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Strength Analysis of Windlass Foundation on Hospital Auxiliary Ship by Using Finite Element Method

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Abstract

Indonesia is a country whose territory consists mostly of waters and islands, to support the health sector, especially for remote and inland areas and disaster emergency response activities, a means of transportation is needed that can cover and serve the area, one of which is the Hospital Auxiliary Ship (BRS). This ship is equipped with hospital facilities and infrastructure equivalent to a Type C Hospital. In its operation, the ship cannot be separated from mooring activities, therefore, the existence of a windlass as a supporting facility for lowering anchor activities is important. The windlass foundation must have optimal strength and efficiency by taking into account the reference or class as the standard used. With these considerations, this research was conducted to determine the optimality of the windlass foundation used by the Hospital Auxiliary Ship, by analyzing the maximum stress value, maximum deflection, and safety factor using the Finite Element Method. The analysis is carried out by providing load variations, namely ship loads and environmental loads. The simulation results will be compared with the calculation results based on Lloyd's Register Rules and Regulation and Biro Klasifikasi Indonesia (BKI) regulations. Reviewing the simulation results due to ship loads and environmental loads when the windlass angle is 0o, the maximum stress is 25.56 MPa, the maximum deflection is 0.01366 mm, and the safety factor is 7.81. Meanwhile, when the windlass angle is 25o, the maximum stress is 23.29 MPa, the maximum deflection is 0.01346 mm, and the safety factor is 8.58. Based on the results of calculations and analysis, it is concluded that several criteria with several angular positions formed by the windlass before and during operation still meet the criteria set by Lloyd's Register Rules and Regulation and Biro Klasifikasi Indonesia.

Keywords: Windlass, Stress, Deflection, Safety Factor.

1. INTRODUCTION

Indonesia has been recognized worldwide as the largest archipelago state that has a strategic geographical constellation. According to the Hydro-Oceanography Center of the Indonesian Navy, Indonesia's waters cover 6,400,000 km2 of the total area of Indonesia's waters and land area of 8,300,000 km2 with a coastline of 108,000 km and a total of 17,504 islands (Hydro-Oceanography Center of the Indonesian Navy, 2018). Thus, a strong defense system is needed in order to maintain the integrity of the Indonesian territory. The Indonesian Navy (TNI-AL) as part of the Indonesian National Army (TNI) plays a major role in sea defense in Indonesia. To support this, one of the elements of strength that must be owned by the TNI-AL is the ship. Some types of ships include warships, patrol vessels, and other supporting vessels. Other types of supporting ships consist of several types, namely Hospital Auxiliary Ships (BRS), Landing Platform Dock (LPD), Tank Transport Ships (AT), Command Ships, and others. Each type of ship has its own role and function, one of which is the Hospital Auxiliary Ship (BRS) which plays a role in carrying out medical operations and evacuation tasks providing humanitarian assistance to people on remote islands and in disaster or war zones.

Windlass on a ship is one of the auxiliary machines that functions to raise or lower the anchor when anchored. The choice of windlass machine is based on several things, including the size of the ship, ship service, losses due to water waves, losses due to friction from the hawse pipe, the size of the anchor and anchor chain. The heavier the anchor weight and anchor chain, the greater the windlass power. Thus, a foundation construction is needed so that the pressure from the windlass power does not go directly to the deck of the ship. Not only internal loads, the windlass foundation is also externally stressed or subjected to environmental loads that affect its structural strength. Such as wind load and current load. If not planned properly, this can cause deflection and result in a reduction in the strength value of the windlass foundation. Therefore, an optimal and efficient windlass foundation construction strength is required to withstand ship and environmental loads to support ship operations, especially in the mooring process.

Based on these problems, the strength of the appropriate windlass foundation structure is analyzed due to ship loads and environmental loads, namely when the windlass is at rest and in operation. In modeling using software assistance in the modeling process and analysis with the finite element method, so that the results of the analysis of the optimality of the strength of the windlass foundation construction when exposed to ship loads, environmental loads, or a combination of both loads in the form of maximum stress values, maximum deflection values, and safety factors that meet the regulations of Lloyd's Register Rules and Regulation and Biro Klasifikasi Indonesia will be obtained.

2. METHOD

The type of research applied in this final project is quantitative research, where quantitative methods are research methods based on the philosophy of positivism, which are used to examine certain populations or samples, which are generally randomly sampled, and data are collected using research instruments, then analyzed quantitatively / statistically with the aim of testing predetermined hypotheses (Sugiyono, 2009). Activities begin with problem identification, problem formulation and viewing and studying related literature, followed by collecting related data (General Plan, Construction, windlass specifications, anchors, and anchor chains).

After obtaining the main data of the ship, the calculation of the load experienced before and during operation by looking at the real loading conditions in the field and the windlass foundation design process is also carried out with the dimensions or sizes used by using the software. The modeling process with the help of numerical software-Finite Element Method is carried out after the input of loading data, loading conditions and foundation design drawings have been completed.

PRINCIPAL PARTICULARS

LENGTH OF ALL (LOA)	abt.	124. 000 m	
LENGTH BETWEEN PERPENDICULAR (LBP)	abt.	107. 450 m	
BREADTH	abt.	21. 800 m	
DEPTH (B.L. TO MAIN DECK)	abt.	6. 700 m	
DRAFT	abt.	5. 000 m	
SPEED (MAX)	18.00		knots
(CRUISING)	14.00		knots
OPERATING RANGE	10,000		nm
MAIN ENGINE AT MCR	2 sets x abt. 5400 kW		

Figure 2.1 Principal Particular of Hospital Auxiliary Ship

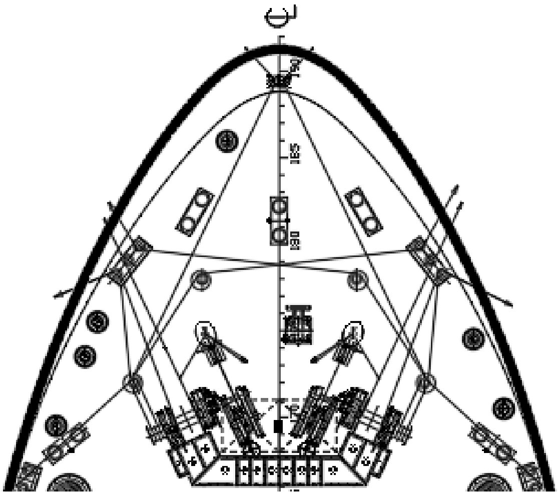

Figure 2.2 General Arrangement Drawing of Hospital Auxiliary Ship

From the general arrangement drawing above, the next is modeling related to the main research object, namely the windlass foundation structure where this activity begins by determining the dimensions or size of the windlass foundation shown in Figure 2.3, drawing with software followed by analysis using the finite element method to obtain results and data analysis.

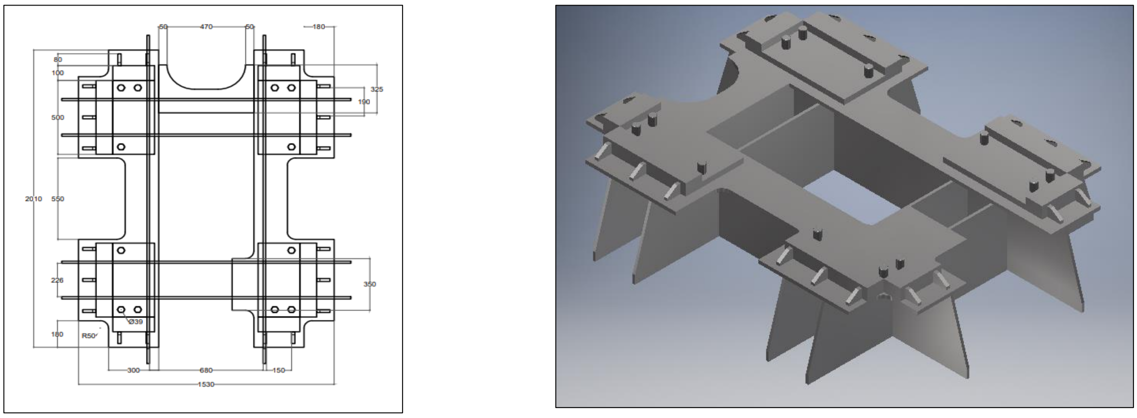

Figure 2.3 2D and 3D Model of Windlass Foundation Top View

3. RESULT AND DISCUSSION

3.1 Load Calculation

The load calculation process carried out in this analysis is internal loading derived from the condition of the ship itself and external loads originating from outside or the environment. The ship loads or internal loads referred to here consist of windlass loads, anchors, and anchor chains in idle windlass conditions and operating windlass conditions. When the windlass is stationary, the angle formed by the anchor and chain is 0^0 and when the windlass is operating, the working angle of the anchor and anchor chain is 25^0 both on the y-axis (vertical) and x-axis (horizontal). The determination of the amount of angle formed is adjusted to the approach obtained when the ship's windlass is stationary and operating. The environmental load or external load in question consists of wind load and current load in its operation in traveling in Indonesian waters.
According to Lloyd's Register Rules and Regulation 2018, Classification of Ships, Part 7 Other Ship Types and Systems, Chapter 8, Section 5, Point 5.6, the safety factor value used for windlass loading design in this study is 1.25. The following is the total load received by each leg of the windlass both on the Portside and Starboard under 0^0 and 25^0 angle conditions in the vertical (y) and horizontal (x) axes :

No	Condition	Load Value (N)
1	$F_{total\ angle\ 0^o\ (y)}$	-7729,09
2	$F_{total\ angle\ 0^o\ (x)}$	30518,3
3	$F_{total\ angle\ 25^o\ (y)}$	-20626,66
4	$F_{total\ angle\ 25^o\ (x)}$	27658,96

Simulation

Assign Materials is the first stage before simulation. The type of material used by the windlass foundation is Mild Steel Grade A, SS 400/ASTM A36. The stress value of Mild Steel Grade A material is yield strength = 235 N/mm^2, tensile strength = 400 N/mm^2, density = 7850 kg/m^3, this is the initial input process in determining the type and property of the material to be used. After determining the material used, the next process is determining the Boundary condition which is the boundary condition in accordance with the real conditions of the model working in the field. In the windlass foundation model, there is a fixed constraint at the bottom face position of the windlass foundation where the load works axially from the weight of the windlass itself and its operations that are exposed to environmental or external influences, this is obtained by directly observing the conditions in the field.

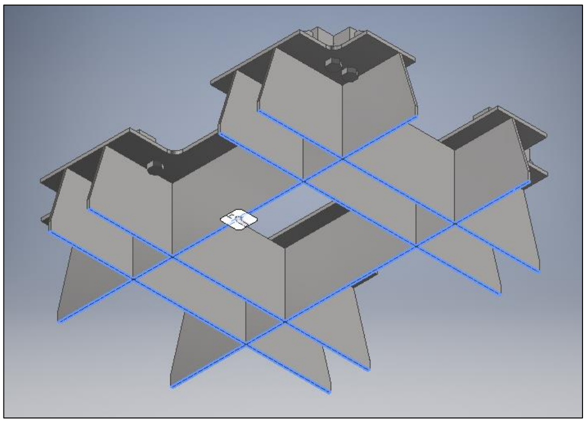

Figure 3.1 Boundary Condition of Windlass Foundation

Meshing is the process of dividing the component to be analyzed into small or discrete elements. This stage will greatly affect the results of the analysis, because the meshing results will determine the calculation in small components with predetermined accuracy. To determine the meshing size to be used in this analysis, a convergence test is conducted. Convergence is one of the ways used to select the right element size in finite element modeling so that the model produces valid values. In this study, using a tetrahedral meshing element shape with an element size of 0.1 mm. The convergence test results can be seen in the following table and Figure 3.1:

Iterasi	*Size Meshing (mm)*		Jumlah *Element*	Tegangan Von Mises (MPa)
	Average	*Minimum*		
0	0,8	0,4	53007	4.9
1	0,5	0,4	53905	4.269
2	0,3	0,4	56461	4.004
3	0,1	0,4	72399	4.026
4	0,09	0,4	85511	4.365
5	0,08	0,4	113289	4.242

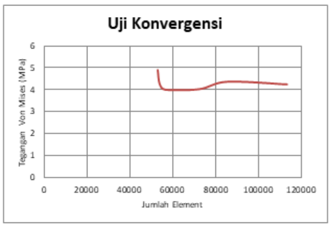

Figure 3.2 Convergence Test Result Table dan Convergence Test Graph

The next simulation is the result process, namely further analysis by Running Finite Element Analysis with data input that has been input previously with several final results in the form of Stress and Deformation values. The results of the foundation simulation when exposed to ship and environmental loads both when the windlass is stationary and working conditions can be seen in the following figures 3.3 and 3.4.

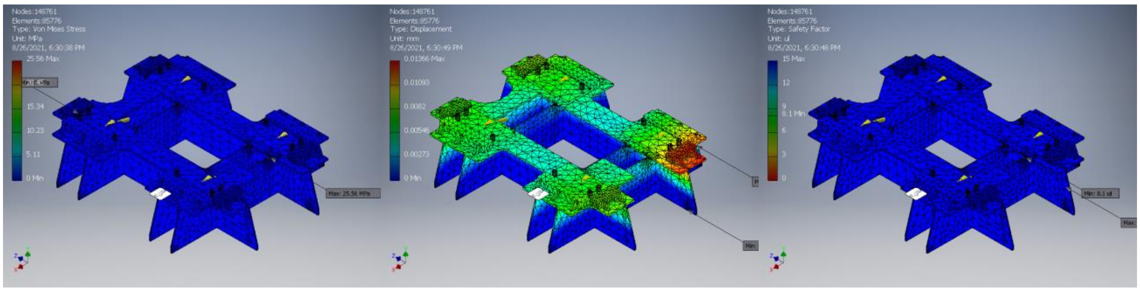

Figure 3.3 Stress Analysis, Deformation, and Safety Factor Windlass Foundation 0^{o} Angle Condition

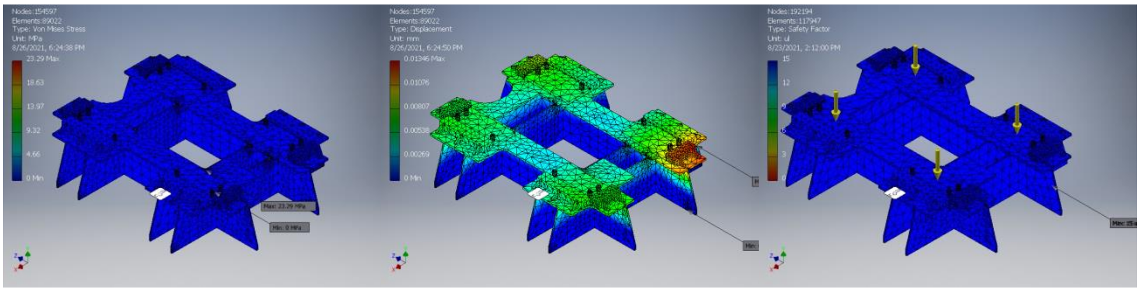

Figure 3.4 Stress Analysis, Deformation, and Safety Factor Windlass Foundation 25^{o} Angle Condition

Based on Figure 3.3 above, it is known that the maximum stress value due to ship loads and the environment in the 0o angle windlass condition is 25.56 MPa and the minimum stress is 0 MPa. The maximum stress result is still below the allowable stress value (σallowable) determined according to Lloyd's Register (LR) of 199.75 MPa, Biro Klasifikasi Indonesia of 190 MPa, and the general equation of 188 MPa. Based on Figure 3.4 above, it is known that the maximum stress value due to ship loads and the environment under 25o windlass angle conditions is 23.29 MPa and the minimum stress is 0 MPa. The maximum stress result is still below the allowable stress value (σallowable) which has been determined according to Lloyd's Register (LR) of 199.75 MPa, Biro Klasifikasi Indonesia of 190 MPa, and the general equation of 188 MPa. From the analysis of the results (figures 3.3 and 3.4) it can be concluded that the analysis of the simulation results with the calculation of the allowable limits according to Lloyd's Register (LR) and the Biro Klasifikasi Indonesia (BKI). can be seen in tables 4.1, 4.2, 4.3, and 4.4 as follows:

Table 4.1 Maximum Stress Limit Checking According to LR

No.	Condition	σ_{actual} (Mpa)	$\sigma_{ultimate}$ (Mpa)	Safety Factor	Status
1.	Windlass Angle 0^{o}	25,56	199,75	7,81	Meet
2.	Windlass Angle 25^{o}	23,29	199,75	8,58	Meet

Table 4.2 Maximum Deflection Limit Checking According to LR

No.	Regulation	$\Delta_{f\ max}$ (mm)	$\Delta_{f\ ult}$ (mm)	Status
1.	Windlass Angle 0^{o}	0,01366	0,544	Meet
2.	Windlass Angle 25^{o}	0,01346	0,544	Meet

Table 4.3 Maximum Stress Limit Checking According to BKI

No.	Condition	σ_{actual} (Mpa)	$\sigma_{ultimate}$ (Mpa)	Safety Factor	Status
1.	Windlass Angle 0^{o}	25,56	190	7,43	Meet
2.	Windlass Angle 25^{o}	23,29	190	8,16	Meet

Table 4.4 Maximum Deflection Limit Checking According to BKI

No.	Regulation	$\Delta_{f\ max}$ (mm)	$\Delta_{f\ ult}$ (mm)	Status
1.	Windlass Angle 0^{o}	0,01366	0,2814	Meet
2.	Windlass Angle 25^{o}	0,01346	0,2814	Meet

4. CONCLUSION

The loading condition of the windlass foundation on the 124 m Hospital Auxiliary Ship or Kapal Bantu Rumah Sakit (BRS) due to ship loads and environmental loads in both the 0o angle windlass condition at rest and the 25o angle when operating in the form of maximum stress value, maximum deflection value and

Safety factor value has met the provisions set by Lloyd's Register (LR) and Biro Klasifikasi Indonesia (BKI). The results of the analysis of maximum stress, maximum deflection and safety factor are sequentially obtained when the windlass angle of 0o conditions obtained a maximum stress of 25.56 MPa, maximum deflection of 0.01366 mm, and a safety factor of 7.81. When the windlass angle is 25o, the maximum stress is 23.29 MPa, the maximum deflection is 0.01346 mm, and the safety factor is 8.58. So from the results of the above analysis, it can be said that the windlass foundation on the 124 m Hospital Auxiliary Ship or Kapal Bantu Rumah Sakit (BRS) under the above conditions still meets the maximum standards of stress, deflection, and safety factor set by the BKI and LR classification bodies.

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