Finite Element Analysis and Topology Optimization Design of Anchor Mooring Winch Support Bracket

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Abstract. The weight of the deck machinery greatly affects the position of the small ship's center of gravity so that it also affects the stability of the ship. Therefore, it is necessary to conduct optimization studies to reduce the weight of ship deck machinery, especially anchor mooring winch, by reducing the weight of ship deck machinery will lower the position of the center of gravity of ship so that can improve ship stability. This paper presents the effects of a topology optimization examination based on the finite element evaluation on anchor mooring winch support bracket using the SolidWorks Simulation module. The main intention to examine is to optimize the general weight of the anchor mooring winch support bracket via way of means of thinning specific regions of the anchor mooring winch support bracket in keeping with the calculated minimum strain energy. The topology optimization algorithm that is used in the current study gives an optimal structural shape of the support bracket of the anchor mooring winch with the largest stiffness, considering the given quantity of mass so that it will be eliminated from the preliminary layout space. The complete sequence of steps for carrying out the topology control optimization study is shown, taking into account the constraints arising from the construction features and the method of manufacturing the support bracket of the anchor mooring winch. The layout became carried out, and the effects have been provided via way of means of evaluating the preliminary version and the optimized version. As the result of topology optimization study, its stress was increased by about 4MPa and mass was reduced by about 15kg in comparison with the initial design.

1. Introduction
Anchor mooring winch is a tool designed to hoist or lower an anchor, it includes a horizontal barrel that is fitted with equipment like projections (cable lifter) that interact with the links of the anchor chain[1]. Anchor mooring winch is one of the essential machinery, which means that if the auxiliary machinery fails during operation, it will cause delays in the shipping process and can cause a large commercial impact. Therefore, the anchor mooring winch’s support bracket must have high structural integrity and good dynamic performance in order for the anchor mooring winch to be reliable. In the last few decades, finite element analysis (FEA) and experimental research have been used to investigate and improve the performance of hydro press frame. [2]. Suryo et al.[3]design and analysis of bucket tooth excavator. An optimized shape is finished through changing the disc type structure at the side of central drum through arm type supporting structure. Stoyan[4] The housing elements of a two-stage reducer topology optimization layout can be completed utilizing the topology optimization principle and SolidWorks Simulation software program. Songr et al. [5] optimizes the shape of the windlass base frame, not only can enhance its performance, however additionally to gain the reason of lowering energy consumption.
Guan et al.[6] applies the finite element evaluation and topology optimization examine to the 12000KN fine blanking press body with Altair Hypermesh software. Furthermore, the optimum design of the anchor mooring winch support bracket may be regarded as a continuum structure optimization problem. In this regard, the current research aims to demonstrate a new approach for the most economical design of anchor mooring winches that optimizes the distribution of material within the support bracket of the winch while retaining its stiffness. Anchor mooring winch support bracket currently in use are designed with large volumes and high costs to achieve high rigidity even under large external loads. In this study, it is the purpose of the purpose to derive a conceptual layout of the most suitable form which can fulfil the excessive stress and structural weight that the existing Anchor mooring winch support bracket has at the same time. Based on the finite element resolution of the initial version according to the phase optimization, dimensional optimization techniques were applied to proceed with the conceptual design and compared to the initial model and the optimized model as a result.

2. Methods
This study's method includes 3D modelling support bracket of anchor mooring winch using SolidWorks 3D CAD, modelling support bracket of windlass using the finite element method in meshing, linear static analysis, and topology optimization study using software SolidWorks Simulation.

2.1 Modelling of Anchor mooring winch Support Bracket
Figure 2 (a) shown the support bracket used in this study was the support bracket of anchor mooring winch 46K3 with chain stoppers. Figure 2 (b) shown the 3D mmodeling of support bracket design using CAD program from the initial geometry. Solidworks 3D CAD is program used to model the support bracket.

![Figure 1](image)

(a) Anchor mooring winch 46K3 with chain stoppers [7] (b) 3D design of anchor mooring winch support bracket

2.2 Boundary Condition
The finite element study is executed withinside the SolidWorks Simulation module. The element type used is parabolic tetrahedral solid elements. The vertical load direction is 23544N, calculated from gross self-weight of anchor mooring winch and 75000N for horizontal Force, acting parallel to the shaft axis, and the bottom is constrain fixed illustrated in figure 2b, the boundary condition is reference to Bureau Veritas Rule Note NR 626 Anchor Windlass as shown in figure 2(a) [8]. The finite element model of existing Anchor mooring winch support bracket consists of 31896 elements and 55314 nodes with detail mesh as shown in figure 3. The original volume of existing anchor mooring winch support bracket is 14681524.20 mm3.
2.3 Material
Because the anchor mooring winch support bracket component will be fabricated by welding, the material SM490 was chosen as a material for the Finite Element Analysis Model. It is a common material in winches because it has enough structural rigidity and vibration damping qualities. The mechanical properties of the SM490 material used in the model were as follows: young modulus = 210 (GPa); Poisson’s ratio = 0.266; mass density = 7800 (kg/m³); yield strength = 355 (MPa).

2.4 Defining goals and constraints of the support bracket model
The optimization goal and the geometric constraints can be controlled with the Goals and Constraints Property Manager of SolidWorks Simulation, which can drive the mathematical formulation of the optimization algorithm [9]. When the “Best Stiffness to Weight ratio” choice is selected, the algorithm attempts to lower the model's global compliance, which is a measure of its overall flexibility (reciprocal of stiffness). Two restrictions for one optimization target can be defined at the same time in SolidWorks Simulation [9]. To obtain a considerable mass savings compared to the baseline design, the option "Best Stiffness to Weight Ratio" with a 30% mass reduction was chosen for the current investigation (i.e., carried out settings through default). With this option, the taken into consideration support brackets'
preliminary mass of 115.25 (kg) can theoretically be reduced to 80.67 (kg) following topology optimization (or by 30%).

2.5. Defining the Manufacturing Controls
The optimization study can develop a design that satisfies the optimization goal and any geometric constraints you outline. However, the layout of support bracket can be not possible to create the use of preferred production techniques, such as casting and forging. Applying right geometric controls prevents opportunity of the formation of undercuts and hollow parts. There are four different types of manufacturing controls in SolidWorks Simulation. The following are some of them[10]:

- Preserved Region Property Manager, this feature can add preserved areas to initial geometry that will not be changed at some point of topology optimization.
- De-mold Control Property Manager, this feature can define de-mold controls to make certain that the optimized layout is manufacturable and may be extracted from a mold.
- Symmetry Control Property Manager, this feature can make the optimum layout symmetrical around a specific plane. For an optimum arrangement, this feature can also enforce a half, quarter, or eighth planar symmetry.
- Thickness Control Property Manager, this feature can observe member size restrictions for a topology optimization that prohibits the creation of areas that difficult to manufacture.

The depth of all the preserved areas with a view to continue to be unchanged throughout optimization turned into set to 20 mm, in line with to the recommended minimal thickness of the side walls for SM490 plate.

3. Results and Discussion
3.1. Linear Static Analysis Result of Existing Support Bracket
Linear static research is carried out to obtain the Von Mises value of design with the carried-out material from the identification results in order to determine whether the material employed does not fail and may be optimized[11]. Figure 9 shown the results of linear static study of anchor mooring which support bracket. The maximum Von Mises value generated on linear static study is 123.60 MPa.

![Figure 4](image_url)

**Figure 4.** (a) Von Mises stress result of initial support bracket (b) Deformation result of initial support bracket
3.2. Topology Optimization Result of Existing Support Bracket

The results of anchor mooring winch support bracket optimization study are illustrated in Figure 11, where the material is removed from the component that is not too affected by the applied force, resulting in a lighter support bracket with a similar stress.

![Figure 5. Topology optimization result of anchor mooring winch support bracket](image)

3.3. Linear Static Analysis Result of Optimized Support Bracket

The optimized design of the new anchor mooring winch support bracket is carried out by using SolidWorks Simulation as shown in Figure 6, and the simulation add on module is used for the linear static study of the optimized support bracket design. In the center a part of the mesh type, 3D solid tetrahedral mesh is used, and the rest is 4-node 3D tetrahedral mesh. The finite element analysis includes 27239 elements and 47600 nodes. The optimized support bracket design volume is 1272250.33 mm³. Figure 7 show the maximum deformation is 1.38 mm and the maximum Von Mises is 114.20 MPa.

![Figure 6. Optimized three-dimensional model of new anchor mooring winch support bracket](image)
3.4. Discussion of Topology Optimization Results

The application of topology optimization in this study targets to alternate the design of the anchor mooring winch support bracket into a lighter design. This method can produce an anchor mooring winch support bracket design that is lighter and optimal. This is indicated by the comparison of the results of design optimization between the preliminary design and the design after optimization inside the Table 1.

|                | Deformation (mm) | Stress (MPa) | Volume (mm³) | Mass (kg) | Safety Factor |
|----------------|------------------|--------------|--------------|-----------|---------------|
| Initial        | 1.28             | 109.90       | 14681524.20  | 115.25    | 3.23          |
| New Design     | 1.36             | 114.20       | 12722250.33  | 99.87     | 3.11          |
| Comparison     | ↑ 6.25%          | ↑ 3.91%      | ↓ 13.34%     | ↓ 13.34%  | ↓ 3.76%       |

4. Conclusion

This paper takes a new anchor mooring winch support bracket as the research object, make use of SolidWorks Simulation to carry on the finite element evaluation and the topology optimization design, and carries on the finite element evaluation to the optimized support bracket. Based on the results of studies that has been done, it can be concluded that after linear static simulations using SolidWorks Simulation, the maximum Von Mises stress value is 109.90 MPa. From the topology optimization results obtained a decrease in mass of 15.38 kg compared with initial design. Also, the maximum Von Mises stress in variation increased to 114.2 Mpa. As a result of the increase in the maximum Von Misses stress makes the value of the safety factor of the optimized is 3.11 which can be said the value of the stress that occurs in new anchor mooring winch support bracket designs even though it has a tendency to upward thrust however remains declared safe.

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