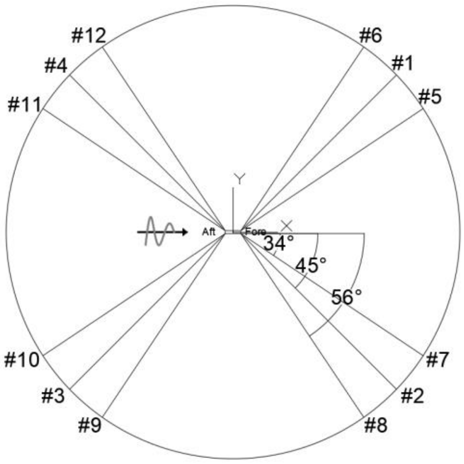


Figure 1. Pola tambat FPSO Aoka Mizu

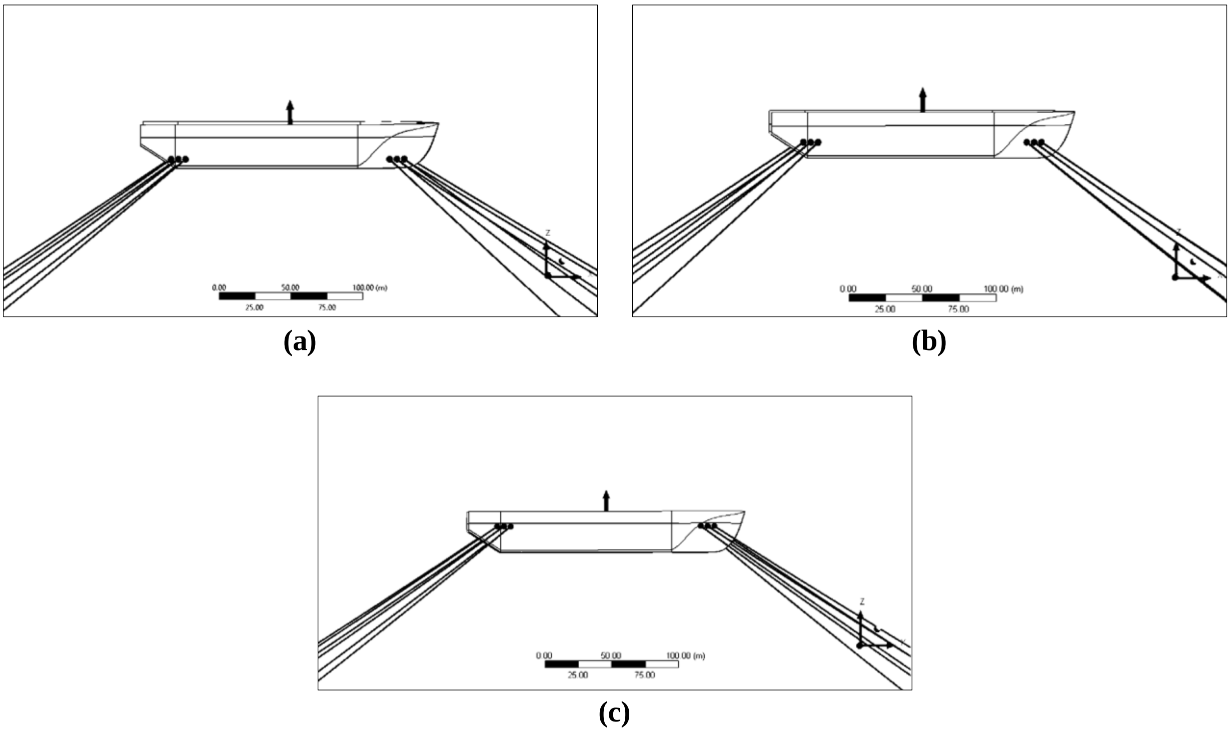


Figure 2. Position variations fairlead: (a) 0.3T, (b) 0.5T, (c) 0.9T

Table 5. Position variations fairlead FPSO Aoka Mizu

Position Fairlead	from FPSO keel		from Draft	
0.3 T =	6.525	m	-15.225	m
0.5 T =	10.875	m	-10.875	m

0.9 T =	19.575	m	-2.175	m

Position fairlead the first is 0.3T (Fig 2.a) where fairlead installed at a distance of 15,225 meters calculated from draft to keel ship, the second variation is position fairlead is at 0.5T (Figure 2.b) with a distance of 10,875 meters from draft to keel ship, while for the third variation 0.9T (Figure 2.c) position fairlead is at a distance of 2,175 from laden to keel boat.

3. RESULT AND DISCUSSION

3.1 Hydrostatic

Figure 3. FPSO Aoka Mizu

Data from hydrostatic analysis can be seen in Table 6. Where is it located center of gravity The FPSO is at the point (0,0,0) in XYZ coordinates. Meanwhile, the heave movement (Z) of the FPSO is 75,339,152 N/m, which reflects response FPSO to changes in sea wave height. Then, roll (RX) and pitch (RY) data depict the rotation of the FPSO in response to ocean waves with each value of -1.20237e8 N.m/° dan 3.99811e9 N.m/°.

Table 6. Data hydrostatic from software Ansys BEST

Item	Aqwa Hydrostatic Results
Center of Gravity Position	
X:	0. m
Y:	0. m
Z:	0. m
Heave (Z):	75339152 N/m
Roll (RX):	-1.20237e8 N.m/°
Pitch (RY):	3.99811e9 N.m/°
Actual Volumetric Displacement:	150587.77 m³
Equivalent Volumetric Displacement:	150586.34 m³
Centre of Buoyancy Position:	
X:	-3.6413188 m
Y:	-8.8326e-5 m
Z:	-10.41728 m
Cut Water Plane Area:	7495.0781 m²
C.O.G. to C.O.B.(BG):	10.41728 m
Metacentric Heights:	
GMX:	-4.5512137 m
GMY:	149.88493 m
COB to Metacentre:	
BMX:	5.8660665 m
BMY:	160.30222 m

Restoring Moments:

MX:	-2098534.8 N.m/°
MY:	69110960 N.m/°

3.2 Response Amplitude Operator

By acquiring Response Amplitude Operator (RAO) uses software Ansys then we can see the movement characteristics of the FPSO. The moorring conditions used to calculate the movement characteristics of this structure are conditions full load. Where are the conditions? full load The structure is at a maximum draft of 21.75 m with a sea depth of 1000 m. The following is a graph of RAO on an FPSO which is differentiated into five wave loading directions, namely wave loading at angle 0°, 45°, 90°, 135° and 180° for surge, sway, heave, roll, pitch, and yaw movements.

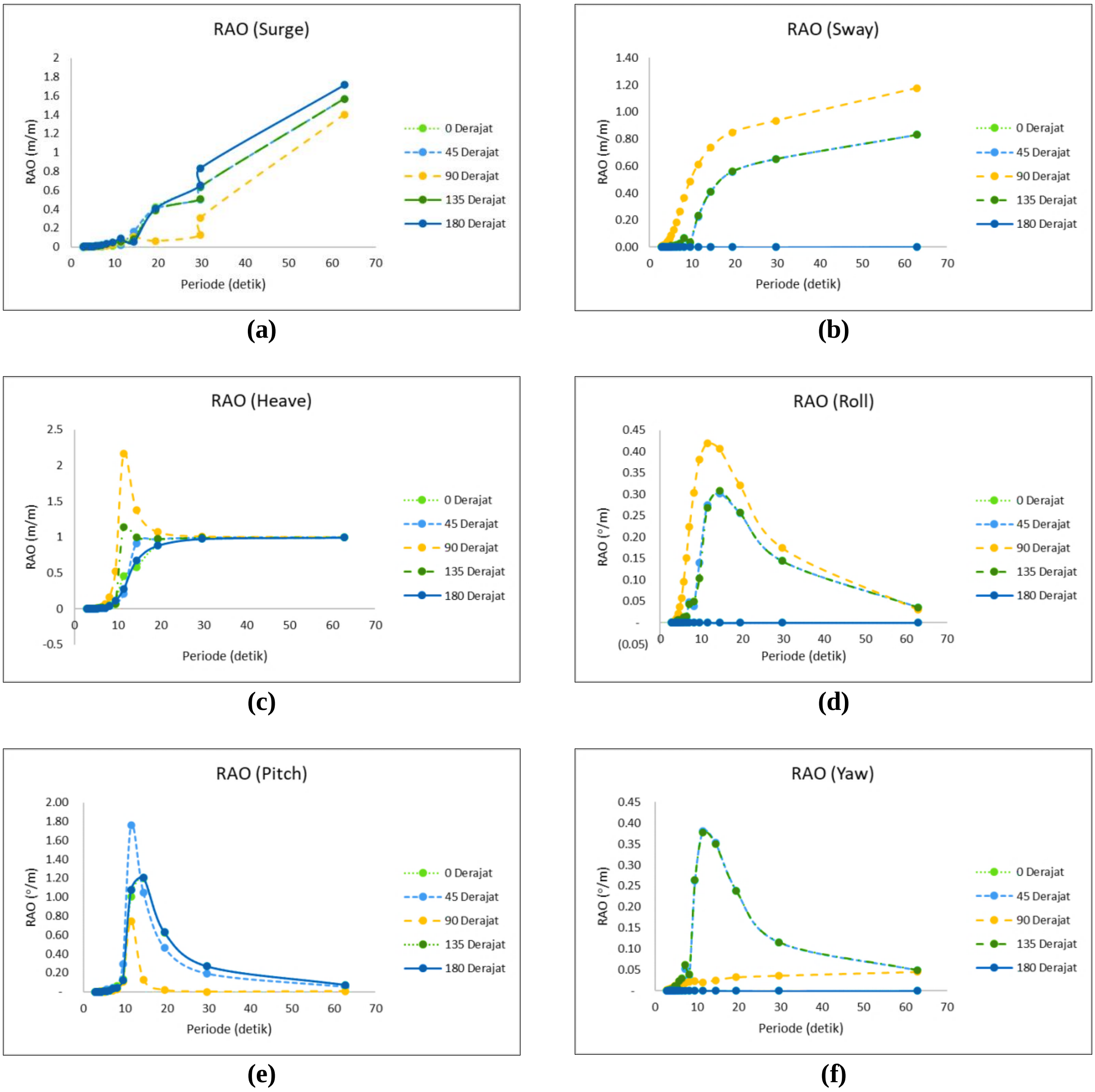


Figure 4. RAO graph of current FPSO movement mooring with heading loading 0°, 45°, 90°, 135° and 180° ; a) surge motion, b) sway motion, c) heave motion, d) roll motion, e) pitch motion, f) yaw motion.

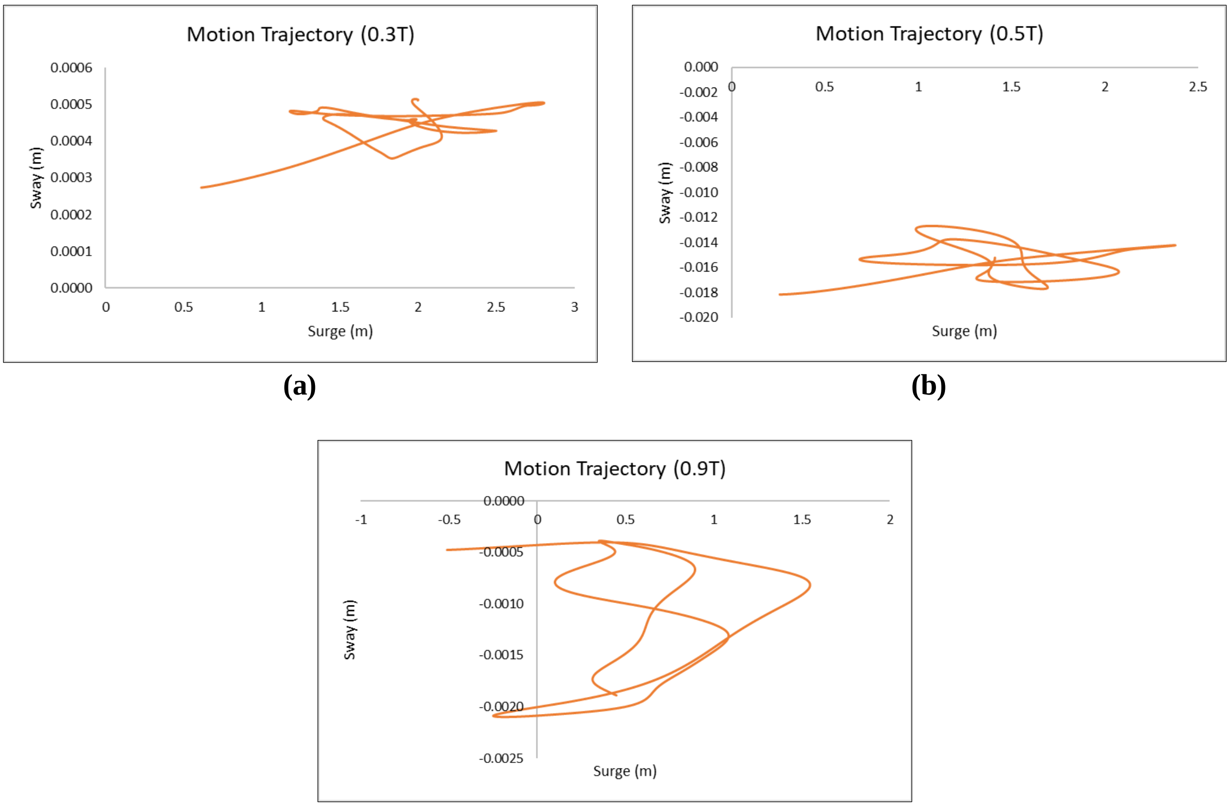
Table 7. The maximum value of RAO FPSO Aoka Mizu

Movement	Unit	RAO Maximum					Max
		0 deg	45 deg	90 deg	135 deg	180 deg	
Surge	m/m	1.716565	1.567544	1.402151	1.567817	1.716904	1.716904
Sway	m/m	0.000025	0.830290	1.175307	0.830294	0.000026	1.175307
Heave	m/m	0.997777	0.998895	2.166739	1.145228	0.997814	2.166739
Roll	°/m	0.000022	0.302473	0.418748	0.307806	0.000022	0.418748
Pitch	°/m	1.201371	1.759610	0.748979	1.203069	1.203069	1.759610
Yaw	°/m	0.000017	0.380306	0.045448	0.377453	0.000022	0.380306

Table 7. shows that for translational movements, the highest surge is 1.716904 (m/m) at heading 0°, the highest sway is 1.175307 (m/m) at heading 90°, while for the highest heavy it is 2.166739 (m/m) at heading 90°. For rotational movements, the highest roll is 0.418748 (°/m) on heading 90°, the highest pitch is 1.759610 (°/m) on heading 45°, and the highest yaw is 0.380306 (°/m) on heading 45°.

3.3 Motion Trajectory

Motion trajectory The ship is a visual representation of the path followed by the ship in its movement. Know motion trajectory The ship can help in predicting the ship's position, estimating the ship's speed, and offset distance from time mooring. Apart from that, this information can also help in planning more efficient and safer shipping routes. Here is a graph motion trajectory (Fig.9.) of the FPSO Aoka Mizu during moored conditions.



(a) (b) (c)

Figure 5. Chart motion trajectory on the current FPSO mooring; a) motion trajectory in position fairlead 0.3T, b) motion trajectory in position fairlead 0.5T, c) motion trajectory in position fairlead 0.9T.

Table 8. Maximum value of surge and sway movement at position fairlead 0.3T, 0.5T, dan 0.9T

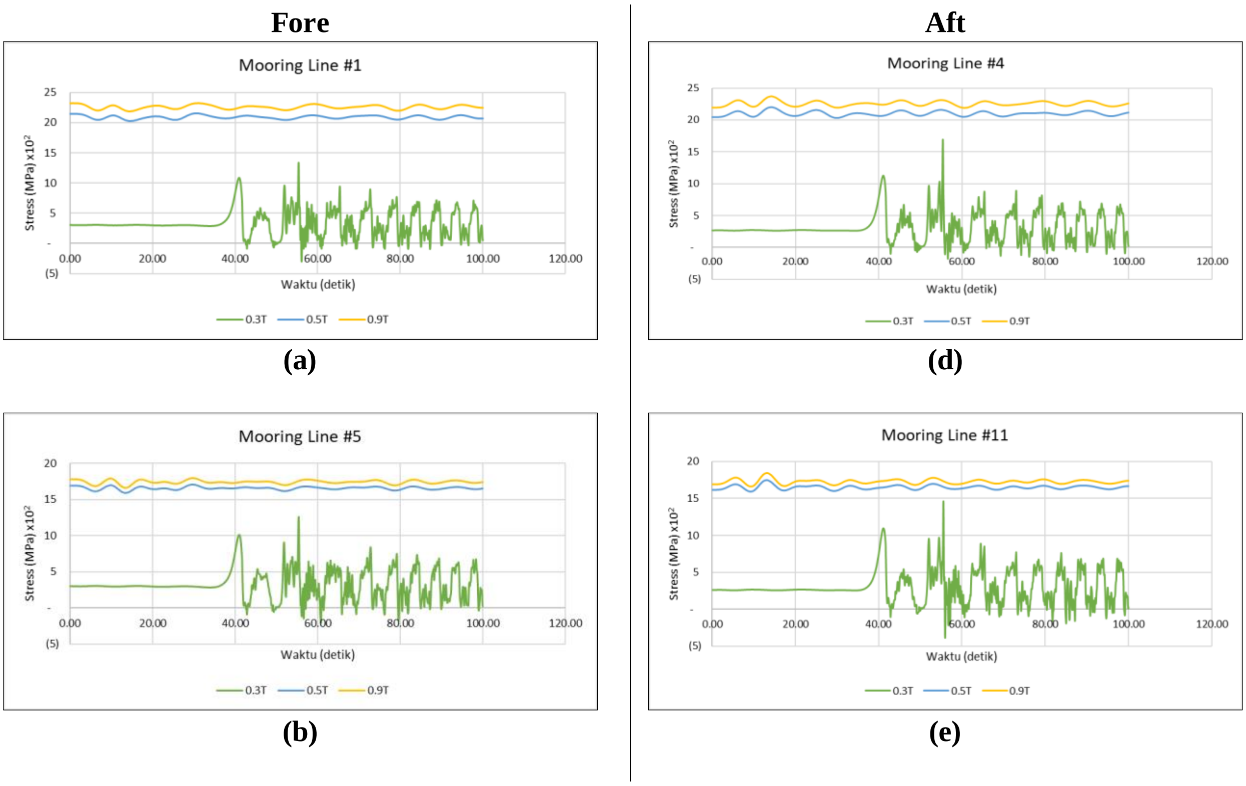
Movement	Position Fairlead					
	0.3T		0.5T		0.9T	
	Surge (m)	Sway (m)	Surge (m)	Sway (m)	Surge (m)	Sway (m)
$Offset_{max}$	2.8	0.0005	2.37	-0.013	1.5	-0.0004
$Offset_{min}$	0.61	0.0003	0.27	-0.018	-0.5	-0.0021
Δ_{Offset}	2.2	0.0002	2.1	0.005	2.0	0.002

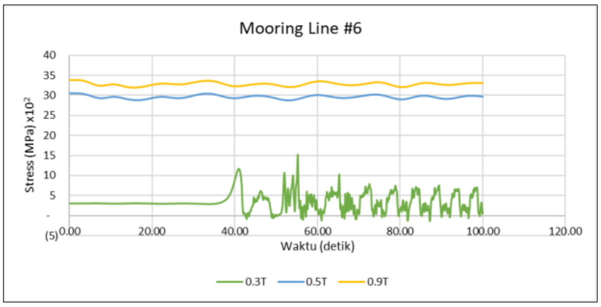
3.4 Mooring Line Stress

Tension on the mooring line system or mooring line stress need to know because it is one of the important factors that must be considered in designing a ship's mooring system. The analysis results show that mooring line stress lowest is in position fairlead 0.3T whereas mooring line tress highest occurs in position fairlead 0.5T and 0.9T. The calculation results on mooring line stress are calculated using the following equation:

$$\mathbf{HSS} = \frac{\mathbf{F}}{\mathbf{A}}$$

Where:
HSS = hotspot stress (N/m^2)
F = tension force in the rope (N)
A = cross-sectional area mooring line (m^2)





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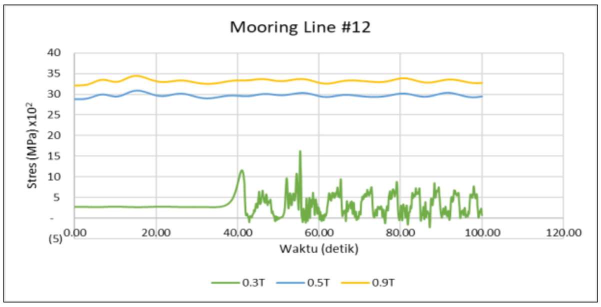


(f)

Figure 6. Chart mooring line stress; (a) Mooring line 1, (b) Mooring line 5, (c) Mooring line 6, (d) Mooring line 4, (e) Mooring line 11, (f) Mooring line 12

Table 9. Calculation results mooring line stress

Mooring Line	**Place**	**HSS_{maks}**		
		0.3T	**0.5T**	**0.6T**
#1	Fore	1.34E+09	2.16E+09	2.32E+09
#5		1.71E+09	1.80E+09	1.53E+10
#6		1.52E+09	3.05E+09	3.38E+09
#4	Aft	1.69E+09	2.20E+09	2.37E+09
#11		1.46E+09	1.75E+09	1.84E+09
#12		1.63E+09	3.09E+09	3.44E+09

3.5 Fatigue Damage Ratio

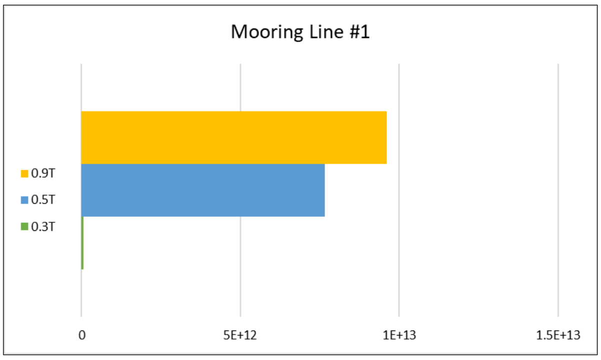
Fatigue damage ratio (fatigue damage ratio) projects the capability of the FPSO catenary structure to withstand external loads without experiencing significant damage. Calculation of the level of fatigue damage is very important in designing structures catenary FPSO to ensure safety and optimal performance during its use period. Calculation fatigue damage calculated with the following equation:

$$\mathbf{D} = \frac{\mathbf{P_i}}{\mathbf{N_i \times T_i}}$$

When:

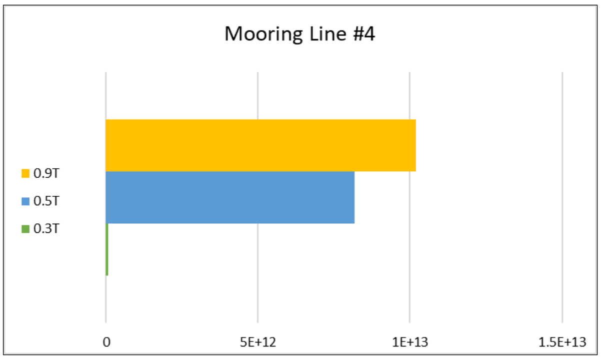
D = fatigue damage ratio
Pi = probability of a particular wave
Ni = number of wave events per stress range
T-i = Wave period (seconds)

Fore



(a)

Aft



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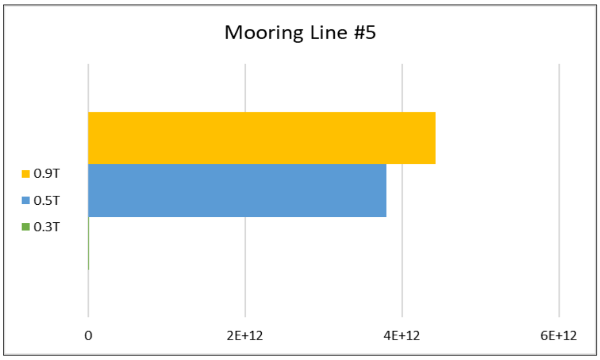

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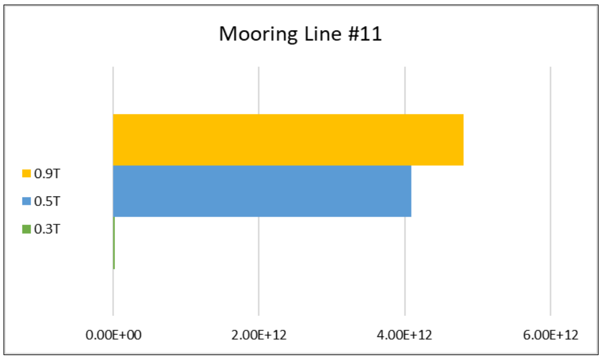

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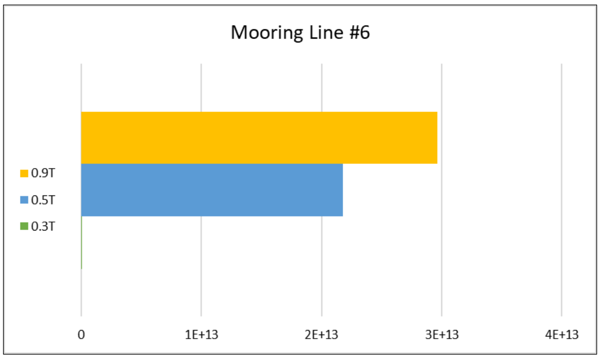

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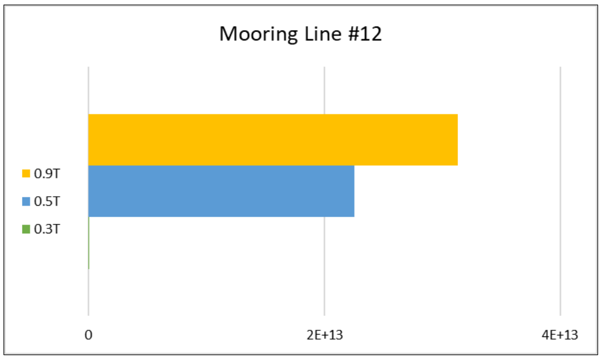

(f)

Figure 7. Fatigue damage ratio (fatigue damage ratio); (a) Mooring line 1, (b) Mooring line 5, (c) Mooring line 6, (d) Mooring line 4, (e) Mooring line 11, (f) Mooring line 12

Table 10. Calculation results fatigue damage

Mooring Line	**Place**	**D**		
		0.3T	**0.5T**	**0.6T**
#1	Fore	7.04E+10	7.66E+12	9.59E+12
#5		1.53E+10	3.80E+12	4.43E+12
#6		2.69E+10	2.18E+13	2.96E+13
#4	Aft	7.35E+10	8.16E+12	1.02E+13
#11		2.40E+10	4.09E+12	4.80E+12
#12		3.30E+10	2.25E+13	3.13E+13

Calculation results fatigue damage indicates that position fairlead 0.3T results in a low breakdown ratio. Rather, position fairlead 0.5T and 0.9T produce higher breakage ratios.

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