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Analysis of Sling Tension on the Lifting Process of Riser Support Jacket on Installation Phase

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ABSTRACT

The increasing exploration and exploitation of oil and gas in the deep sea has led to an increasing need for new technologies to support these activities. In this study, a riser support structure in the form of a jacket is used to support the riser so that the stress can be minimized. Like the jacket structure in general, this riser support structure can be installed using various methods, including the lifting method. This study discusses the stress in the sling when the lifting process is carried out. The crane barge used in this study was first modeled using MOSES Software to determine how the barge moves when the lifting process is carried out. The result of the barge movement analysis is a Response Amplitude Operator (RAO). In the sway, heave and roll movements, it is known that the maximum value is at 90° heading, while in other movements, it varies. The riser support structure is modeled using SACS Software to determine the center of gravity, then the sling length is calculated. From the calculation, the sling length at lifting point 1 is 34.10 m, lifting point 2 is 34.14 m, lifting point 3 is 36.08 m, and lifting point 4 is 36.10 m. The lifting model is input into the OrcaFlex Software to analyze the sling stress. The analysis was performed in five loading directions, namely 0°, 45°, 90°, 135°, and 180°. The maximum stress occurs in the loading direction of 90°, with the result that sling 1 is 1,932.70 kN, sling 2 is 1,905.65 kN, sling 3 is 1,161.64, and sling 4 is 1,193.65 kN.

Keywords: *Riser Support Jacket, RAO, Lifting, Sling*

1. INTRODUCTION

Exploration and exploitation of oil and gas are more intensively conducted in line with the increasing need for oil and gas, so offshore platforms must be developed. Offshore platforms, in general, are divided into two types: fixed structures and floating structures [1]. In an offshore platform, the structure is divided into the main jacket and the topsides.

The jacket is the construction of the steel substructure made of pipes that serve to sustain the buildings during the period of bridge operation. The jacket has a function, which is not only to sustain the deck above the surface of the water, but the jacket's structure also can prop up the module at the bottom of the sea. In this study, the jacket analyzed the riser support jacket, which sustains the riser location at the bottom of the sea. The jacket is the construction of the substructure of steel made of pipes that sustain the buildings thereon during the period of operation of the bridge.

The jacket design stages are divided into three major stages: fabrication, load out and installation. The installation stage, the end of the jacket's manufacture, is the installation stage at the location already determined beforehand. The installation method of the jacket's structure can be determined by considering the jacket's profile and how the conditions of the environment, such as waves, currents, and wind, are at the installation's location. Lifting and launching are two methods most often used for the jacket installation process. In this case, the method that will be used for the installation is lifting. The method of lifting in the jacket installation is using the help of a floating crane or crane located above the floating structure, such as a barge or ship or, ordinarily, a heavy lift structure.

When lifting the installation stage, the load environment, such as waves and wind, certainly will affect the movement of the barge, which, in the end, will also affect the voltage sling used during the lifting process. In this study, the sling stress will be analyzed in each wave direction, where the conditions are analyzed in five wave directions: 0°, 45°, 90°, 135°, and 180°.

2. LITERATURE REVIEW

Safety in the offshore lifting process is a very risky thing because the movement of the barge caused by waves, currents and wind at the installation location will affect the lifting process that is being carried out so that the structure will get an added load when the lifting process is carried out [2]. In addition, the movement of the barge will affect the displacement of the center of gravity of the lifted structure. Shifting the structure's center of gravity must not exceed a predetermined limit. This movement is because the displacement of the center of gravity, which is too significant, can cause instability of the structure when it is lifted, which results in a failure during the lifting process [3].

During the lifting process of the jacket structure, the load on the structure is certainly different when in the water and the air, in addition to the environmental loads mentioned above also have a significant effect on the lifting process so that the calculation of loading is divided into two, namely static load and dynamic load [4]. Calculation of the static load involves the total vertical load that occurs on the structure without any additional load from its environmental conditions. In contrast, the calculation of this dynamic load is added to the static load of the structure for the effects of the working environmental conditions, usually from the calculation of static amplification with DAF (Dynamic Amplification Factor) or static load addition factor, which is assumed to be close to the actual environmental conditions. The nominal value of DAF itself is obtained from practical standards often used, such as DNV OS H-205 Lifting, GL Noble Denton, and so on [5].

3. RESEARCH METHODOLOGY

3.1 Problem Formulation and Goal Setting

The first step is to formulate a problem to be discussed. Formulating a problem not only presents the problem but also explains its causes and how to solve it. After formulating the problem, the research objectives are determined so that the implementation of the research is clearer, structured, and directed.

3.2 Data Collection

It is preceded by a literature study to obtain books or journals related to this research to assist in its completion. After that, data was collected on the structure of the riser support jacket, crane barge, rigging components, and environmental data, with the following data:

- Water Depth: 119.6 m
- Barge Data:
  1. LoA : 121.92 m
  2. Lpp : 121.92 m
  3. Breadth : 32.31 m
  4. Depth : 8.69 m
  5. Draft : 5.52 m

  Weight:
  Displacement : 19,477
  Lightship Data:
  1. LCG : 63.55 m (after bow)
  2. VCG : 8.28 m (above b/l)
  3. TCG : 1.03 m (to stbd from centreline)
- Structure Data:
  Elevation : EL (-) 71.9 m, EL (-) 81.6 m, EL (-) 92.6 m, EL (-) 105.3 m, and EL (-) 119.6 m.
  Width : 18 m (Row-A & Row-B)
  Height : 50 m

3.3 Crane Barge Modelling

The crane barge is modeled using MOSES Software, and the model is adjusted to the data from the stability book barge.

3.4 Crane Barge Motion Analysis

Calculations are performed to find RAO (Response Amplitude Operator) from existing wave data. The calculation is done with the help of MOSES Software. The transfer function is a function of response to the movement of the dynamic structure caused by a wave with a range of frequencies specified.

RAO is a tool for transferring wave forces into structural responses [6]. The motion response or RAO for translational motion, namely surge, sway, and heave (k = 1, 2, 3 or x, y, z), is a direct comparison between the amplitude of the movements compared to the amplitude of the incident wave (both in length units):

$$RAO = \frac{\zeta_{k0}}{\zeta_o}(m/m) \quad (1)$$

Remarks:
ζ_0 = amplitude of the wave (m)
ζ_{k0} = amplitude of movement (m)

Meanwhile, the non-dimensional response or RAO for the rotational motion of roll, pitch, and yaw (k = 3, 4, 5 or θ, Φ, ψ) is the ratio of the amplitude of the rotational motion (in radians) to the slope of the wave g, which is the multiplication of numbers. Wave, kw = w2/g, with the amplitude of the incident wave:

$$RAO = \frac{\zeta_{k0}}{k_w\zeta_0} = \frac{\zeta_{k0}}{(w^2/g)\zeta_0}\left(\frac{rad}{rad}\right) \quad (2)$$

Remarks:
ζ_0 = amplitude of the wave (m)
ζ = amplitude motion (m)
g = gravity (9.81 m/s2)
ω = frequency sense wave incidence (rad/s)

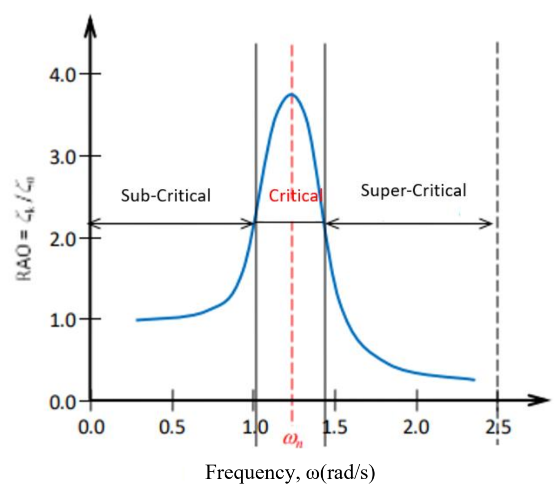


Figure 1. General Form of Floating Building Movement Response Graph

3.5 Structure Modelling

The riser support jacket structure is modeled using SACS Software before finally analyzing the rigging configuration. The riser support jacket structure itself will be lifted in a lie-down position:

1. Centre of Gravity Analysis

Identifying the location of the center of gravity during the lifting process. Calculating the center of gravity or center of gravity is done with the help of SACS Software.

2. Load on Structure Analysis

After making a structural model, the next step is to model the load on the structure. The loads contained in the structure include the structure's load (self-weight), anode, and upending padeye.

3. Sling Specification Calculation

The dimensions or sizes of the slings and shackles used in this study were determined based on the total load of the structure. In this paper, variations in the rigging configuration are selected in a configuration rigging with four slings without using a spreader bar, as shown in Figure 2. The formulations used to look for the angle tilt sling, the height of the hook of the piece on the structure, and great possibilities angle oblique structures when lifted are as follows [7]:

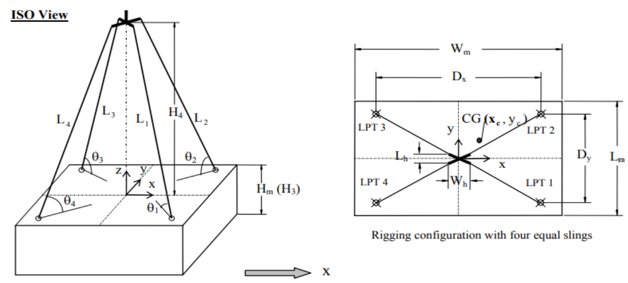


Figure 2. Four Lifting Point Rigging Configuration Without Spreader Bar

$$L_n = \sqrt{H^2 + \underline{LPT\ O}^2} \tag{2}$$

$$\theta_1 = \theta_2 = \theta_3 = \theta_4 = \left(\frac{\sqrt{\left(\frac{D_x}{2} - \frac{W_h}{2}\right)^2 + \left(\frac{D_y}{2} - \frac{L_h}{2}\right)^2}}{L_1} \right) \tag{3}$$

$$H_4 = \left(\sqrt{(L_1)^2 - \left(\frac{D_x}{2} - \frac{W_h}{2}\right)^2 + \left(\frac{D_y}{2} - \frac{L_h}{2}\right)} \right) \tag{4}$$

$$\gamma \approx tg^{-1}\left(\frac{\sqrt{(x_c)^2 + (y_c)^2}}{H_4} \right) \tag{5}$$

Remarks:

θ = Angle between the sling and the horizontal plane of the lifting object

γ = Possible angle slope of the object when the process of lifting is underway

$L_{1,2,3,4}$ = Length of sling (m)

H_4 = Height of the hook point to the horizontal plane of the lifting object (m)

D_x = Distance between the lift points are located on the axis x (m)

D_y = Distance between the lift points are located on the axis y (m)

W_h = Total width of the structure along the x-axis (m)

L_h = Total length of the structure along the y-axis (m)

LPT = Lifting Point

O = CoG Point

4. Sling

Sling is a cable made of several strands of metal wire into a helix. Sling consists of several components, such as sling eye, termination, and sling body. Bend diameter, sling capacity, load and length are the determining factors in selecting the right sling for lifting operations. The actual angle (α) between the sling and the horizontal plane for standard practice is greater than 60°, as shown in Figure 3 [8].

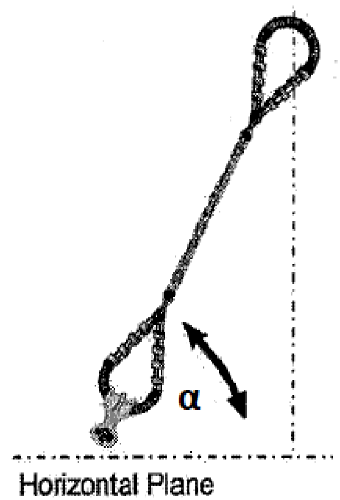


Figure 3. Angle Between Sling and Horizontal Plane

Sling capacity can be determined from its breaking load capacity. The safety factor of the sling can be determined by dividing the Minimum Breaking Load of the sling (MBL) by the weight of the load, as shown below:

$$SF = \frac{MBL}{Load} \geq 4 \tag{6}$$

3.6 Lifting Modelling

Barge modeling in OrcaFlex adapts to the original Trim & Stability Book data. The following are the parameters that are used as modeling inputs in the OrcaFlex Software:

1. Principal Dimension
2. Displacement and Centre of Gravity Barge
3. Radius Gyration
4. Displacement RAO and Load RAO
5. Wave Drift Force

6. Stiffness
7. Added Mass & Damping
8. Current Drag
9. Wind Drag

3.7 Tension Sling Analysis

Tension analysis on the sling during the lifting riser support jacket process was carried out with the help of OrcaFlex Software. The OrcaFlex model has five conditions: waves in the direction of 0°, 45°, 90°, 135°, and 180° with a significant wave height (Hs) of 2.8 meters.

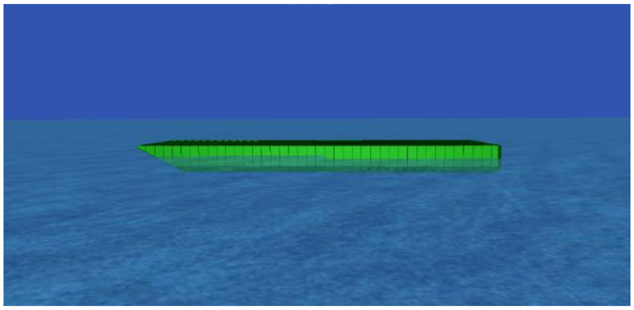
4. RESULT AND DISCUSSION

4.1. Crane Barge Modelling

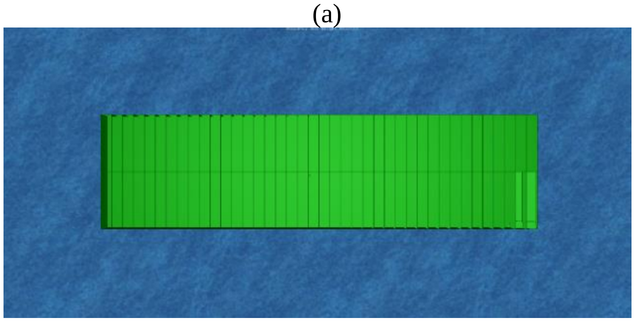
The barge is modeled using MOSES Software with the conditions adjusted during the lifting process, namely that there is already an additional structural load on the back of the barge. After that, the model is validated again to ensure it resembles its original shape and condition. Validation is carried out on the barge's displacement and center of gravity. The following are the results of the barge modeling:

Principal Dimension [9]:

- LoA : 121,92 m
- Lpp 121,92 m
- Breadth (B) : 32,31 m
- Height (H) : 8,69 m
- Draft (T) : 5,52 m



(a)



(b)

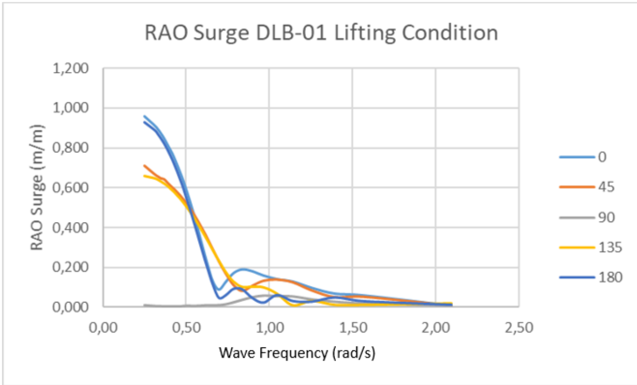
Figure 4. (a) Side View of Barge Model, (b) Top View of Barge Model

Table 1. Validation of MOSES Model with Data from Stability Book

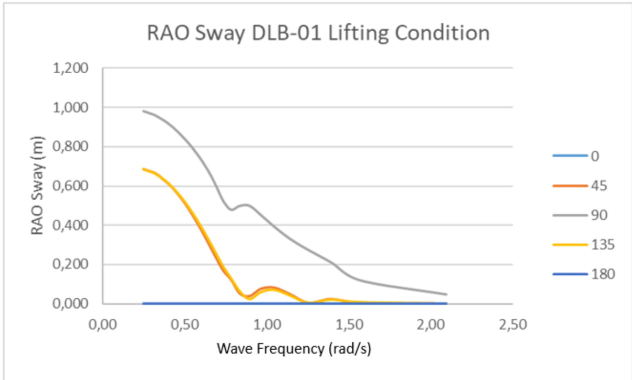
Model Validation			
	Stability Book	Calculation	Percentage
Disp.	14,577	14,668	0.63%
LCG	63.55	63.27	0.44%
VCG	8.28	8.21	0.79%
TCG	1.03	1.03	0.36%

4.2. Motion Analysis of Crane Barge

After the model is validated, the next step is to analyze the movement of the crane barge on a regular wave, usually called the Response Amplitude Operator (RAO). RAO itself is information about the characteristics of the movement of the floating building against the movement of ocean waves, which is presented in a graphic form where the abscissa is the frequency parameter, and the ordinate is the ratio between the amplitude of the floating building movement (ζ_{k0}) and the wave amplitude (ζ_0). The following are the conclusions of the RAO movement based on its movements:



(a)



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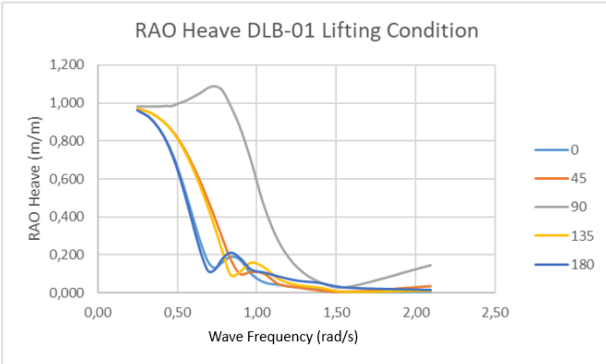

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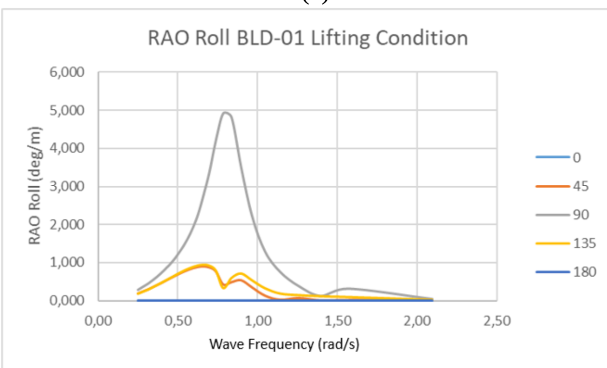
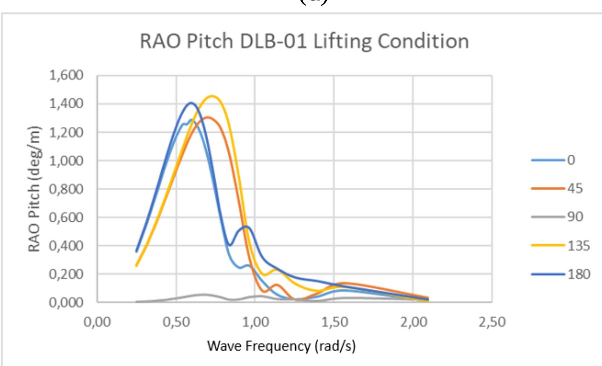
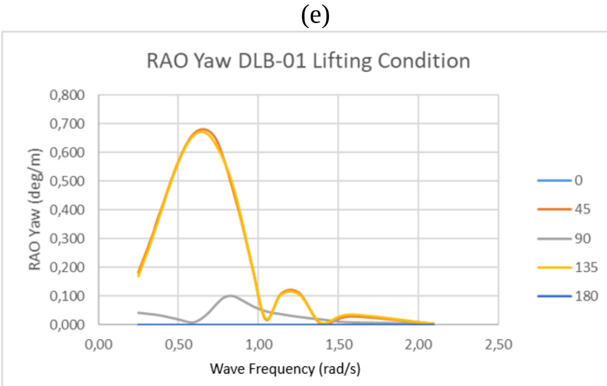


(d)



(e)



(f)

Figure 5. RAO graphic of crane barge DLB-01 in six degrees of freedom, which are (a) Surge, (b) Sway, (c) Heave, (d) Roll, (e) Pitch, (f) Yaw

4.3. Structure Modelling in SACS Software

The riser support jacket structure is modeled using SACS Software before finally analyzing the rigging configuration. The riser support jacket structure itself will be lifted in a lie-down position, so it has the following dimensions:

- Length : 50 m
- Width : 22 m
- Height : 18 m

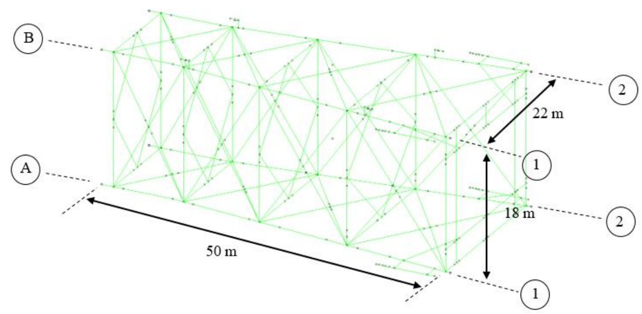


Figure 6. Riser Support Jacket Model in SACS Software

After making a structural model, the next step is to model the load on the structure. The loads contained in the structure include the structure's load (self-weight), anode, and upending padeye. Below are the results of the load modeling on the structure.

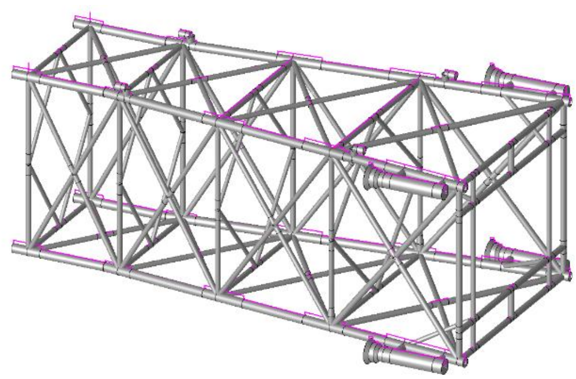


Figure 7. Load Model on Riser Support Jacket Structure

Table 2. Load Data on Riser Support Jacket Structure

Load	Quantity	Weight (MT)	Total Weight (MT)
Anodes	160	0,3	48
Upending Padeyes	4	1,5	6
Dead Weight	1	440	440
Total Weight (MT)			494
Total Lift Weight (with *contingency factor*)			**518.7**

The next step is determining the structure's lifting point and center of gravity when the lifting process is carried out. The number of lifting points determined is four (4) lifting points. Each is placed at EL (-) 107.84 m with a total of 2 points and EL (-) 82.37 m with a total of 2 points.

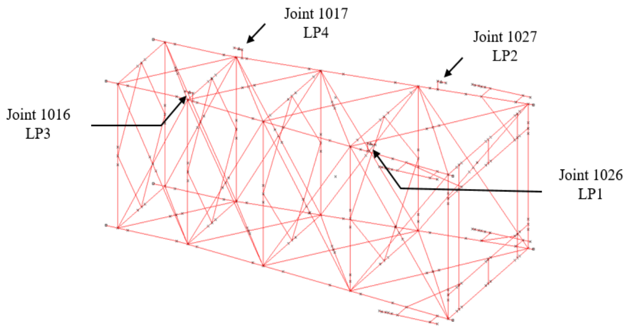


Figure 8. Lifting point Position

The table below shows the center of gravity located in the structure:

Table 3. Coordinate of the *center of gravity*

Axis	Coordinate (m)
X	18.62265
Y	-0.0594
Z	9.20968

4.4. Rigging Configuration Analysis

The first step in analyzing the rigging configuration is calculating the sling length needed to carry out the lifting riser support jacket process. The angle formed by the sling to the structure's surface is 60°. Then, the length of the sling obtained is as follows:

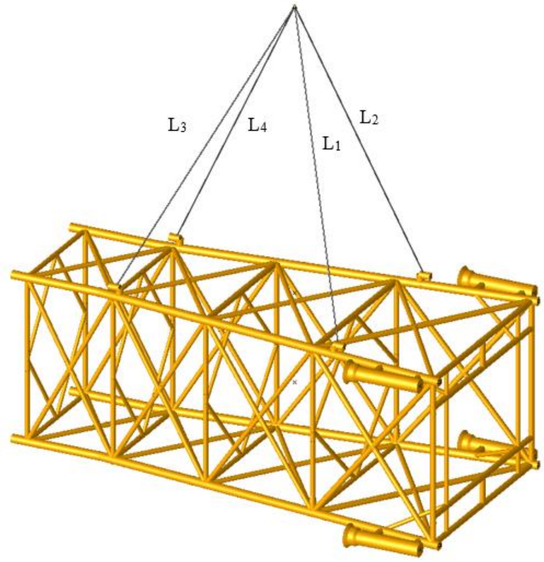


Figure 9. Rigging Model on SACS Software

Table 4. Distance from CoG to the lifting point

Lifting Point	Distance from CoG to Lifting Point	
	m	ft.
LP1	13.63	44.71
LP2	13.71	44.98
LP3	18.00	59.07
LP4	18.05	59.22

Table 5. Hook Height Calculation

Rigging	Minimum Sling Angle	Hook Height	Min. Hook Height
	(deg)	(m)	(m)
L_1	60	23.60	31,26
L_2	60	23.75	
L_3	60	31.18	
L_4	60	31.26	

Table 6. Sling Length Calculation

Rigging	Angle	Sling Length		Hook Height
	(deg)	m	ft.	(m)
L_1	66.45	34.10	111.88	31,26
L_2	66.32	34.14	112.00	
L_3	60.06	36.08	118.36	
L_4	60.00	36.10	118.43	

4.5. Crane Barge and Structure Modelling on OrcaFlex Software

Modeling the crane boom and crane control room using the 6D Buoy in OrcaFlex so that they can attach with the barge so that the effect of the barge movement is also transmitted to the crane, which will affect the tension in the sling due to wave motion. The following is an image of the model in OrcaFlex Software:

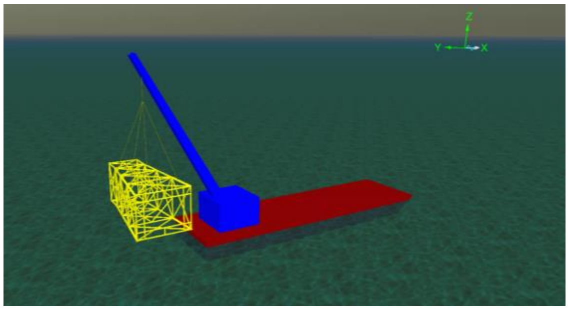


Figure 10. Lifting Model on OrcaFlex Software

The sling used in this case works with a wrapped sling condition. The sling will experience a reduction factor in the MBL value, namely the reduction in the value of the MBL due to the sling's bending so that it cannot distribute the load evenly throughout the sling body. In the lifting process with the trunnion, a double sling arrangement will be used, where the sling will be wrapped around the tubular trunnion, and both sling eyes will be attached to the shackle.

Table 8. Sling Specifications

Rig.	OD	Load	Safety Factor	MBL	MBL sling	Safety Factor
	in	MT		MT	MT	
R#1	4.50	197.09		810.29	940.00	4.77
	3.50				564.00	5.72
R#2	4.50	194.33		798.94	940.00	4.84
	3.50		4.11		564.00	5.80
R#3	4.00	118.89		487.14	647.00	5.46
	3.00				425.00	7.17
R#4	4.00	121.73		500.46	647.00	5.32
	3.00				425.00	6.98

4.6. Tension Sling Analysis

The analysis below results in a calculation of the dynamic stress on each sling used in the OrcaFlex Software. The analysis was carried out in various wave direction conditions, namely 0°, 45°, 90°, 135°, and 180°.

a. Heading 0°

Table 9. Sling Tension on heading 0°

Heading 0°				
Line	Dynamic Effective Tension			
	Maximum Tension		Average Tension	
	kN	MT	kN	ton
Sling 1	1,873.06	191.01	1,864.81	190.17
Sling 2	1,846.36	188.29	1,838.18	187.45
Sling 3	1,151.05	117.38	1,149.65	117.24
Sling 4	1,182.24	120.60	1,181.24	120.46

b. Heading 45°

Table 10. Sling Tension on heading 45°

Heading 45°				
Line	Dynamic Effective Tension			
	Maximum Tension		Average Tension	
	kN	ton	kN	ton
Sling 1	1,879.97	191.72	1,864.84	190.17
Sling 2	1,853.83	189.06	1,838.18	187.45
Sling 3	1,152.26	117.51	1,149.65	117.24
Sling 4	1,181.41	120.46	1,181.23	120.46

c. Heading 90°

Table 11. Sling Tension on heading 90°

Heading 90°				
Line	Dynamic Effective Tension			
	Maximum Tension		Average Tension	
	kN	ton	kN	ton
Sling 1	1,932.70	197.09	1,865.36	190.23
Sling 2	1,905.65	194.33	1,838.67	187.50
Sling 3	1,161.94	118.49	1,149.42	117.22
Sling 4	1,193.65	121.73	1,180.98	120.43

d. Heading 135°

Table 12. Sling Tension on heading 135°

Heading 135°				
Line	Dynamic Effective Tension			
	Maximum Tension		Average Tension	
	kN	ton	kN	ton
Sling 1	1,881.29	191.85	1,864.72	191.85
Sling 2	1,853.31	189.00	1,838.17	187.45
Sling 3	1,151.57	117.44	1,149.65	117.24
Sling 4	1,183.89	120.73	1,181.24	120.46

e. Heading 180°

Table 13. Sling Tension on heading 180°

Heading 180°				
Line	Dynamic Effective Tension			
	Maximum Tension		Average Tension	
	kN	ton	kN	ton
Sling 1	1,871.37	190.84	1,864.81	190.17
Sling 2	1,844.72	188.12	1,838.17	187.45
Sling 3	1,150.29	117.31	1,149.65	117.24
Sling 4	1,181.25	120.53	1,181.25	120.46

5. CONCLUSION

Based on the research results conducted through the steps above, it can be concluded that in this study, the barge movement reaches its maximum value when the loading direction is 90° on a regular wave with free-floating conditions. The maximum barge movement certainly affects the results of the sling stress that occurs during the lifting process. Namely, the sling stress reaches its maximum value in the direction of loading 90°. It is known that in the direction of loading 90°, with a sling length of 34.10 m the maximum stress on sling 1 is 1,932.70 kN, sling 2 with a length of 34.14 m, the maximum stress that occurs is 1,905.65 kN, sling 3 with a length of 36.08 m the maximum stress that occurs is 1,161.64, and sling 4 with a length of 36.14 m the maximum stress is 1,193.65 kN.

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