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Structural Framework Design Analysis for Development of a Tidal Testing Rig

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ABSTRACT – In the field of simulation and analysis, many testing rigs worked out to simulate the real event for a controlled experiment. Main concern in developing a rig is the costs; considering its size and material used. In this study, a tidal testing rig (TTR) was design as resemblances of tidal phenomena by varying the speed and water flows during the test. The initial design of TTR was analyse with topology optimization. At the end of this study, an optimized design of rig structure was developed by comparing the weight, displacement and safety factor as well as the Von Mises stress value.

1. INTRODUCTION

In this study, a tidal testing rig (TTR) was made to study the likeness of Malacca River tidal phenomenon. This rig used to observe the movement of in-water trash collector whether it can move along with the tidal. The design and strength of the rig should be taken into the measure as it must be able to withstand a load of force exerted onto it. In making such experiment, it requires the rig to be built in large size. Thus, the material used should be optimized yet maintaining the factor of safety before the fabrication work is carried out.

2. METHODOLOGY

2.1 Material properties of TTR structure

For this project, steel ASTM 500 is used due to its resistance to the atmosphere, steam, water and other weak corrosive environment [1]. However, the result obtained after fabricated may differ from the virtual result depending on the material properties [2]. Table 1 shows the material properties.

Table 1 Material Properties of ASTM 500

Properties	Data
Tensile Strength	$7.86 \times e^{-9}$ t/mm^3
Yield Strength	315 Mpa

2.2 Design space

Initial framework design of the testing rig as in Figure 1. It consists of one main tank and two smaller tanks. The main tank will be filled with water and the in-water trash collector will deploy inside it. While the two-small tank act as a controllable tank. However, the rig must be able to withstand the force initiated onto it. Total force exerted onto the rig is 26,000N. The specific force that exerted onto the rig was in Table 2 as the initial weight of the rig is 7122.1 kg using solid material by steel AISI 1015.

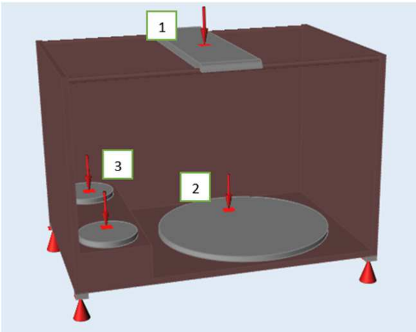

Figure 1 Initial Framework Design of Testing Rig

Table 2 Force onto the Rig

Part	Force (N)	Explanation
1	3,000 N	As observer platform. Can support up to 300kg persons.
2	19,000 N	Main tank
3	4,000 N	2 units of drum placed

2.3 Topology optimization

Solid Thinking Inspire was implemented to simulate the selected design space based on boundary conditions and then generates an optimized design as in Figure 2. The model is then imported to Computer Aided Design (CAD) to interpret the new conceptual design based on the optimization result.

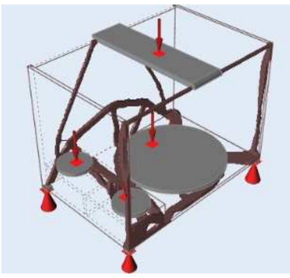

Figure 2 The Optimized Body Structure of TTR

2.4 Result analysis

Three iterations were done to reduce the structure mass while retaining the Von Mises Stress below 100.0Mpa as the fourth iterations also shows the same result as the third. The final optimized design is shown in Figure 3.

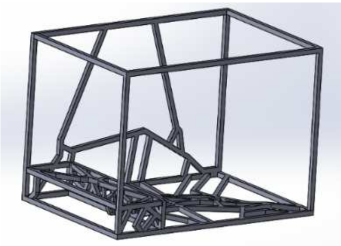

Figure 3 The Final Design of TTR

3. RESULTS AND DISCUSSION

The comparison analysis result for TTR structure are presented in Table 2. The initial weight of TTR structure mass is logged as 7122.1 kg, but after the third optimization process is implemented, the structured weight decreased to 1242.1 kg. This was as much as 83% material reduction from the initial state. The displacement value is $2.87 \times e^{-3}$ m recorded at the observer plank on top of TTR where the force is assumed to be uniformly distributed. Next, the safety factor value was reduced to 6.4 rather than 30.6 from before. This indicates that the rig is strong enough to hold the load yet applying ASTM 500 steel.

Table 2 Comparison of Mass Data After Optimization

Parameters	Before	After
Total weight, kg	7122.1	1242.1
Displacement, m	$4.71 \times e^{-4}$	$2.87 \times e^{-3}$
Factor of safety	30.6	6.4
Von Mises Stress, MPa	$9.33 \times e^{6}$	$4.48 \times e^{7}$
Tension, MPa	$8.15 \times e^{6}$	$3.12 \times e^{7}$

On the other hand, the result of Von Mises stress shown in Figure 5 was $4.48 \times e^{7}$ MPa meaning that the force was distributed uniformly to all bases and as material start yielding when it reaches maximum value. For this study, we refer to Von Mises stress rather than principle stress since this approach was much popular on treating failure criteria from the energy perspective obtain from the ductile material [3]. Maximum shear stress also valid for ductile theory, where it provide maximum factor of safety but may lead to slightly uneconomical design [4]. Meanwhile, the analysis of tension and compression is $3.12 \times e^{7}$ MPa which shows that the material was able to hold the tension since the force is uniformly disseminated at the base and reach maximum value to expand and squeeze at its best capability.

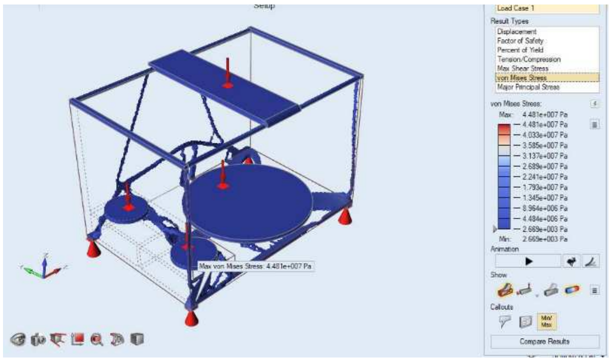

Figure 5 Von Mises Stress Analysis of TTR

4. CONCLUSION

This study was set out to design an optimized test rig that will be used for tidal phenomena testing. A body framework for TTR was analyzed by implementing topology optimization from Solid Thinking Inspire. Thus, a simplified and optimized TTR was developed. From the results obtained, an optimized TTR has 83% lighter than the original design. The overall frame composite structure is summarized to a modest design that meets all the necessary condition in fabricating the rig. Even though CAE software is limited to solid meshing only, topology optimization finds the best distribution of material given and remains the most general and powerful tool for developing novel shapes and concept designs.

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