Design for Manufacturing, Reliability, and Economics

Group 21

New Housing Structure for Deep Sea Equipment

Earth, Ocean and Atmospheric Science

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Abstract

The Florida State University's Earth, Ocean, and Atmospheric Science group is looking to update the frame for their aquatic tether operated vehicle (TOV). A TOV is an underwater vehicle dragged behind a boat to survey, in this case, the ocean floor. Their current frame is too heavy, too tall, has too much empty space, does not tow straight, and is difficult to transport for their cruises. Through the design process, this group was able to analyze and choose the best model to both aesthetically please the sponsor as well as complete the desired tasks to fix the aforementioned problems. This document contains a detailed description of the manufacturing process, the systems reliability, and the structures economics. Included is a detailed process on how to assemble the newly designed TOV, how it was confirmed that the system can withstand large forces as well as environmental effects, and lastly, the cost breakup of the final design.

Acknowledgements

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1. Introduction

The Earth, Ocean, and Atmospheric Science (EOAS) group at Florida State University is interested in updating their current aquatic TOV to a smaller, lighter, more modular, levelly oriented, and easily portable design. A TOV is an underwater submersible that it attached via a cable (tether) and is dragged behind a self-propelling vehicle. The design currently is a 3 feet by 3 feet by 6 feet rectangular prism with 17 pieces of equipment attached to collect data and house necessary electronics. It cruises at approximately 6,600 ft. (2,000 m) below the sea level. This TOV needs to be able to withstand pressures of 2,900 psi and be impact resistant in case of collisions with rocks on the ocean floor. After brainstorming possible new designs, analysis approach techniques, and performing experiments, a design was chosen. Below is a detailed explanation on how to manufacture the housing, its reliability, as well as its total cost.

2. Design for Manufacturing

Although the final prototype has not been built, based off previous model testing and engineering analysis, the design chosen, the model in Figure 1a, will have an expected necessary performance to complete system operation. Two models were tested and both were able to tow straight without the simulated equipment weight. Adjusting the lengths of the cable attachments of the model allowed the model in Figure 1a to tow parallel to the ocean floor, these lengths will be scaled up for the final prototype. Below is the final models analyzed during the last testing. Both were machined as is, however, both had additional open tubes like that of the back horizontal tubes of Figure 1a for ease of machining.

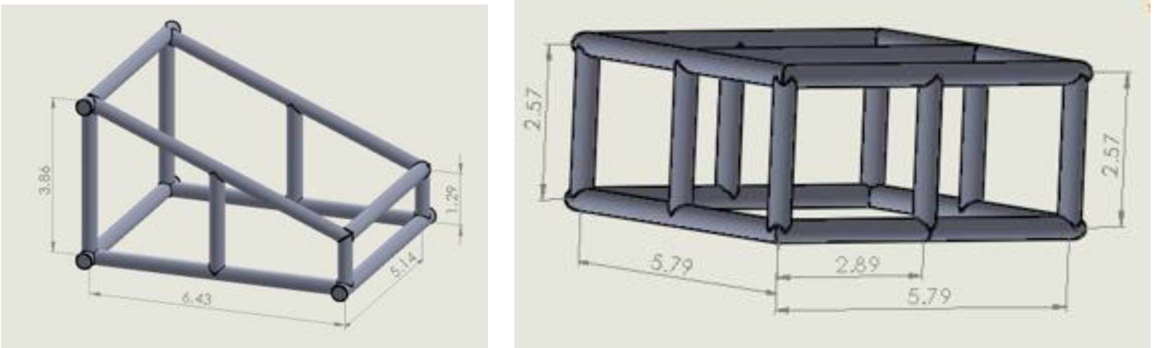

Figure 1a: Final trapezoidal model in inches. Figure 1b: Final square model in inches.

Figure 1: Final model designs.

Even though the final prototype has not yet been machined, the process for the prototype has been thoroughly thought out and discussed with the project sponsors. Once the final model is machined, with all necessary holes for the zinc-chromate plating, it will be taken to be plated to ensure the prototypes ability to withstand the environmental weathering of the ocean. When returned, the system will undergo internal attachments starting with U Clamps along the inner side of the bars on the housing. Available technicians who are familiar with attachment techniques of the U Clamps will aid us in attachment. When secured, unistrut will be attached using similar metal screws to the U Clamps in various positions which will be measured out to ensure the equipment will have enough space between unistruts. Again, when secured, the equipment will be attached onto the unistrut; previous testing was conducted and showed that as long as the equipment remained within the tether attachment points, the system would remain balanced above water. The equipment is attached to the unistrut with U Clamps and screws depending on the size and weight of the equipment.

Following internal equipment attachment, external equipment will be secured, i.e. side panels and tether points. The side panels will have long holes which will be attached to the housing using hose clamps. The tether will be attached to the housing at predetermined locations machined on the prototype using lifting shackles which can withstand 2000 lbs. There will be three tethers: two attached to the back of the model and one attached to the front. The two attached to the back will be rigid rods while the front one will be adjustable in case an issue with parallel towing occurs.

The total assembly process is projected to take a maximum of three days to include the time it takes to find the best placements of all the inside equipment and attachment tools; it is similar to a puzzle as pieces must be moved around to find its optimum placement and orientation. The amount of attachment tools will be minimized throughout the process, however, its simplicity is key in tool mobility, ease of placement, as well as user friendly operation. Below is the final prototype design:

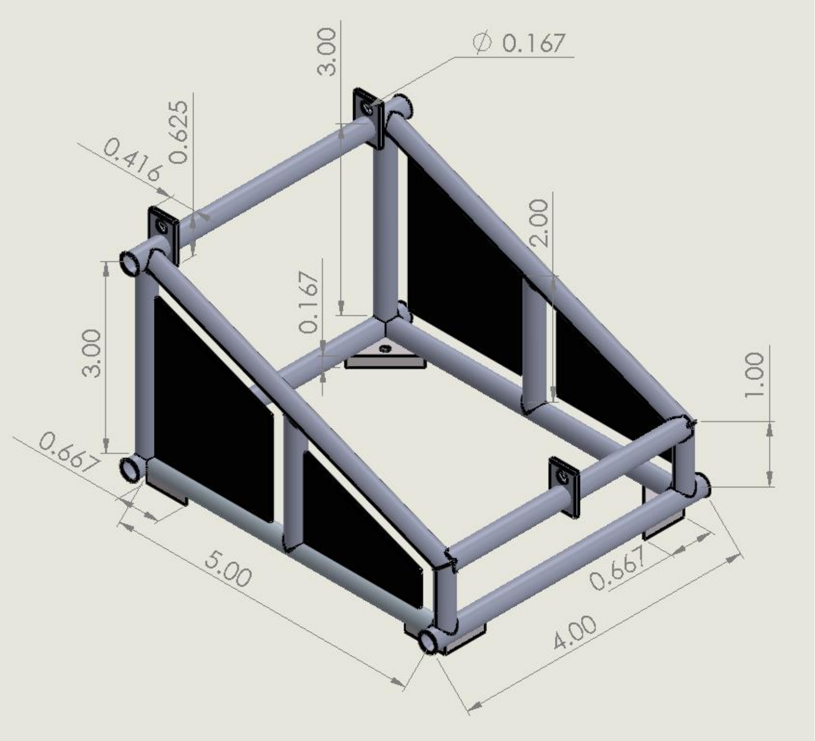

Figure 2: Final prototype, in feet.

3. Design for Reliability

As previously mentioned, the final prototype has not been finished. However, the models have been tested multiple times. During the first testing, the system ran smoothly and no damages or changes occurred to the model. While testing, the model did hit the wall but this did not affect the models shape or cause any damage to the housing. The previous TOV owned by the oceanography department withstood decades of use which leads us to believe that our model will perform similarly; this was confirmed in the stress analysis conducted which showed there will be little to no damage when a large force of 10 times its own weight is acted upon the housing. The main reasons for this analysis was to guarantee all the equipment inside would not deform the housing and to ensure that any large objects, such as rocks, on the ocean floor would not drastically damage the housing. If an issue with deformation did occur, the sponsors have a list of the materials which need to be ordered for the design as well as the CAD files. Therefore, if the model was critically damaged, the sponsors will have the necessary information to solve the issue, and bring the required information to a professional machinist to fix the problem at hand.

Figure 3 is an example of the stress and deformation analysis performed on the final design to ensure that the equipment weight will not deform the model. In this analysis, the equipment and frontal drag loads are applied mid beam and the constraints are applied at the tether locations. As seen on the left in Figure 3, the largest stress is on the front tether location with a stress value of 860 psi. The majority of the model has a stress between 9 and 90 psi, therefore, most of the model does not experience large stresses. Even the largest stress calculated (860 psi) falls well within Aluminum 6061's yield stress of 40,000 psi, which gives a calculated safety factor of 47. The right analysis in Figure 3 is the deformation analysis. It is exaggerated as the largest deformation is 0.0067 in. In regards to this design, which is 5 ft. at its largest and 1 foot at its smallest, the deformation can be considered negligible.

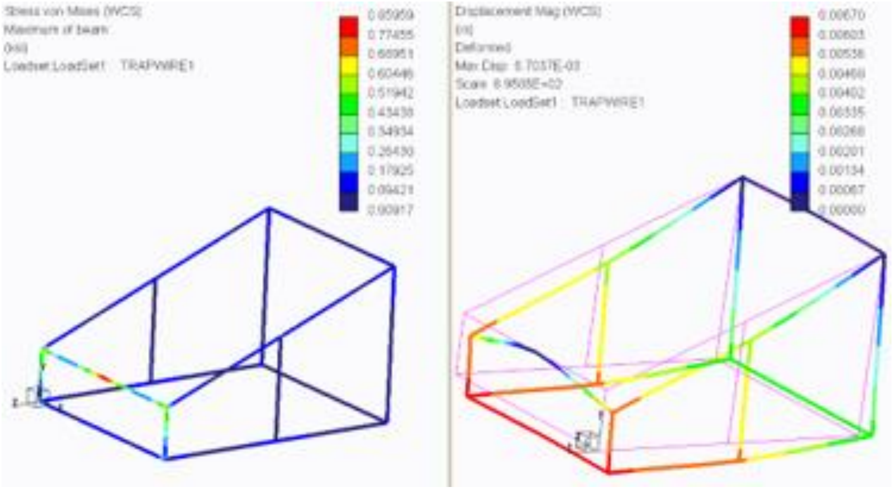

Figure 3: Stress and displacement analysis of final design.

Besides large force impacts, the housing will be coated with zinc-chromate plating to ensure corrosion will not occur. To help with this, the housing should be kept in a dry and clean environment to reduce wear and tear. Additionally, there are external components such as the wheels, hose clamps, lifting shackles, oblong master links, and unistrut that are also subject to wearing down after many uses. Again, the sponsors will be given the list of parts that are ordered in case replacement is necessary.

4. Design for Economics

The overall cost for the prototype will be $1,822.22. This includes the cost of the material, the wheels, the unistrut, and the zinc-chromate plating. The material needed is made up of ten 6ft long and five 4ft long, 3in diameter piping. If anything goes wrong during machining, an extra pipe for each length will be additionally ordered making the total cost of the material $1,016. Four wheels are needed, one for each bottom corner. The system will weigh a maximum of 550 lbs. with all the equipment loaded. Therefore, each wheel with the ability to withstand 250 lbs. is more than enough to hold the entire structure. The total cost of the four wheels will be $54. Although the sponsors already have unistrut, it is made out of steel so to avoid dissimilar metal problems, aluminum unistrut will be ordered. It is estimated that the needed amount will be two 5 ft. long, ten 4 ft. long two 3 ft. long, and two 1 ft. long unistrut channels, bringing its total cost to $312.22. Lastly, the zinc-chromate plating process is estimated to be $440, which is necessary due to the operating conditions being in the ocean. This total cost brings us in under budget by $177.78. For a more visual breakup of the cost, Figure 4 below is a pie chart of the cost break down. Luckily, if any unforeseen issues occur, the project sponsors said that additional funding is available if necessary.

Aside, no similar products are on the market. This is a product made on an individual need basis. Therefore, other prototypes similar to this project do not have information regarding funding or total cost of the project. While some universities have TOVs, the information regarding cost and products used to build the structure is not readily available.

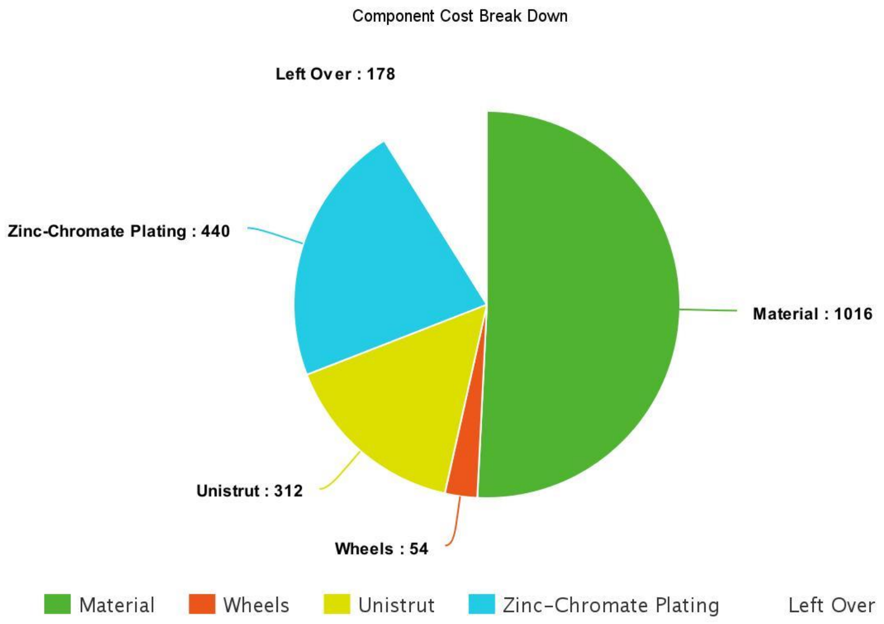

Figure 4: Pie Chart of individual component costs of budget.

5. Conclusion

The Florida State University EOAS group is interested in updating their current aquatic tethered operated vehicle to a smaller, lighter, more modular, levelly oriented, and easily portable design. Through the design process, this group was able to analyze and choose the best model to both aesthetically please the sponsor as well as complete the desired tasks to fix the aforementioned problems. The assembly process is complex in that it is similar to that of a puzzle – pieces must be moved around to find the optimum position and orientation to fit inside the model. This process is expected to take a maximum of three days to complete. Upon completion of a thorough stress analysis, it was clear that the system could withstand large forces acting on the housing. Therefore, if the structure runs into something, its ability to maintain structural integrity is guaranteed up to a load of 40,000 psi. Finally, the cost of the system, which includes necessary material ($1016), wheels ($54), unistrut ($312.22), and the zinc-chromate plating ($440), is estimated to be $1822.22.

References

[1] http://www.mcmaster.com/#strut-channel-systems/=11s3ncc

[2] http://lccc.galvanizeit.org/report/f24e978ab316ad8ccd9b337855e99860