Maximizing the Thrust on the Tail Fin of an Autonomous Air Swimmer

Allen Mehrafshan
Dr. Sharath Girimaji, Mentor
Texas A&M Aerospace Engineering

Introduction/Background
Large, high altitude balloons might replace many satellites in the future because of economical advantages. In order for the satellites’ orbits to be geosynchronous, they need a strong and efficient method of propulsion. NASA originally proposed a motor fan. However, it would be too expensive, heavy, and inefficient, so it was eventually rejected. Tail fins, similar to those of fish, have been proposed as an alternative propulsion method.

Objective
The objective of this project is to determine the best shape, frequency, and amplitude of the tail fin of a neutrally buoyant balloon to maximize its thrust. The five shapes tested are shown below – a rectangle a 10 degree trapezoid, a 20 degree trapezoid, a chevron, and a crescent.

Methods
We set up our experiments by cutting out five pieces of balsa wood into five different fin shapes. We placed each of them into a closed circuit wind tunnel with a 1 ft x 1 ft test section, shown below. We tested each shape with a constant tunnel velocity of 2 m/s. We then used a force balance to record the thrust that each shape produced.

Results
Results are shown in the two graphs below. Nine different trials were run for each fin shape – three different amplitudes and three different frequencies were run for each test. The average force shows the net force in the horizontal direction. Positive values indicate more drag than thrust, and negative results indicate a net thrust force.

Analysis/Conclusion
As can be seen in the previous graphs, the 20 degree trapezoid produced the most amount of net thrust. This is not surprising because most fish fin shapes resemble the trapezoid more than they do any other of our shapes. The two graphs are very similar because the difference between the different amplitudes and frequencies is not as significant as the difference between each shape. Every shape except the crescent produced more thrust than drag as can be seen by the negative values. The crescent is the only shape that produced more drag than thrust in every trial.

Future Work
Further propulsion studies should include shapes that are closer to the trapezoidal shape in order to investigate the finer parameters not included in this study that affect the thrust in less noticeable ways. The area and sweep angle should be further investigated with finer measurements. We experimented with a 10 degree and 20 degree trapezoid. Further studies should include measurements such as 15 degrees and 25 degrees and even more measurements in between. In the further scope of this project, more should be done to find better propulsion methods. This project aims to move the methods away from the motor fan, which is too expensive, heavy, and inefficient. Fin propulsion is a promising method, and more research should further our development of better propulsion methods. Also, different methods of obtaining results should be utilized, and reliable results should be found. Although the force balance we used gives very accurate data, more numerical data from different sources should be used to obtain more reliable conclusions.