International Journal of Marine Engineering Innovation and Research, Vol. 9(1), March. 2024. 193-192
(pISSN: 2541-5972, eISSN: 2548-1479)

Analysis Of Lifting Strength Of Padeye Subsea Structure Using Finite Element Method

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(Received: 22 Maret 2024 / Revised: 26 Maret 2024 /Accepted: 9 March 2024)

***Abstract*—Indonesia's natural resources which are one of the sources of income for the Indonesian state, namely from the results of oil and gas management, subsea is one of the processes of exploring oil and natural gas which is increasing, with all the practicalities of technology and also the system it has and operational costs that are fairly cheap. Infield Umbilical Termination is one part of the subsea processing, which functions as a terminal for connecting electricity under the sea, therefore a construction is needed to protect the system from the Infield Umbilical Termination, known as the subsea structure so that it is protected from disturbances while in the sea. The construction process will never be separated from the activity called lifting. Padeye is an item to help lifting activities. the construction of the padeye plays a very important role when lifting is in progress because it is necessary to test the structural strength of the padeye. with the help of the finite element method, from the analysis results obtained the value of the structure experienced by the padeye at an angle of 45 degrees obtained the maximum stress value of 131.835 Mpa, Strain of 0.000433 mm, Displacement of 0.12 mm, Factor Of Safety 1149.413 and for an angle of 60 degrees obtained a stress value of 73.628 Mpa. Strain 0.000244, Displacement 0.0661 and Factor Of Safety 3.237. From the two stress values, the padeye structure can be declared safe, because it has not exceeded the yield strength value of the material of 345 MPa.**

Keywords— Subsea Structure, Lifting, Padeye, Strength, Finite Element Method.

I. INTRODUCTION

Indonesia is rich in natural resources on land and down to the seabed. The natural resources that are the largest source of state revenue are oil and gas. The oil and natural gas produced will be sold in the form of cargo and pipelines in the sea, known as pipelines. This system is a transportation system that can deliver enormous amounts of fluid [1]. Along with the development of the times, various technologies have been developed in technology known as offshore activities. In the early 1970s, a concept was created by placing exploration production equipment and all the components inside and then packing it in a closed room. The resulting hydrocarbons then flow from the wells that are equipped with production equipment to the nearest processing facility, both for the processing carried onshore and existing offshore platform buildings. This concept is the beginning of the subsea production system [2]. Subsea Production is a term used to refer to the equipment, technology, and methods used to explore, drill, develop, and operate oil and gas fields that are below the surface of the water. It can be for shallow areas (shallow) or deep sea (deepwater) [2].

Infield Umbilical Termination (IUT) is a part of subsea processing which functions as a terminal for connecting electricity under the sea. Control and good monitoring will be carried out through an electro/hydraulic vortex connected to the Infield Umbilical Termination (IUT). The subsea structure protects the equipment to avoid disturbances such as boat anchors or fishermen's nets. Padeye is one of the objects attached to the object to be lifted. Padeye plays an essential role in lifting activities where the lifting process is carried out. The task of the pedeye is to withstand the heavy weight of an object being lifted in a company that is given the initials PT. Z, has designed the padeye, which is attached to the subsea structure. This padeye is designed to lift and hold the load from a subsesa structure that has been fabricated for loadout purposes and will also be used when laying it in the sea later. Therefore, an analytical study is needed to determine the strength of the padeye structure by determining the value of the stress, strain, factor of safety (FOS), and the node (element).

A. Strength of Steel Plate Structure

The strength of the structural elements and components works vertically or horizontally to withstand the loads that arise. Structural components function to withstand vertical or horizontal forces [3]. The plate is a material with a specially produced rigid structure and is made of a monolithic composition of taller and smaller, which is designed to withstand loads that generally act from various directions and spread. [4].

B. Lifting Process

The lifting process is lifting objects that humans cannot carry out with the capacity of objects of large sizes or offshore building structures. The lifting operation method is used for offshore platform installations, and specialized crane vessels are the most critical activities at sea [5]. The process of lifting, construction, and installation is fundamental. For this reason, understand the lifting calculation because the work depends on the lifting calculation [6]. Lifting is raising or lowering a structure using heavy equipment such as a crane [7].

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The lifting of the deck structure is related to the rigging configuration used and is closely related to the determination of the lift point and spreader bar [8].

C. Subsea Structure

Subsea equipment, technology, and methods used to explore, drill, and develop. Oil and gas fields below the water surface for shallow and deepwater areas, according to the conditions of the oil and gas, exist in the area [9]. Subsea Structure is part of a subsea processing building. This structure is installed and becomes the foundation and protection for underwater oil processing facilities and systems, consisting of several systems such as flowlines and umbilical systems. From this system, gas or oil obtained from gas or oil fields can be channeled easily from under the sea through control systems designed to the sea level, one of which can be transferred to offshore structures such as platforms. or an FPSO ship.

D. Padeye

Padeye, also known as the lifting lug, is part of the construction of a structural building that functions as an auxiliary tool for the lifting process. Padeye is designed based on the load to be lifted. At this design stage, one must follow the standards and pass tests, so there is no failure during the lifting process.

II. Method

A. Data Collection

The data collection method used is a quantitative data collection method. The data obtained is in the form of output data, where the data out can be in the form of padeye design drawings and images of the subsea structure.

The geometry of the padeye also influences the strength of the padeye's FOS (Factor of Safety) planning or not. The shape of the geometry of the padeye affects all aspects of stress, strain, transition, and FOS when lifting [10].

E. Finite Element Method (MEH)

In structural mechanics, the property of materials subjected to nonlinear stresses is considered to cause collapse or creep and the appearance of local buckling. Problems arising in the material become nonlinear due to stiffness, resulting in the load being a transition function or deformation—determination of boundary conditions even for simple problems. The finite element method is complicated in numerical methods, and determining the boundary conditions can be overcome by dividing the continuum into small parts called elements [11].

The matrix equation is solved numerically, and the result answers the given load conditions on the workpiece. The mathematical solution to calculating the inverse matrix is obtained by the equation of the one-element matrix form, and the total matrix is a combination of element matrices [12].

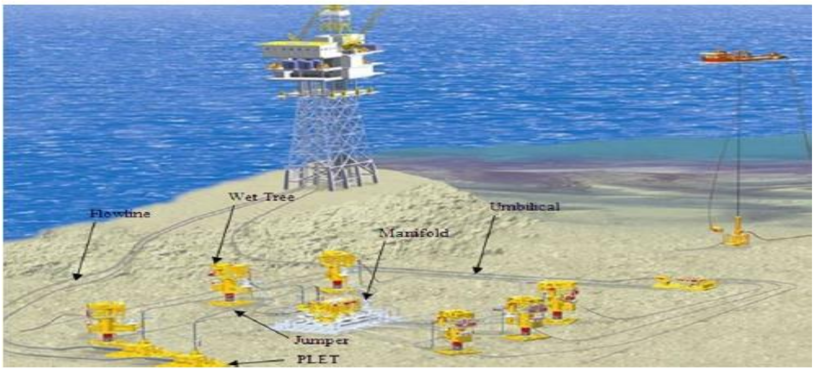


Figure. 1. Subsea Production System [2]

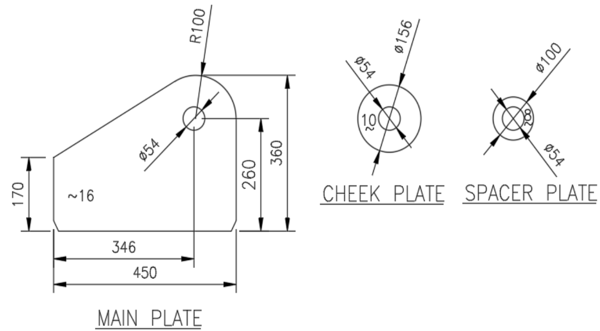


Figure 2 Padeye Design

Figure 2 illustrates the design and size of the padeye that will be installed in the subsea structure building, which consists of the Main Plate (the main structure of the padeye), then the Cheek Plate, and the Spacer Plate.

TABLE 1
BILL OF MATERIAL

Qty	Material	Size (mm)	Total Weight (Kg)
1	Main Plate (16 Thk)	450 x 359	20.35
2	Cheek Plate (10 Thk)	Dia. 156	7.64
4	Spacer (8 Thk)	Dia. 100	2.51

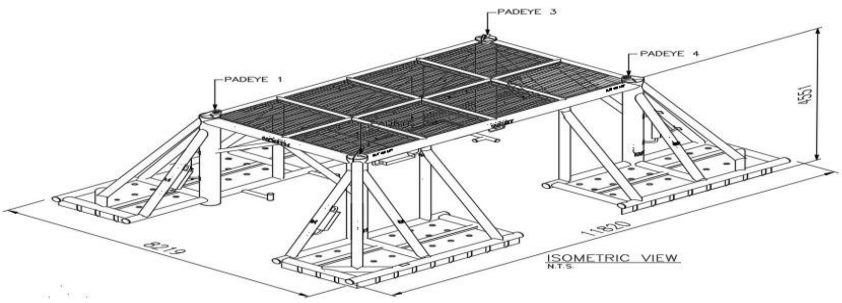


Figure 3 Padeye Position and Size of the Subsea Structure

Table 1 explains the size and weight of each part of the padeye design, which will be installed and will support the load from the subsea structure. The total weight of the padeye structure itself is 30.5 kg.
Four padeyes will be installed on the Subsea Structure. As for the padeye placement position, it will be installed on each foundation or leg. Padeye will be installed at the top of the subsea structure leg, and the size of the subsea structure will be lifted to a maximum length of 11820mm with a maximum width of 8219mm and a height of 4551mm, which is shown in Figure 3.
The total weight of subsea structure has a net weight of 23.02 tons. This weight includes the overall weight of the Subsea Structure.

B. Design Load

In lifting activities, it is not only the load from the individual structure that becomes the burden. Many factors need to be considered in getting the value of the weight to be lifted or received by the padeye. The factors referred to include:

- Static Load
- Dynamic Load
- Additional Load
- Contingency Factors
- Consequence Factors

Each of these loading factors has its criterion value, which has been determined based on the rules of the game, namely DNVGL-ST-N001, which is used as a lifting standard [13].

C. Determining the Value of the Direction of the Sling Force

Newton's third law “For every action, there is an equal and opposite reaction. Alternatively, the reciprocal action of one against the other between two objects is always equal and directed to the opposite side” [14]. Therefore, necessary to calculate the value of the sling force direction used. In contrast, the sling direction criteria which will be used when the simulation are the angles of 60 and 45 degrees. The angle value refers to DNVGL-ST-N001, which explains that the sling angle cannot be less than 45 degrees [13].

D. Padeye Modelling

The analysis was carried out using the help of Solidwork 2015 Software. Previously, a 3D model or design was made of the Padeye shape to be analyzed with dimensions following the Padeye design that has been made as shown in Figure 4.

E. Stress

Stress is the ratio between the compressive force acting on the cross-sectional area of the object. Voltage is formulated as follows:

$$\sigma = \frac{F}{A} \quad (1)$$

where:
F = pull/push force (N)
A = cross-sectional area (m2)
σ = stress (N/m2)

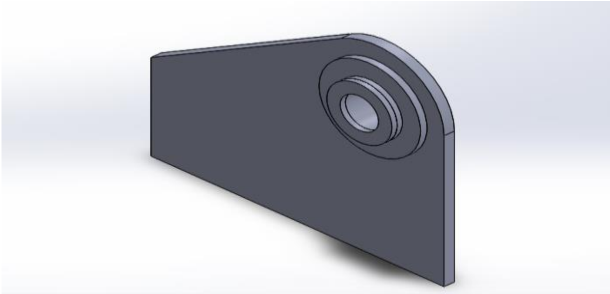


Figure 4 3D Design From Padeye Using Solidwork 2015 Software

F. Strain

Strain is defined as the ratio between the increase in length of the object to its initial length. Strain is formulated as follows:

$$\varepsilon = \frac{Lo - La}{Lo} \quad (2)$$

where:
Lo = Initial Length
La = Final Length
ε = Strain

G. Elastic Modulus (Displacement)

The elastic modulus is often referred to as Young's modulus, which is the ratio between stress and axial strain in elastic deformation. The elastic modulus describes the tendency of a material to change shape back to its original shape when given a load. The modulus of elasticity is formulated as follows:

$$E = \frac{\sigma}{\varepsilon} \quad (3)$$

where:
E = Elastic Modulus
σ = Stress
ε = Strain

H. Factor Of Safety (FOS)

The structure must withstand a load greater than the load that must be received. The actual strength of a structure must exceed the required strength. The ratio of actual strength to required strength is called the factor of safety. The factor of safety is formulated as follows:

$$FS = \frac{\text{yield strength}}{\text{required strength}} \quad (4)$$

where:
FS = Factor of Safety

I. Material Properties

The materials used by padeye use API 2H Grade 50 materials.

TABLE 2
SPECIFICATION OF MATERIAL API 2H GRADE 50

No	Property	Value	Units
1	*Yield Strength*	345	MPa
2	*Tensile Strength*	483-620	MPa

III. Results and Discussion

A. Determination of Load Factor Value (Desain Load).

The values listed in table 3 are the factors that affect conditions during the lifting process. This value refers to the DNVGL-ST-N001 rules. Therefore, the value of this factor will be an added value to the subsea structure load. The value of this factor is also the value of the safety factor, where the multiplication of this value is 2.68, therefore the value of the overall load of the subsea structure is 61.64 tonnes. This value is obtained from the multiplication of the values of all the factors listed in table 3 and then multiplied by the load of the subsea structure itself of 23 tons.

TABLE 3
LOAD FACTOR VALUE

No	Description	Factor Value
1	*Contingency Factor*	1.1
2	*Consequence Factor*	1.3
3	*Skew Load Factor*	1.25
4	*Dynamic Amplification Factor (DAF)*	1.5

B. Sling Force Value

With the action or weight of the subsea structure, with a load weight of 61.64 tons, the same reaction or pull is needed. Knowing the object's mass is 61.64 tons, the object's weight is equal to 61640 kg x 9.81 m /s2 = 604688.4 KN. The results of the object's action and weight obtained for lifting or the required reaction must be the same.

In the Subsea Structure, there are 4 padeyes used. This is because of the shape and COG obtained in the middle of the structure. Therefore, the load from the subsea structure is distributed to the 4 padeyes, with each padeye holding a heavy load of 604688.4/4=151172.1 KN. In this case, apply at a sling angle of 90 degrees.

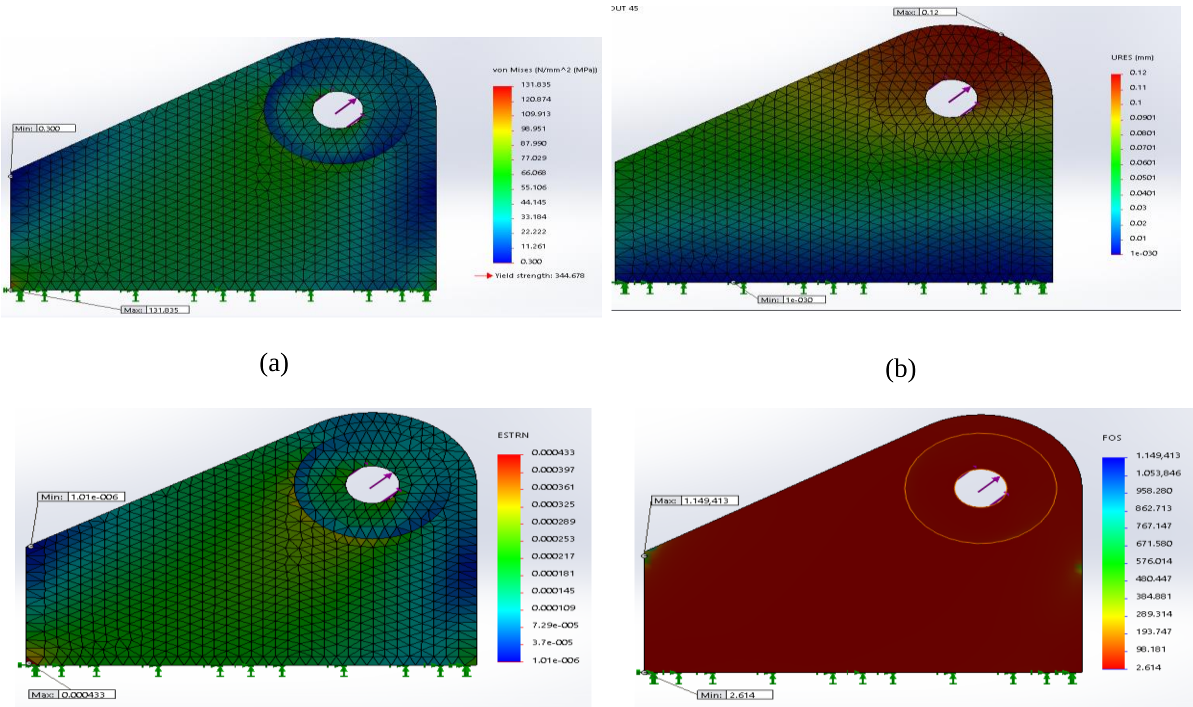
However, in the subsea structure, the sling angle is 60 degrees, so the load or force received from each sling is F=151172.1/sin60= 174558 KN. As for the reaction force needed for an angle of 45 degrees, F=151172 /sin45=213789 KN.

C. Results of Analysis with an Angle of 45°

Figure 5 shows the result of an analysis carried out using the Finite Element Analysis tools from Solidworks 2015.

at node 18413 for the maximum value and 1e- 030 at node 230 for the minimum value.

In this case, the loading on the padeye uses an angle of 45° with the load or force received by padeye of 213789 KN. Obtained for the results of a Stress value of 131.835 MPA at node 230 for the maximum value and 0.300 MPA at node 11412 for the minimum value, then for the Displacement value from the analysis results obtained a value of 0.12 mm at node 179 for the maximum value and 1e- 030 at node 230 for the minimum value. For the value of the strain experienced by padeye from the analysis, results obtained a value of 0.000433 at node 3134 for the maximum value and 1.01e-006 at node 5938 for the minimum value. Furthermore, finally, the value of the factor of safety (FOS) from the analysis results obtained a value of 1149.413 at node 11412 for the maximum value and 2.614 at node 230 for the minimum value. For the value of the factor of safety itself, the smaller the value of the factor of safety obtained, as the best of the results.



(a) (b) (c) (d)

Figure 5 (a) Stress Value, (b) Displacement, (c) Strain, (d) Factor Of Safety (FOS).

D. Results of Analysis with an Angle of 60°

Figure 6 illustrates the result of a loading analysis on the padeye using an angle of 60o with a load or force received by the padeye of 174558 KN. Obtained for the results of a Stress value of 73,628 MPA at node 230 for the maximum value and 0.106 MPA at node 11406 for the minimum value, then for the Displacement value from the analysis results obtained a value of 0.0661 mm

For the value of the strain experienced by padeye from the analysis, results obtained a value of 0.000244 at node 4766 for the maximum value and 4.15e-007 at node 3324 for the minimum value. Moreover, finally, the value of the factor of safety (FOS) from the analysis results obtained a value of 3237 at node 11406 for the maximum value and 4681 at node 230 for the value. For the value of the factor of safety itself, the smaller the value of the factor of safety obtained for the better results.

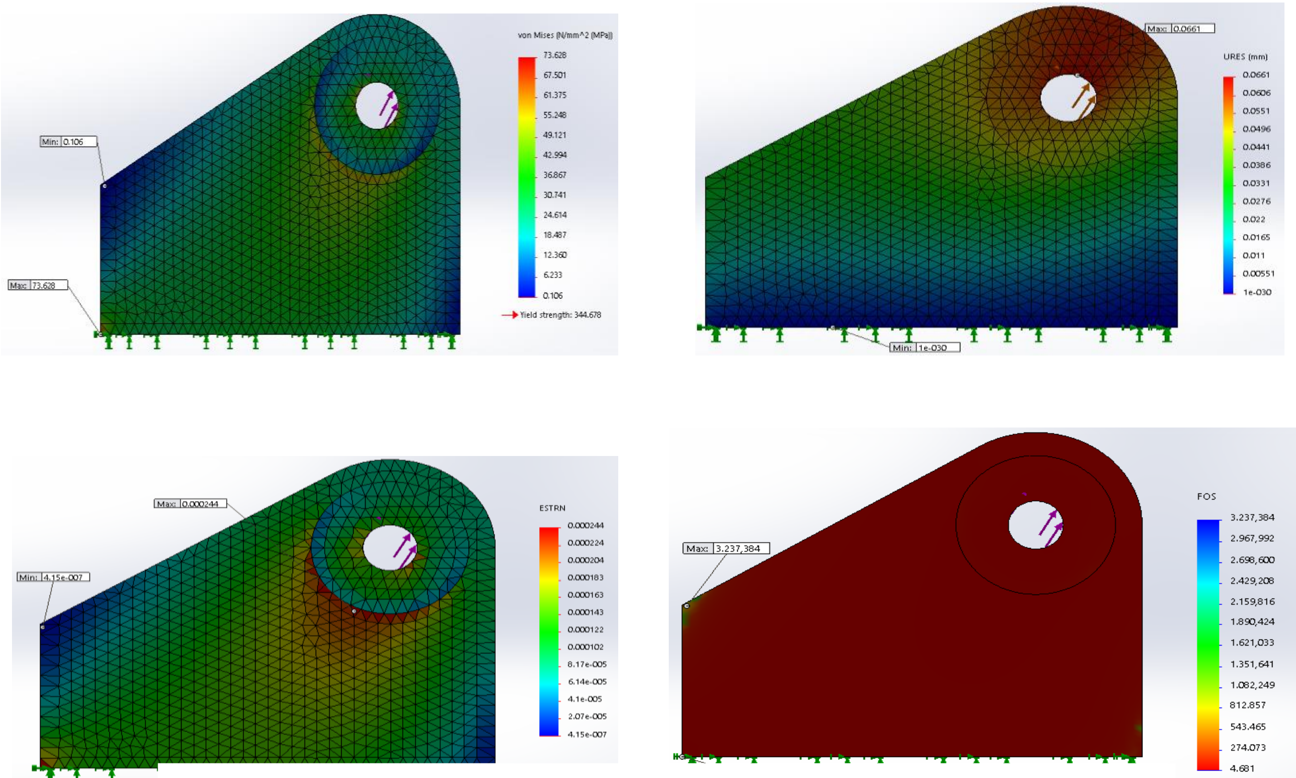


Figure 6 (a) Stress Value, (b) Displacement, (c) Strain, (d) Factor Of Safety (FOS).

TABLE 4
OVERALL SIMULATION RESULTS

ANGLE		Stress (N/mm)	Strain (mm)	Displacement (mm)	FOS
45	max	131.835	0.000433	0,12	1149.413
	min	0,300	1,01e-006	1e-030	2.614
60	max	73.628	0,000244	0,0661	3.237
	min	0.106	4,15e-007	1e-030	4.681

Table 4 shows the simulation results from 45 degrees and 60 degrees angles. From these results, the value of stress for an angle of 60 degrees is smaller than the result of stress experienced by an angle of 45 degrees.

IV. CONCLUSION

The conclusions from the results of the analysis and simulation are as follows:

1. For an angle of 45o, a stress value of 131.835 MPa is obtained at node 230, a displacement of 0.012 mm at node 179, a strain of 0.000433 at node 3134, and a factor of safety (FOS) value of 1149.413 at node 11412.
2. For an angle of 60o, a stress value of 73.628 MPA is obtained. At node 230, the displacement is 0.0661mm at node 18413, the strain is 0.000244 at node 4766, and the factor of safety is 3.237 at node 11406.
3. Padeye's design is stated to be safe for lifting the Subsea Structure. This can be seen from the stress values experienced from the two angles that have not exceeded the yield strength of the material used, which is 345 MPA.

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