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Finite Element-Based Structural Evaluation of a Rescue Boat Crane Mount on LCT 153 Vessel

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Abstract

Rescue operations onboard marine vessels rely on effective and reliable deployment mechanisms for rescue boats, particularly in emergency scenarios. Cranes are commonly installed to assist in lowering rescue boats, but their performance depends greatly on the strength and reliability of their mounting systems. This study investigates the structural performance of a rescue boat crane mounting system on an LCT 153 vessel using finite element analysis. The problem addressed in this research is the lack of quantitative data on how different crane configurations affect the structural integrity of their mounting base under operational loads. Two crane models with different outreach and load specifications were assessed to identify the most structurally efficient option. Stress distribution and deformation were simulated using 3D models and meshed at various sizes to ensure convergence accuracy. The results revealed that the configuration with a 6-meter outreach generated lower stress (19.69 MPa) and deformation (0.004 mm), while the 7-meter alternative showed higher values. The findings contribute to safer and more efficient crane mounting designs and serve as a reference for shipyards in selecting appropriate equipment based on load performance and structural reliability.

Keywords: finite element analysis; crane foundation; landing craft tank; rescue boat mechanism.

1. Introduction

In Indonesia, people and goods' mobility is largely dependent on maritime transportation, the largest archipelagic nation in the world [1]. The crane, a tool used to lift and move heavy machinery like ship engines, steel structures, and other vital loads, is one of the most important parts of shipbuilding and maritime operations [2]. Depending on the job and area of the yard, shipyards frequently use a variety of crane types, including gantry cranes, tower cranes, overhead cranes, and boat cranes [3].

As a result of developments in industrial technology, cranes are now integrated onboard ships for operational needs in addition to use during shipbuilding [4]. One important use is in the distribution of rescue boats during crisis evacuation. The strength and design of the mounting structure, which must securely withstand the operational loads under marine conditions, greatly influence the size and type of rescue boat crane installed [5].

Directly linked to deck or hull constructions, crane foundations or mounting systems aboard ships must be able to transfer the operational loads without endangering the ship's integrity [6]. Therefore, designing a crane mounting system calls for careful engineering standard-based analysis to guarantee functionality and safety [7]. The finite element method (FEM), which helps engineers to forecast stress distribution and deformation under load, is a generally used technique for studying such structural elements [8].

Previous work using FEM has looked into the structural analysis and design of several kinds of cranes. For instance, Zhao [9] carried FEM-based simulations on trolley crane components while Fard et al. investigated the structural behaviors of an offshore sheerleg crane [10]. Meanwhile, Gerdemeli and Kurt concentrated on gantry crane construction [11]. Although very few studies have focused on the mounting structures of boat cranes —

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especially in relation to LCT-type vessels—these studies mostly address the crane structures themselves or their main load-bearing elements [9].

Therefore, this work uses finite element analysis to investigate the strength of the rescue boat crane mounting structure on the LCT 153 vessel. A few studies have concentrated on the structural basis of rescue boat cranes [12] - [14], and the performance under different crane configurations is not well known [15]. By means of two crane alternatives and stress and deformation analysis-based determination of the best choice, this work intends to close that gap [16], [17].

2. Experimental Methods

In this research, a systematic approach is employed to analyze the strength of the rescue boat crane mounting structure of the LCT 153 vessel. The analysis was carried out based on the FEM with the aid of three-dimensional modeling and simulation. The research steps are as follows.

2.1. Literature Review and Field Study

A literature study was conducted to get references from previous researchers on crane structures, finite element analysis, and marine safety devices. A field survey was also conducted at a shipyard on the northern coast of Gresik Regency to gather vessel information, information on rescue boats, and crane alternatives considered for installation.

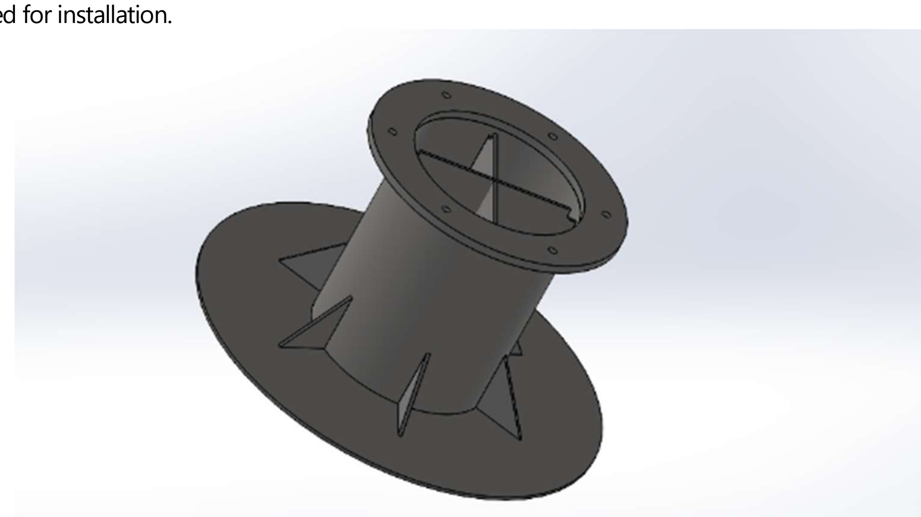

Figure 1. Rescue boat crane mounting structure

2.2. 3D Modeling of the Mounting Structure

A 3D design model of the rescue boat's crane mounting structure was developed with the help of finite element analysis (FEA)-based design software. The model is a geometrical representation of the crane base and is used for subsequent simulation. The geometry includes interface connections with the ship deck and significant structural details that are necessary for load transfer. To replicate the interaction between the crane and the ship's deck, a three-dimensional model of the rescue boat crane mounting structure was created. The actual configuration and design drawing utilized for the finite element analysis is represented by the overall geometry, as seen in Figure 1 and 2.

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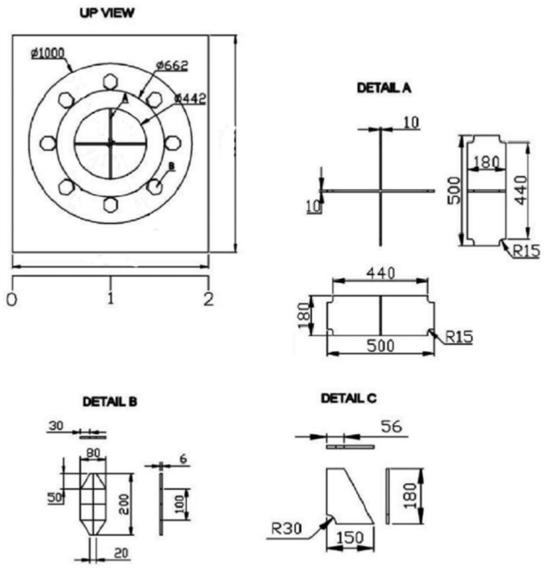

Figure 2. Crane mounting design drawing

2.3. Selection of Crane Alternatives

Two alternatives of cranes were selected to compare: SWL 1.6T6 m and SWL 1.6T7 m. Both cranes differ in reach, capacity, and mechanical options. They were selected to compare the effect of the crane design on the structural behavior of the mounting base. Options are working radius, load moment limitations, motor power, and slewing angles. To support the selection of the most appropriate crane configuration, a comparative assessment of the technical specifications for both crane alternatives was conducted. The detailed specifications for Crane Alternative 1 and Alternative 2 are presented in Table 1 below.

Table 1. Specifications of crane alternatives 1 and 2

No.	Specification	1.6T6 m	1.6T7 m
1	Max. working radius	6 m	7 m
2	Min. working radius	2 m	1 m
3	Hoisting speed	0-15 m/min	-
4	Hook travel	25 m	-
5	Slewing speed	0-0.8 r/min	-
6	Slewing angle	360 free	395 limited angles
7	Luffing time	35s	-
8	Luffing angle	0-75°	-
9	Design temperature	-20 to +45°	-10°C to +40°C
10	Working condition	TRIM≤2 HEEL≤5	TRIM≤2 HEEL≤5
11	Deadweight	1600 kg	1833 kg
12	Motor	Power: 11 kW Speed: 1450 r/min	Power: 14 kW Speed: 1600 r/min
13	Advised oil Flow	25 L/m	-
14	Certification	IACS certification, RINA	RINA
15	Price range	Rp 51.031.500,00	Rp 32.412.000,00

2.4. Material Assignment

The structure is constructed of ABS Grade A steel, which is commonly used in marine conditions. The material parameters employed in the simulation were [18]:

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-Density: 7.850 kg/m³
-Poisson's ratio: 0.35
-Yield strength: 235 MPa
-Ultimate tensile strength: 517.1 MPa

2.5. Boundary Conditions and Loading

The boundary condition applied was an imposed constraint of a constant along the interface between the ship's deck and the mounting structure to simulate real operational limits. The loads applied were:

-Dead weight of crane: 1,600 kg (Alt. 1) and 1,833 kg (Alt. 2)
-Safe working load (SWL): 1,600 kg
-Total vertical load: 31,360 N (Alt. 1) and 33,643 N (Alt. 2)
-Applied moment: 40,246.5 Nm (Alt. 1 with 6 m arm), and 46,954.25 Nm (Alt. 2 with 7 m arm).

To mimic the limitations imposed by the ship's deck, fixed boundary conditions were applied at the base of the mounting structure in the simulation setup. Figure 3 shows the boundary conditions used.

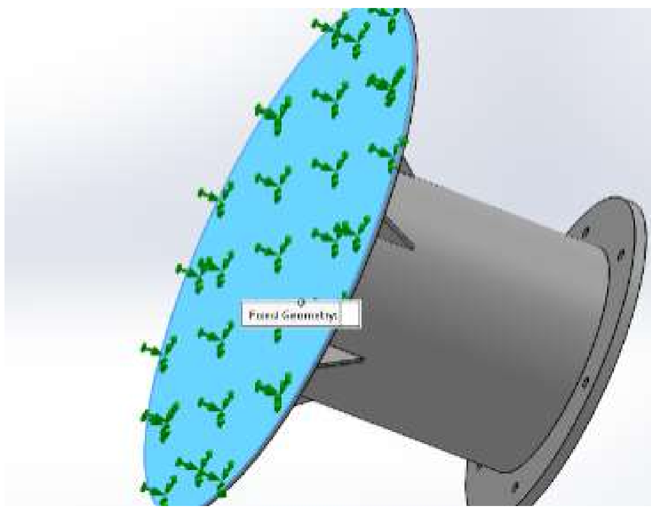

Figure 3. Rescue boat crane mounting boundary condition

2.6. Simulation and Analysis

The model was discretized through meshing techniques with different mesh sizes (30 mm to 10 mm) for convergence. Finite element computations were carried out to obtain the stress distribution and deformation under conditions of loading for both crane options.

2.7. Crane Selection

Based on the simulation results, the most suitable crane option with the best structural response — minimum stress and deformation — was selected as the most appropriate option to be installed on the ship LCT 153.

3. Results and Discussion

By simulating two crane alternatives using the FEM, this study examines the structural performance of the rescue boat crane mounting structure on the LCT 153 vessel. In order to identify the best crane configuration, the assessment focusses on stress distribution and deformation.

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3.1. Vessel and Rescue Boat Specifications

The LCT 153 vessel's main dimensions are as follows: draft of 2.35 m, depth of 3.05 m, breadth of 12.65 m, length overall (LOA) of 46.52 m, and length between perpendiculars (LBP) of 40.94 m. Its service speed is 10 knots. The study's rescue vessel is a 3D Tender A430 model with design category C, which is 4.30 m long and 1.87 m width, can accommodate six people, and can carry a maximum load of 684 kg.

3.2. Material and Load Input

ABS Grade A steel was selected as the material for the crane mounting structure due to its common use in marine applications and compliance with classification society standards. This steel type has a yield strength of 235 MPa and an ultimate tensile strength of 517.1 MPa, based on marine-grade structural steel data. In this analysis, two crane models were assessed.

- Alternative 1: SWL 1.6T6 m, with a 6-meter of maximum reach
- Alternative 2: SWL 1.6T7 m, with a 7-meter of maximum reach

The total vertical load applied includes both the crane's dead weight and the safe working load (SWL). It is assumed that both cranes and its operational load are acting simultaneously in the worst-case static loading scenario (no dynamic amplification applied). This condition represents a conservative design approach. The following assumptions were made: the SWL is applied as a point load at the maximum reach of the crane arm, and the crane's self-weight acts concentrically on the mounting point.

- Alternative 1: 31,360 N (1,600 kg SWL + 1,600 kg dead weight)
- Alternative 2: 33,643 N (1,600 kg SWL + 1,833 kg dead weight)

To compute the applied moment on the mounting base, it was assumed that the full operational load (rescue boat and crane hook) acts at the maximum crane radius. The rescue boat's weight of 684 kg was multiplied by the respective outreach:

- Alternative 1: 684 kg × 6 m = 40,246.5 Nm
- Alternative 2: 684 kg × 7 m = 46,954.25 Nm

3.3. Finite Element Analysis and Convergence Study

A mesh convergence study was carried out using different mesh sizes ranging from 30 mm to 10 mm in order to guarantee precise and reliable simulation results. Table 2 provides a summary of the maximum stress values that resulted for each mesh size and crane option.

Table 2. Maximum stress values for different mesh sizes

No.	Mesh size	Max stress alternative 1	Max stress alternative 2
1	30 mm	21. 83 MPa	29.28 MPa
2	**25 mm**	**19.69 MPa**	**26.78 MPa**
3.	20 mm	22.66 MPa	32.08 MPa
4.	15 mm	33.01 MPa	53.56MPa
5.	10 mm	29.72 MPa	40.07 MPa

The mesh convergence test yielded consistent results, as shown in the Table 2, with the 25 mm mesh size producing the best surface quality and the smallest deviation when compared to other mesh sizes. Figure 4 display the findings of the stress analysis for each crane option.

Alternative 1's stress at 25 mm mesh is significantly lower than the material's yield strength (235 MPa), yielding a safety factor of about 12. Furthermore, the results of the deformation revealed:

- Alternative 1: 0.004 mm
- Alternative 2: 0.008 mm

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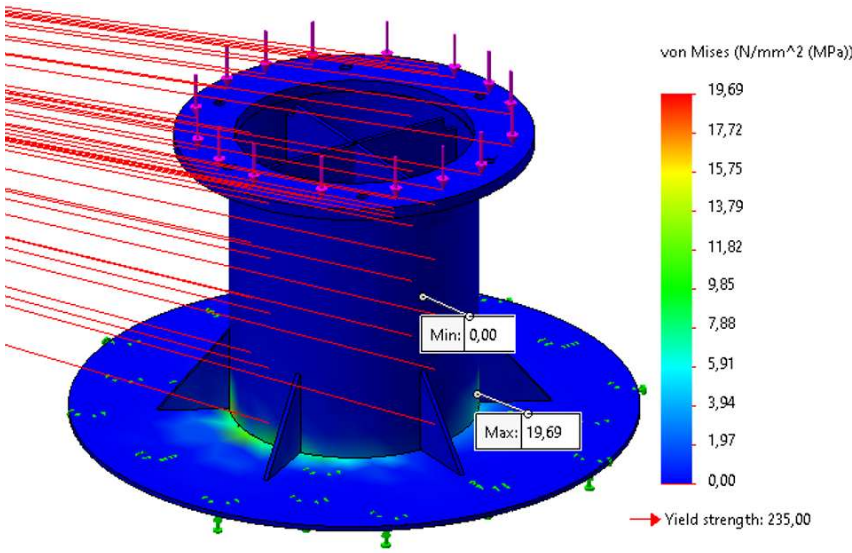
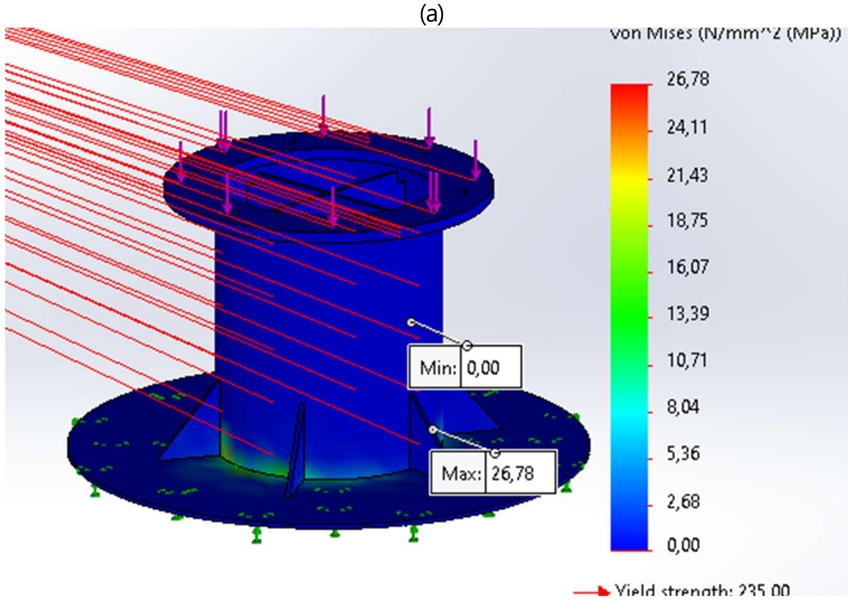


(a)



(b)

Figure 4. Stress distribution analysis of crane with 25 mm mesh size (a) alternative 1 and (b) alternative 2

3.4. Manual Stress Calculation Comparison

To validate the finite element simulation results, manual calculations of von Mises stress were performed for both crane alternatives. For alternative 1, the manually calculated stress was 19.74 MPa, compared to 19.69 MPa from the simulation, yielding a negligible error of 0.2%. For alternative 2, the manual result was 25.62 MPa, versus 26.78 MPa from simulation, with a slightly larger error of 4.5%. These small discrepancies confirm the reliability of the finite element modeling approach used in this study.

3.5. Structural Performance Evaluation

The simulation results indicate that the highest stress concentration occurred in the lower portion of the mounting structure, specifically at the transition between the cylindrical base and the deck plate interface. Among

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the two crane configurations evaluated, alternative 1 (SWL 1.6T6 m) exhibited more favorable performance, with significantly lower stress (19.69 MPa) and deformation (0.004 mm), making it the safer and more structurally efficient option. Compared to prior studies on crane structures and supports—such as Gerdemeli and Kurt, who analyzed gantry crane behavior, and Zhao, who simulated crane trolleys—this research uniquely focuses on the mounting structure of a rescue boat crane in a real-world LCT vessel application [11], [9]. Unlike the broader structural evaluations in offshore or industrial crane settings, our study highlights the critical influence of outreach variation on the mounting base stress profile in a marine safety context. The integration of static load assumptions with simulation validation also adds practical value for shipyards during equipment selection and foundation design.

4. Conclusion

This study has shown that the structural performance of a rescue boat crane mounting structure on the LCT 153 vessel can be efficiently assessed using finite element analysis. The mounting structure for the 1.6T6m crane (Alternative 1) showed less stress and deformation than the 1.6T7 m crane (Alternative 2) when two crane configurations with distinct reach and load characteristics were compared. The findings, which were verified by hand computation, attest to the chosen mounting design's safe compliance with structural specifications under operating loads. By offering a comparative method based on real stress and deformation data, this study helps to improve crane mounting design practices. Shipyards can use the methodology and results as a guide when choosing crane systems that guarantee structural integrity and operational effectiveness. To increase its applicability, future research might expand this analysis to include dynamic load conditions or different kinds of vessels.

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