Progress Report #3

AUV Project

Phase I

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This independent study for phase I constitutes the design and development of a proof-of concept autonomous underwater vehicle (AUV) capable of meeting all technical requirements to participate in the *2024 International Robosub Competition* [1]. Progress reports #1, #2, and #3 document the technical development of the project.

Executive Summary

Progress report #3 of the AUV project describes completed tasks beginning March 27th until April 30th and describes completed tasks, current tasks underway, and next month's tasks. Progress report #3 describes task components of milestone #2 and #3 out of the four milestones that constitute the project. Completed tasks since March 27th consist of designing custom parts for the AUV, consulting with machinists, progressing on ANSYS computational fluid dynamics (CFD) engineering simulations, presenting Power Point #1, and in determining theoretical buoyancy calculations for the AUV. Current tasks are geared towards completing remaining unfinished tasks from milestone #2 and #3 and beginning the tasks necessary to complete milestone #4. The completion of milestone #2 requires finishing the ANSYS CFD simulations, enhancing the sophistication of the AUV CAD model, and in the machining and 3D printing of custom designed components. The completion of milestone #3 requires the physical build and programming of the AUV model along with conducting testing and debugging. Milestone #4 tasks include submitting the project's final report and final presentation.

Tasks

Tasks completed during the months of March and April consist of submitting and presenting power point #1, designing custom components for the AUV, and progressing on

ANSYS CFD simulations. Consulting with machinists and determining the AUV's theoretical buoyancy calculations were additional tasks completed during the months of March and April. Power Point #1 describes the context of the competition as well as the technical requirements, capabilities, and specifications the AUV must meet for competition eligibility. Thruster mounts were custom designed using Solid works. The thruster mounts are shown in *Figure 1.* The thruster mounts have dimensions of .584 inches in width, 1.81 inches in length, and a 6 inch radius of curvature on the bottom surface. The purpose of the thruster mounts are to securely hold the eight thrusters to the thruster ring as show in *Figure 2*. Upon consulting with an expert machinist, the thruster mounts require the use of computer numerical control (CNC) machining to create the 6-inch radius of curvature on the bottom surface of the mount. The thruster mounts will be 3D printed for the AUV proof-of-concept design and machined for the project's phase II AUV prototype design.

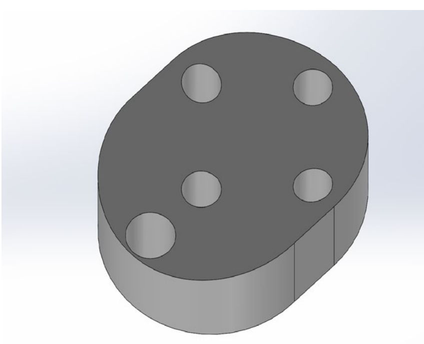

Figure 1*:* Thruster Mount

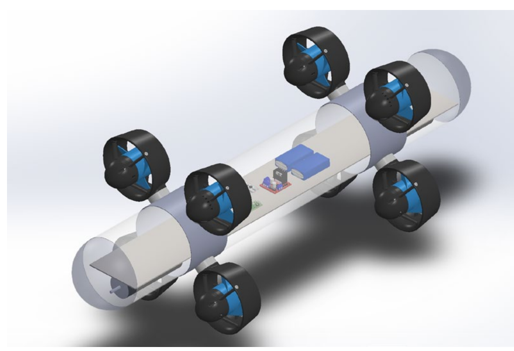

Figure 2: Thruster rings as shown in AUV model

During conduction of the ANSYS CFD engineering simulations, several errors were encountered but were ultimately resolved through several implemented solutions to make progress towards gathering the necessary simulation data. Upon importing the AUV model as a CAD file into the ANSYS simulation software, the error generated was described as the "surface mesh was intersecting due to tolerance mismatches." This error can be seen in *Figure 3*, displaying the AUV cad model in the ANSYS simulation software. To resolve this error, the

AUV cad model was imported as an STL file rather than a CAD assembly into the ANSYS software. This method generated a second error of which the ANSYS software described as "the mesh failed and cannot be performed." A second strategy to minimize the number of errors generated in the ANSYS software was to import an STL file of only the AUV's cylindrical hull as shown in *Figure 4.* Upon importing the STL file of the AUV's cylindrical hull, another error was generated described the file as having "meshes that were self-intersecting." The solution to this error was to use a feature of the ANSYS software termed shrink wrap on model facets. This feature successfully resolved the generated error and an enclosure was created to surround the STL cylindrical hull as shown in *Figure 5.* All previous aforementioned errors prevented an enclosure from being created for the model, which is the first step before generating a surface mesh to begin the simulation process. The enclosure represents the surroundings of the model, in this case, an enclosure of chlorine water, while the surface mesh generates a grid map of the entire body of the model to use for engineering simulation analysis. Consequently, progress was made towards establishing the necessary steps before producing engineering simulation data.

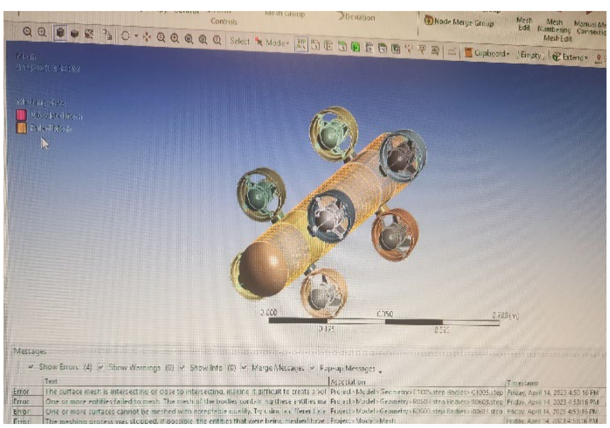

Figure 3: AUV model imported as CAD file into ANSYS with associated errors

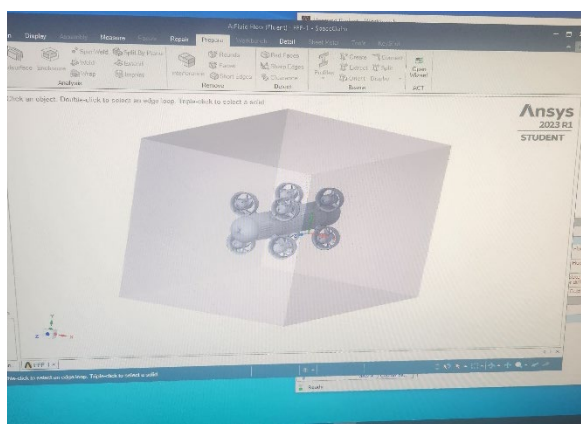

Figure 4: AUV model imported as STL file into ANSYS (errors not visible in picture)

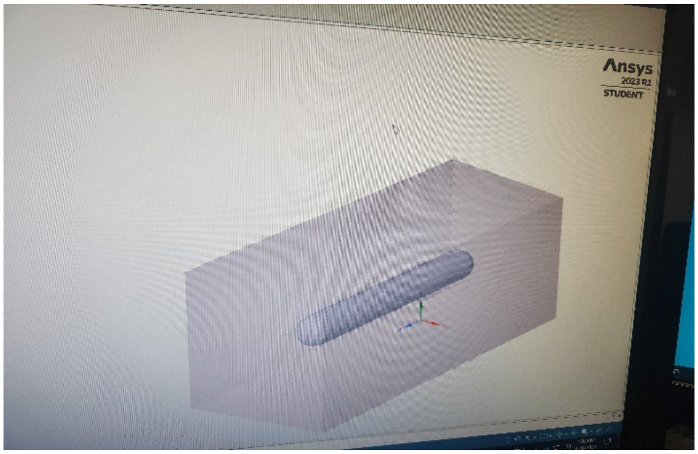

Figure 5: **Figure 5:** *Cylindrical hull imported as STL file into ANSYS displaying the enclosure.*

Additionally, theoretical analysis for three different AUV buoyancy conditions were determined, with results shown in *Table 1.* Three buoyancy cases were analyzed; an empty syringe with no water intake, a half-full syringe of water intake, and a completely full syringe of water intake. For the first buoyancy condition, both AUV syringes are closed and there is no water intake. The total volume of the AUV was calculated to be, $V_T = V_E = V_{cyl} + V_D - V_{Elec}$ where V_{cyl} represents the volume of a cylinder, V_D represents the total volume of the two dome end caps on the AUV. V_{Elec} represents the volume displaced by the AUV's electronics. For the second buoyancy condition, both syringes are half-full of water, and the total volume is calculated as, $V_{HF} = V_T - 2V_s - V_{Elec}$. For the third buoyancy condition, both syringes are full of water, and the total volume is calculated as, $V_{SF} = V_T - (0.5)2V_{cyl} - V_{Elec}$

The mass of water displaced takes into account the total volume of the AUV plus the mass of the electronics, electronic acrylic bay plate, and thrusters which total up to 10 lb. The total volume taken up by all the inside electronics of the AUV is subtracted from the total volume of the AUV as well which is about roughly 2.22E-03 m^3. The buoyant force is then calculated as, $F_B = \rho_w * V_{sub} * g$ where V_{sub} represents the volume of the AUV at the chosen condition

(Empty, Hal-Full, or Full Syringe), ρ_w, is the density of water, and g is the acceleration due to gravity. The buoyant force is equal to the weight of the AUV, of which the mass of the AUV can be determined. The total mass of the AUV's inside electronics is then subtracted from the AUV's mass. The objective is for the AUV to achieve neutral buoyancy which requires that the mass of water the AUV displaces is equal to the mass of the AUV. To achieve positive buoyancy, the AUV's mass must be less than the mass of water it displaces. To achieve negative buoyance, the AUV's mass must be greater than the mass of water it displaces.

Buoyancy Condition	Mass of water displaced (lb)
Empty Syringe	46.23
Half-Full Syringe	45.82
Full Syringe	45.41

Current tasks underway consist of adding a sliding mechanism for the electronics bay plate inside the AUV, custom designing an inside electronics enclosure, and completing the ANSYS CFD simulations. This sliding mechanism for the electronics bay will either be custom designed or purchased. A rack and pinion system, roller drawing slides, or soft ball bearing slides or all ideas being considered. A custom designed secondary containment electronics enclosure will protect the AUV's inside electronics from any water damage. This part will be either machined or 3D printed. Next steps in the ANSYS engineering simulation software is to generate a surface mesh and gather simulation data for the AUV's buoyancy and thruster control.

Upcoming tasks to be completed before the end of this month consist of the physical build of the AUV, 3D printing the thruster mounts, programming the AUV for full autonomous operation, and successfully ensuring all electronics work together seamlessly. Testing and debugging will also be conducted to ensure the AUV can perform the desired functions of moving up, down, forward, reverse, left and right autonomously. Experimental testing will be done to ensure the AUV can achieve a neutral buoyancy state which allows the AUV to hover underwater, neither sinking nor floating. To achieve a neutrally buoyant state weight may have to be added or removed to the AUV.

References

[1] "Robosub," About Robosub, Robonation, 2023, https://robosub.org/about/ .