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Shape Optimization of Remote Operated Vehicle Structure Using Finite Element Method

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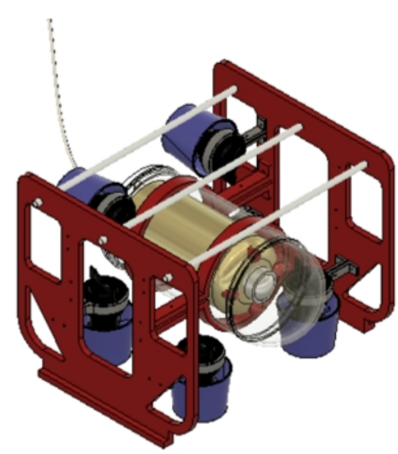
ABSTRACT

Analysis for optimizing the mass that can apply to the Remote Operated Vehicle (ROV) structure, it is necessary to do a shape optimization analysis on the structure. Because the presence of a heavy structure in the ROV will cause the motion to decrease and tend to require a lot of power in the ROV, it is necessary to conduct a study for structure optimization. Before optimizing to apply, the structure analysis must be safe and strong enough to do a review to analyze static, vibration, and buckling loads using finite element. Shape optimization will provide a level of structure that is strong but not over-strength. It will also provide economic value benefits regarding material requirements designed at ROV. In addition to minimizing the condition of excess strength in the ROV structure that results in the high cost of making these structures, or can realize low-cost technology by ensuring the structure remains strong. The mass of the left or right cover on the ROV structure with an initial weight of 1.8 kg while the results obtained after the optimization of the structure obtained results of 1.3 kg so that the material can reduce mass by 25%.

1. Introduction.

To optimize the gravity of the ROV construction that has been designed, the ROV must re-design the structure to have a light construction weight so that the thrust can be optimum in its operations. In addition to minimizing the condition of excess strength in the ROV structure that results in the high cost of making these structures or creating low-cost technology, by ensuring the structure remains strong. In the initial stages of designing, the ROV designs aluminum material with marine used specifications. At first the design of the existing ROV can do review in the following picture below (see figure 1).

Figure 1: General structure of existing ROV.



Source: Authors.

The components of the ROV part can be categorized into constituent parts, including the structure of the ROV, driving motor, mainboard, and control system.

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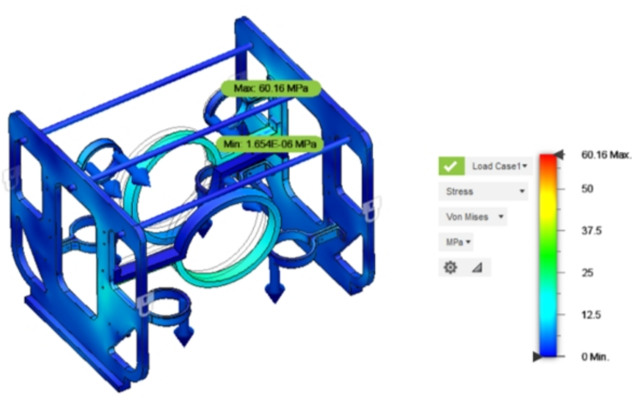
Analysis structure to ensure the strength of the structure that remains strong in accepting the load in operation required supporting calculations. The structure is divided by numerical pattern into structural elements that apply to existing placement and loading conditions. One of the supporting technologies performs calculations using the finite element method. In the previous research, several analyzes carry to ensure the strength and safety of the structure, including static load analysis, capital frequency analysis, and Buckling analysis. Where results can be shown as follows:

1.1. Static analysis.

Static analysis is a structural analysis to determine the stress and deformation by comparing with the allowable stress and allowable deformation values. The actual condition of the Voltage in the ROV structure is still Fulfilled can be shown in the picture below (figure 2). The static analysis quality depends on the analysis techniques used by program software, but the best combination of such techniques may be different for different program sofftware (Jihyeok Park, 2022).

Figure 2: Static load analysis of ROV.



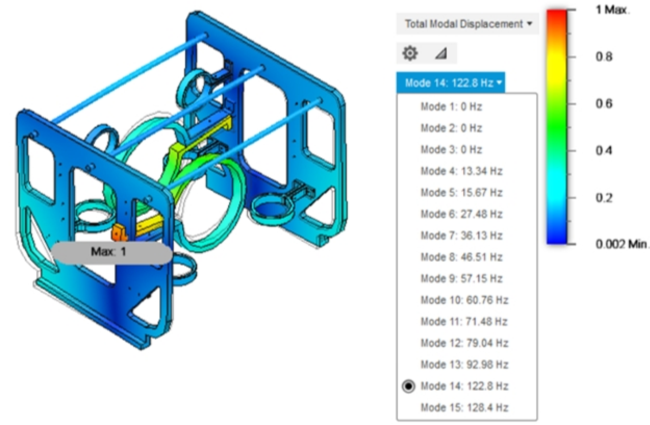
Source: Authors.

The structure can be quite strong and safe in operation if the value of the stress that occurs is smaller than the allowable stress value (Budianto, 2018). The allowable stress has included elements in the material and safety factors.

1.2. Modal frequency analysis.

In the condition of vibrations that occur due to the excitation frequency of the ROV's driving force (motor and propeller), it is necessary to analyze the capital frequency to cope with excessive vibration in the ROV structure (Mohammad Basuki Rahmat, 2020). An excessive vibration occurs if the value of the excitation frequency is the same as the natural frequency value. The modal frequency analysis calculates the natural frequency value owned by the ROV structure. In the analysis of natural frequency, called eigenvalue structure, the natural frequency can be calculated by calculating from several components of mass and stiffness. The results of the analysis of capital frequency can be shown in the analysis of capital frequency in the figure below (figure 3).

Figure 3: Modal frequency analysis of ROV.



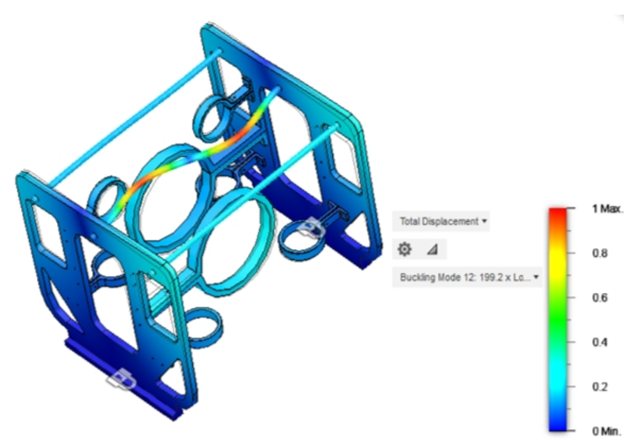
Source: Authors.

The analysis and calculation results show that the natural frequency value is not the same as the value of the excitation frequency that occurs from the driving force (motor and propeller), so it can be said that the structure is still safe in excess vibration conditions.

1.3. Buckling Analysis.

Bending load analysis is indispensable in maintaining structural strength at ROV. The bending load is hazardous to the structure, which can cause the structure to break or deform. So a buckling analysis is performed with the following results figure below (figure 4).

Figure 4: Buckling analysis of ROV.



Source: Authors.

In the picture above, the Buckling condition is still safe from the condition of the allowed buckling load on the ROV structure condition. The maximum bending risk is most at risk in the connection section of the ROV structure.

The analysis structure does optimize the mass load designed on the ROV structure, and it is necessary to do a shape optimization analysis. So this will provide a level of structure that is strong but not strength. It will also provide economic value benefits regarding material requirements designed at ROV. Somebody can do aspects of shape optimization Aspects of shape optimization in three activities the form geometric space, concept analysis, and efficient optimization (Welker, 2022).

2. Analysis Process.

Finite element application to analyze the structure. Finite element provides various structural analysis methods to carry out on finite elements in the structure. In the development of finite elements, analytical technology uses by various engineering. The objects are discretized into constituent elements. (Suzana Ereiz, 2022) The application of finite elements can be used in some structural analyses, flow-form, and others. At this time of designing structures up to date, the density and magnitude of the load have increased, and the requirements for regulation have also become more stringent (Gang Bao, 2022).

RUV (Remote Underwater Vehicle) is a robotic device that can take data in water depths. So it can replace the role of divers in the investigation of objects that are in the sea. In RUV, the fundamental difference with the control system is that of the cable system. In technical terms, several experiments characterize optical links and demonstrate remote control in RUV. The purpose of the ROV is to perform translational, ascent, descent, and rotational movements on three axes (Aguirre-Castro, 2019).

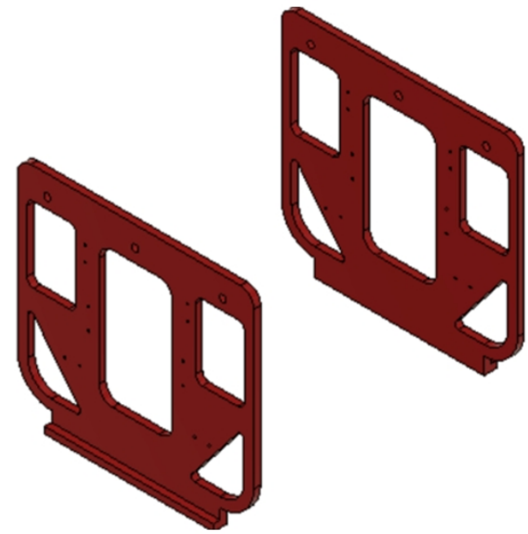
Lightweight materials in general and alumunium alloys in particular are increasingly becoming important engineering materials in order to improve the sustainability aspects of engineering products for design and analysis process (Ul Haq M, 2021). Two digits of 60xx alloys commonly used in the marine industry are 6061-T6 and 6082-T6. Such materials usually have resistance in corrosive operational conditions. This is evidenced by the shallow rate of corrosion and marine life attached to the hull or building structures.

CAD and Material Definition are required in the analysis of this study. The beginning of the analysis can be done by making CAD with existing components. Then do the material definition using 5083 marines used aluminum alloy material. The meshing process is carried out to discuss the object into the ROV constituent elements, which are conditioned in fine mesh conditions. Load in constrain is the loading process placed in the structure's loading area, which is then entered for the value of the force acting. It's as placement is applied at the bottom of the structure. The presence of stresses acting on the structure that can continuously cause work-related fatigue depends directly on the characteristics of the working environment facing the object of the structure, particularly the type of demands imposed by the task (Angel M. Costa, 2020). Analysis Process is the analysis process refers to the method of form optimization by getting the optimum mass design in the ability to accept existing loading.

2.1. Analysis Result.

In-shape optimization analysis refers to the target Left and Right Cover Weight. It indicates the weight that can be reduced by shape-optimized structure. The components that are modeled on the Left and Right Cover are shown in the following see figure below (figure 5).

Figure 5: Left and right body cover to optimized.



Source: Authors.

On the physical material, the material shows aluminum material 5083 (Fusion360, 2022), which on the left and right cover components are designed. The existing mass can show a value of 1.8 kg. The physical table is shown in the table below.

Table 1: Physical material properties.

Material physical properties		Units
Material	Alumunium 5083	
Area	1.670E+05	mm^2
Density	2.660E-06	kg/mm^3
Mass	1.774	kg
Volume	6.668E+05	Mm^3

Source: Properties form Autodesk Fusion 360 material properties.

Bounding Box is an analysis structure package facility produced. It gets information on emphasis and moment of inertia given information from CAD in the form of bounding boxes (Autodesk, 2013). Computer Aided Design (CAD) is the use of computer based software to aid in design modeling, design analysis, design review, revision, and design documentation (Bonsa Regassa Hunde, 2022). The bounding box values are obtained from the table result below (see table 2).

The aim is to generate optimal material distributions with high-quality interfaces within a uniform geometric representation for topology and shape optimization to apply this case (Bartz R, 2022). Analysis to reduce the weight required form optimization by applying a reduction of 25% of its weight so that the target can be reduced to 75%. Where the results of Shape Optimization are shown in the following results (seee

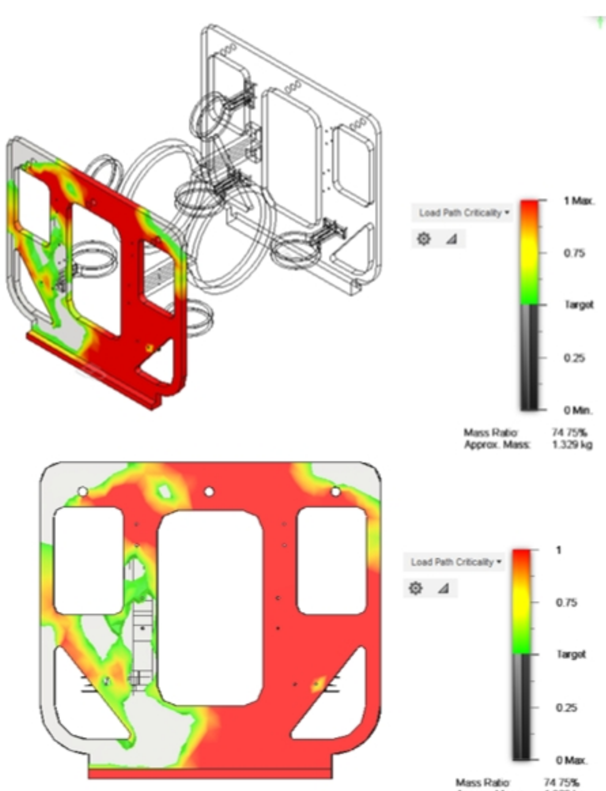
Table 2: Object optimatization properties.

Object Shape Optimization		
Length	200.00	mm
Width	325.00	mm
Height	350.00	mm
Center of mass		
X	357.072	mm
Y	298.47	mm
Z	330.141	mm
Moment of Inertia at Center of Mass		
Ixx	3.794E+04	kgmm^2
Ixy	-99.895	kgmm^2
Ixz	-0.004	kgmm^2
Iyx	-99.895	kgmm^2
Ixz	1.766E+04	kgmm^2
Iyz	-1.198	kgmm^2
Izx	-0.004	kgmm^2
Izx	-1.198	kgmm^2
Izz	2.032E+04	kgmm^2

Source: Authors.

figure 6).

Figure 6: Shape Optimization Result.



Source: Authors.

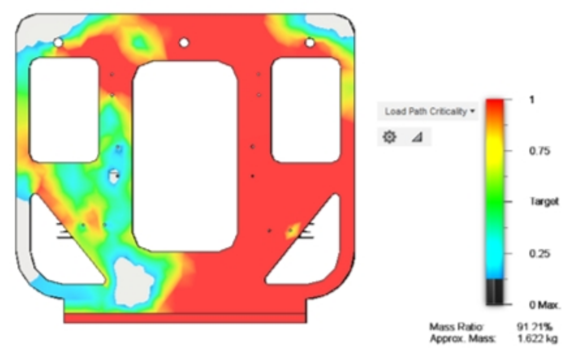
While the mass of the left or right cover on the ROV structure with an initial weight of 1.8 kg, while the results obtained after the optimization of the structure obtained results of 1.3 kg so that the material can save 25%.

3. Discuss and recomendation.

3.1. Mass application.

The recommended reduction is only applied 10% of the weight of the construction left or right cover to maintain strength and increase the value of the existing safety factor risk. The results can be shown as follows for the application of the design.

Figure 7: Mass Reduction Application.

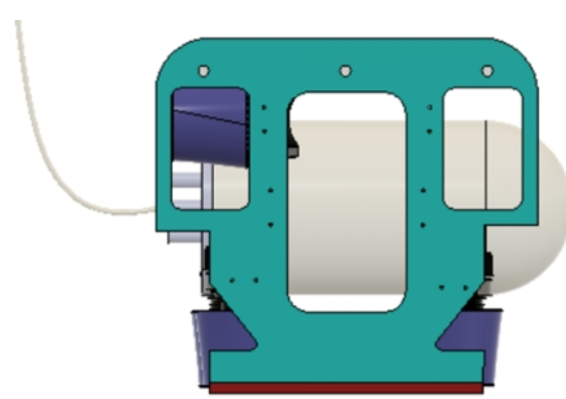


Source: Authors.

3.2. Recommendation.

The design after optimization can be shown in the form of ROV structure models can be shown in the picture below as follows:

Figure 8: Final optimization design of ROV.



Source: Authors.

Conclusions

The mass of the left or right cover on the ROV structure with an initial weight of 1.8 kg while the results obtained after the optimization of the structure obtained results of 1.3 kg so that the material can reduce mass by 25%.

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