Design for Manufacturing, Reliability, and Economics

Design and Development of an Autonomous Underwater Vehicle

Team 23

AUVSI Robosub

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Abstract

The goal of Team 23 is to represent the FAMU/FSU College of Engineering in the 19th annual AUVSI robosub competition, which occurs from July 25th to July 31st of 2016. This will be accomplished through the design, development, and extensive testing of a modular sub which meets all of the competition requirements provided by the AUVSI Robosub competition. The particular aspects of design that the mechanical team will endeavor are a redesign of the hull to make it less buoyant, torpedoes design and actuation, and finally the gripper mechanism, which are all normally tasks required of the AUV in the robosub competition.

Team 23 is also not the only team to be working on the robosub this year, team 4 of the ECE teams will also be working to reach the goal of reaching the competition this year. While the two teams will be assisting each other in the development of various subsystems required for the AUV, team 4 will be more focused on the navigation and vision systems for the sub while team 23 focuses more on the mechanical subsystems for the sub. This collaboration of work will give the teams the best chance at sending a sub to compete in competition.

Acknowledgements

We would like to thank the people who have helped us thus far and the ones who plan to help us in the future. This includes Kim Hinckley at the Morcom pool for letting us use FSU’s dive pool for testing. Dr. Gupta and Dr. Shih for guidance and constructive criticism throughout the project and the course. Dr. Clark for pushing us to set high goals and achieve them. Dr. Harvey and Dr. Hooker for their support and suggestions and the ME and ECE department for funding our senior design project.

1 Introduction

This report conveys the importance of taking into consideration manufacturability, reliability, and cost analysis when designing a product. However, the Robosub team's project was to produce a single product for competition means; not something meant for large scale manufacturing. Reliability and cost analysis however, is very important in any engineering project because being able to afford the components and ensuring that the product actually works is key.

2 Design for Manufacturing

2.1 Hull/Frame fabrication

The new hull is constructed from ¼ inch stainless steel welded to form a box measuring 12" x 18" x 5". Six panels where cut using a cnc waterjet machine. 15 holes were drilled for electrical penetrations and 18 holes were tapped for bolting on hardware. Six stainless steel adjustable toggle latches are bolted to the side of the hull to clamp the lid down to form a watertight seal. The toggle latches grab stainless steel hooks which are bolted to an aluminum lid which provides even compression across the acrylic lid. A rubber seal is fit over the rim of the hull and joined together using glue to form the rectangular shape of the hull.

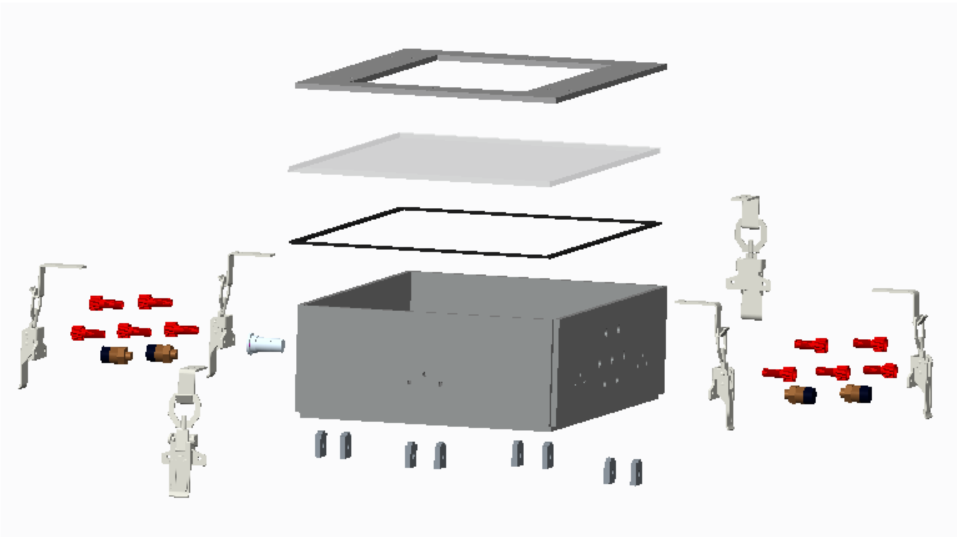

Figure 1: Exploded View

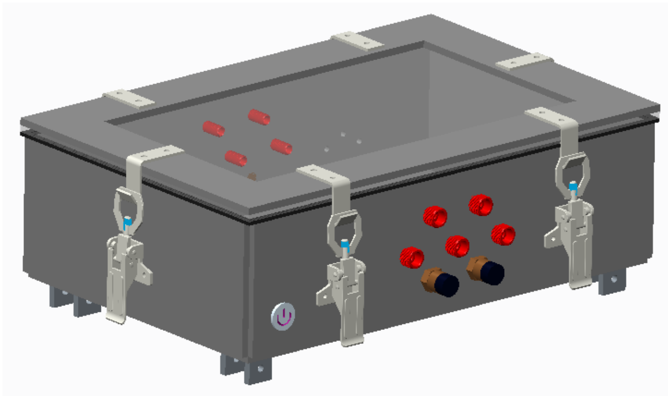

Figure 2: CAD of hull

The frame is composed of 8020 extruded aluminum which was cut to size by the distributor. The frame uses two 34 inch 10 series bars in the long direction and several 8 inch 10 series bars for support and hardware. The frame is assembled using a variety of t-slot fasteners. The entire frame can be assembled and attached to the hull with an Allen wrench.

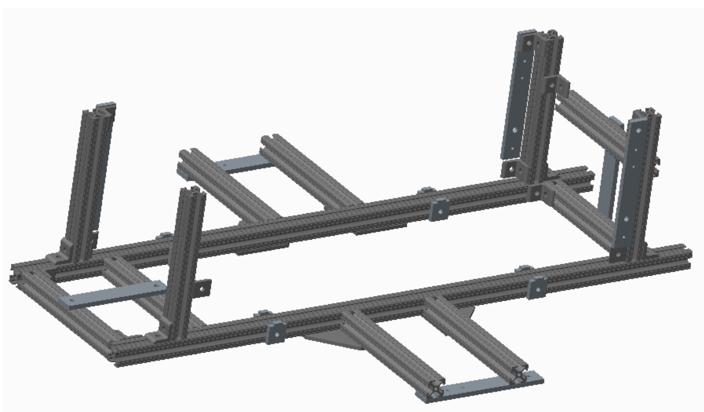

Figure 3: Framing for hull

2.2 Marker dropper fabrication

The marker dropper is made out of two aluminum 6061 parallel plates that contain a curved guide track. Both the curved boundaries of the guide track and the containing plates can be cut and drilled using a waterjet cnc machine. Spacers are located between the bars of the guides and plates held in place by the screws and lock nuts that hold the frame together. The spacing is adjusted by the addition of washers along these same shafts. This is mounted to the frame by an 80-20 piece of aluminum. A waterproof servo is held in the window of the aluminum plate with a standard servo arm and held in place with the servo mounting screws that came with the servo.

This subsystem has a very simple design that can be manufactured and assembled easily within a few hours. One of the best qualities of this design is its open air set up, which allows for easy testing and does not require any external water sealing. If this system were to be redesigned it may be beneficial to replace the curved guide rails with individual tubes to contain the markers. This would ensure that the markers stay in place during transit which may be an issue that arises that we are as of now unaware of due to the lack of extensive testing. This change would likely not affect the manufacturing or assembly time.

2.3 Torpedo fabrication

The torpedo was built in four steps. The initial step is the development of the CAD model. Taking designs of real world torpedoes and rubber torpedo pool toys an initial design is made. Upon completion of the CAD model the file is saved as a stereolithograph at relatively high constraints. The stereolithograph is moved to a slicing software such as makerware to prepare it for the 3D printer. In the software it is important to take into account build tray limits and part orientation, it should be oriented vertically to reduce potential model errors during printing. The model is printed out of ABS plastic and with any infill density. The finished 3D printed part once finished is post processed using increasingly fine grits of sandpaper to produce a smooth surface finish to ensure the part will be better streamlined. The third step in the fabrication is development of a two-part plaster mold. In setting up this mold it is important to consider the shape of the part and the orientation of the pour spouts, the mold material will not completely fill the mold if airways are not located at the highest parts of the designed piece. In order to cast this mold a basin to hold the wet plaster is required. In general cardboard is used with hot glue sealing cracks to prevent leaks. Additionally, a stand may be used to suspend the part within the basis to ensure a consistent height, this can be done with a piece of hot glue. Before pouring the plaster both the mold and the torpedo must be coated in wax or some other seal releasing agent to ensure separation of the piece from the mold, this must be done every time the mold is used and between each mold half during fabrication. After pouring the first half of the plaster into the mold, when the plaster begins to thicken, notches are made in the piece to create places for the two mold halves to lock together. At any point the plaster mold edited through the use of a scalpel to carve away any problem areas. The final step in the manufacture of the torpedo is to pour the mold material into the mold. The material used is Simpact 85A urethane rubber purchased from Smooth-on, it used an 1:0.85 mixing ratio by mass which therefore requires a scale to measure properly. Though not required, it should be handled with nitrile gloves to minimize skin contact. This material has a very short pot life of only about 4 minutes, and as such requires rapid mixing and pouring. Once poured the material is given forty eight hours to cure fully before releasing the mold to ensure the part does not tear. Final touches to clean the part are made using a scalpel and sandpaper.

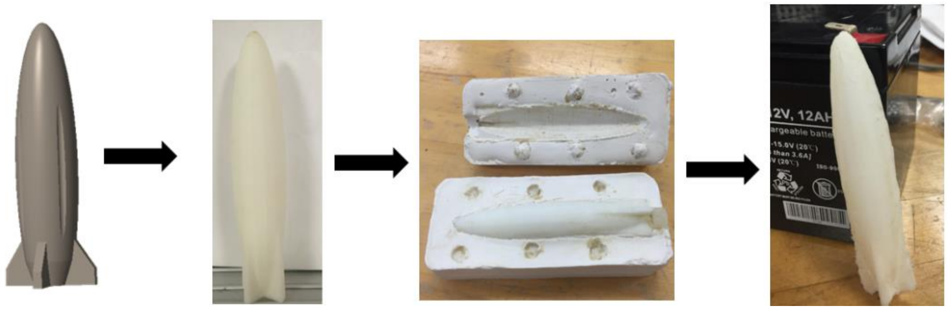

Figure 4: Torpedo Process

This process in its entirety takes a minimum of three days. Though it seems highly involved it was made to mimic the injection mold process used by most companies which work with polymers as well as sculpting techniques. If this was every required to be mass produced an assembly line could easily complete many of these in a short time frame. One possible way for this process to be improved is to rather than designing a torpedo first and creating a plaster mold a direct mold design can 3D printed and used to fabricate the torpedo. This would slow prototype editing and active model adjustment but could improve mold durability and accuracy of a well established design.

3 Design for Reliability

To ensure the Robosub is successful for multiple performances, the design and modifications have been implemented to allow for long lasting, consistently successful performances. The design choice of making the hull out of stainless steel to prevent corrosion from occurring from continued usage within the water. The major concerns for this project that needed to be addressed are the overheating of the electronics and ensuring the watertight nature of the submersible.

4.1 Waterproof Testing and Ports

In order to prevent the sub from having any leaks several measures were taken. To connect the microcontrollers to the mechatronic systems attached to the frame two methods were used, the Seacon ports and the cable penetrators. The Seacon ports were carried over from previous years as a reliable method, but upon further inspection the Robosub team noticed major corrosion and deterioration. The cable penetrators were used instead as both an economic alternative, when properly assembled they do not allow water to pass through them. The cable penetrators feature a paint coated outside and an aluminum structure. The addition of the painted coat will improve corrosion resistance and thereby increase the lifespan of the part.

Pressure washers are attached at the entrance of every exterior hole behind both the ports and screws acting as the front lines of defense against water passage. Teflon tape was used around every screw traveling from outside to inside the sub as an additional leak prevention measure. Liquid Electrical Tape is used at the junction of any electronic connection just as secondary measure in addition to the waterproof components. These considerations were made to ensure reliable usage of the submarine.

4.2 Replacement and Addition of Electronics

Starting with an older design, there were numerous electronic systems that needed to be updated. The submersible consisted of three motor controllers powering six thrusters. After careful inspection, it was discovered that one of the motor controllers was malfunctioning. This led to the implementation of a third motor controller which is identical to the other two and equally reliable. This has resulted in the consistent success and operation of all six thrusters.

Furthermore, electronics were not only replaced, but also added within the Robosub. The fabrication of a relay system allowed functioning torpedo and gripper subsystems. The relay system has been tested successfully numerous times, is compact, and allows reliable operation of multiple subsystems. In addition, a waterproof servo was added to the marker dropper subsystem. This allows for a functional marker dropper that is reliable because it is waterproof.

A new kill switch was purchased and implemented to the submersible to allow an operator to easily shut down the electronics from outside of the hull. This is important so that in case the autonomous submarine does something that may cause damage to itself or the surroundings the robot can be shutdown to prevent any further damage from occurring.

3.1 Organization of Electronics

The organization of electronics allowed for a more reliable and aesthetically pleasing product. Most of the internal electronics were initially in an unorganized state, which made pinpointing errors difficult, and allowed limited flexibility with interior modifications. To fix this, two black boxes were implemented to house separate subsystems. Instead of the motor controllers being connected to the Arduino MEGA with unorganized jumper cables and a breadboard medium, the motor controllers and Arduino MEGA are connected directly to the main CPU. Because the Arduino, internal jumper cables, and motor controllers are housed within a black box, this allows for flexibility with interior modifications and a more reliable product. The second black box consists of the relay system for the torpedo and gripper subsystems and allows for increased internal efficiency and reliability.

4 Design for Economics

The Robosub senior design project was allotted $2000 dollars total over the course of two semesters as a budget. In order to meet these budget contraints the team realized the budget had to be properly managed in order to insure the proper funding throughout the project. For example some of the components that are on the sub which have been used over the years like the BTD150 thrusters and Seacon ports could use some replacement, but given they're high expense that was not a priority. The project is comprised of many different subsystems, so for simplicity categories have been broken down into the main areas seen in the pie chart below.

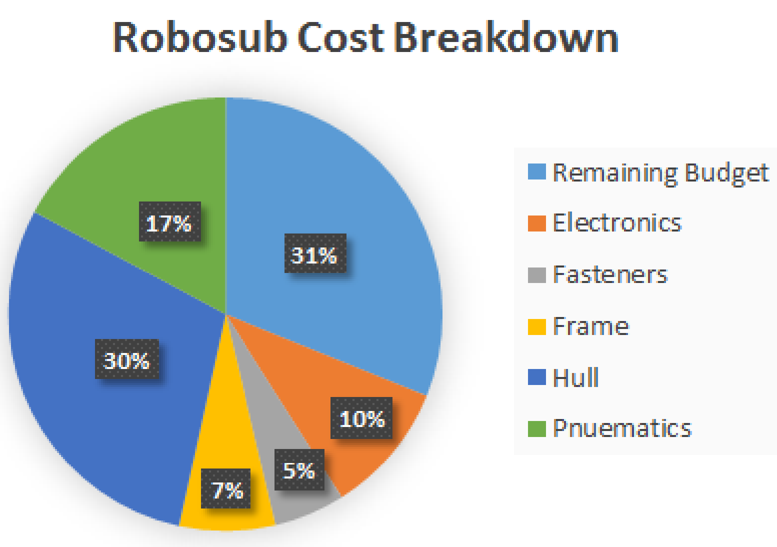

Figure 5: Budget Breakdown

In general, up to now the majority of the budget has been spent on the fabrication of the new hull equating to 30% of the total budget which comes out to $590. These cost when mainly to the purchases of raw materials, including the stainless steel for the hull, aluminum for the lid, and also the stainless steel toggle latches for enclosing. These were some of the more expensive items necessary to improve the design of the Robosub. The pneumatic system has made a lot of progress and was a large focus while the new hull has been under construction. Many items were required to get the pneumatics up and running which include the torpedoes firing and gripper actuation. Some of the items that have been purchased for these systems were the compressed air tank, pneumatic actuator, solenoid valves, and of course the hose and waterproof connections to tie it all together. Seen in the pie chart this has contributed to 17% of the total budget coming down to roughly $350. The three remaining categories including the electronics, fasteners, and frame go hand in hand with the major components of the submersible. The frame can be elaborated upon to include more subsystems if needed which require additional electronics and fasteners for integration. These categories grow together with progression of the project each contributing between 5 and 10% of the budget which is about $150 each.

The market for underwater vehicles is rather limited in scope, as most people do not have a need or desire for them. Although there is a lack of demand for these kinds of products they still do exist, for instance the company Blue Robotics sells their own ROV at $1290 and is an unassembled kit which contains a frame, electronics housing and thrusters with speed controllers, but nothing else. The robosub team, with components grandfathered from previous years, was able to design and manufacture a similar product but also was able to include additional subsystems for about the same amount of money spent.

5 Conclusion

In general, the design was significantly improved over the previous years mechanical design. The new hull has a more complex fabrication method than previous years however due to the user friendly access and the addition of modular components it solves the problems of the old design. The cable penetrators and the kill switch change will improve the lifespan and safety of the submersible body. The alteration of the marker dropper enabled new functionality and can be replicated and altered easily. The Torpedo fabrication was an extensive process but can be done entirely in house in four steps. The process is easily repeatable and can be used to quickly produce multiple parts from a single design. Electronics being shift into modular boxes and electrically insulated provide an easy access and safe work space for the user. It also makes the transfer of new electrical components easier for the user. The remaining budget after several purchases is 31% of our total budget after replacing most of the physical systems. When compared with previous year's expenditures there is a significant improvement in total system cost.

6 References

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7 Appendix