How Flow Speed and Distance from Surface Affect Lift and Drag on Various Hemispheroids

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Introduction

Professor Luhar studies how fluid flows over complex surfaces. Our mentor, Mark Hermes, has run experiments with rigid 3D-printed starfish models to understand the hydrodynamic effects associated with body shape and surface position. Our objective was to create various hemispheroids as a simpler design to find how distance from the attachment surface and body shape affect the forces on them. We measured the lift and drag on the hemispheroids in a water channel, as we varied their distance from the surface and the flow speed. The goal of this research is to find an optimal design that minimizes drag and maximizes downforce (negative lift), which relates to how starfish attach to a surface. The application for this research on starfish could be used to create a soft-bodied morphing robot for use in the ocean to attach to a ship or other surface.

Experimental Methods

1. My lab mate and I designed and 3D printed three hemispheroids with the same diameter (19cm), but different aspect ratios of 1, 1.73, and 3.73 with respect to radius and height using SolidWorks.
2. For each trial, we attached one of the hemispheroids to a linear actuator and set its distance from the surface at 5mm and 30mm.
3. Then, we ran our offset script with no flow.
4. For each distance, we set the flow of the water to a low and high speed and ran our script to gather data on the forces acting on the hemisphere.
5. We used the LDV to gather data on the velocity of the flow.

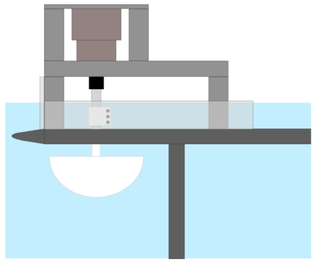


Figure 1: The experimental setup.

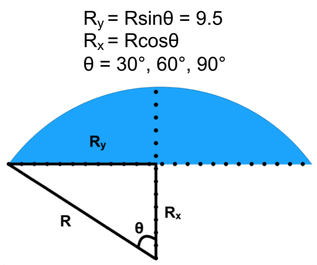
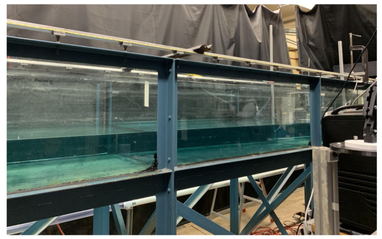


Figure 2: The design for the hemispheroids.



Water channel. PC: Jacklyn Oldoerp

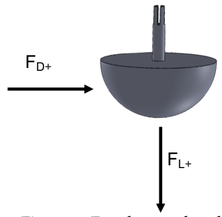


Figure 3: For the graphs, the flow is considered as moving to the right with positive drag in the same direction as the flow and positive lift down away from the surface.

Results

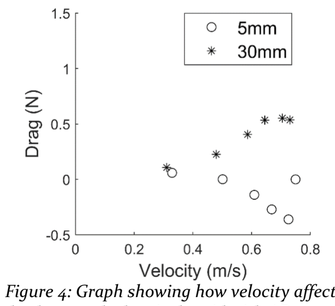


Figure 4: Graph showing how velocity affects the drag on the hemispheroid with AR=1.73 at different distances from the surface.

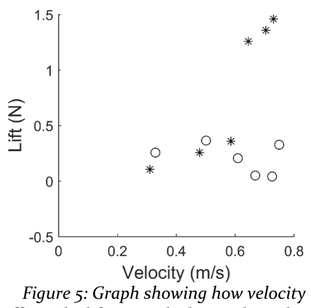


Figure 5: Graph showing how velocity affects the lift on on the hemispheroid with AR=1.73 at different distances from the surface.

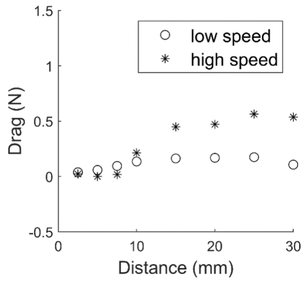


Figure 6: Graph showing how distance from the surface affects the drag on the hemispheroid with AR=1.73 at different speeds.

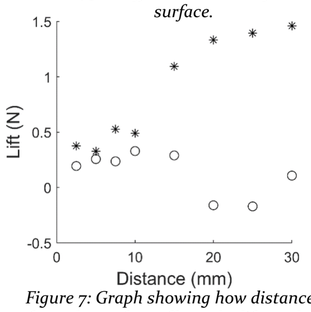


Figure 7: Graph showing how distance from the surface affects the lift on the hemispheroid with AR=1.73 at different speeds.

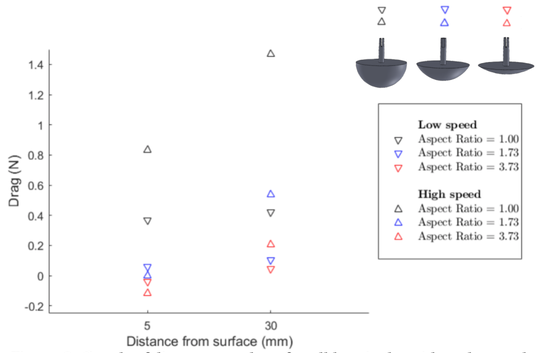


Figure 8: Graph of distance vs. drag for all hemispheroids at low and high speeds.

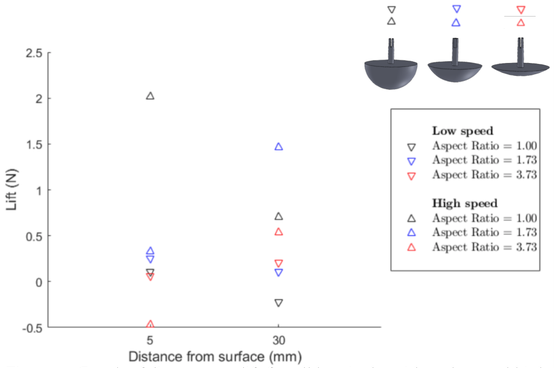
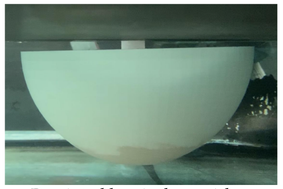


Figure 9: Graph of distance vs. lift for all hemispheroids at low and high speeds.

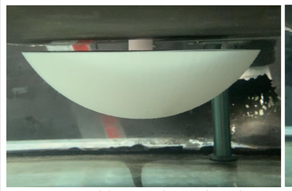
Summary of Results

- Overall, the forces of lift and drag tended to increase as the distance from the surface increased for higher speeds, although for some of the hemispheroids, the forces increased for the lower speeds as well.
- Other cases included trends of negative lift for the low speed at a greater distance and for the high speed at a closer distance.
- Another observation was decreased lift at a greater distance for hemispheroids with aspect ratios of 1 and 1.73 for various speeds.
- An unexpected finding was that closer to the surface, the drag was negative for hemispheroids with an aspect ratio of 1.73 for the high speed and with an aspect ratio of 3.73 for high and low speeds.
- Using Particle Image Velocimetry technology, we observed that there was a vortex region at the front of the hemispheroid with an aspect ratio of 1.73, which may be the cause of the negative drag cases.

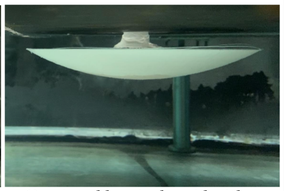
Dye injection showing how the flow between the surface and the hemispheroid with an aspect ratio of 1.73 moved in the opposite direction to the motion of the water at the closer distance. PC: Jacklyn Oldoerp



3D-printed hemisphere with an aspect ratio of 1. PC: Jacklyn Oldoerp



3D-printed hemispheroid with an aspect ratio of 1.73. PC: Jacklyn Oldoerp



3D-printed hemispheroid with an aspect ratio of 3.73. PC: Jacklyn Oldoerp

Skills Learned

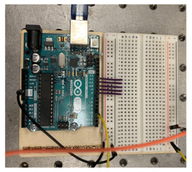
Arduino Uno and Arduino IDE
- used the Arduino software and microcontroller board to control a linear actuator that was powered by a servo motor

MATLAB
- wrote the code for the NI DAQ device to acquire force measurements from the ATI Gamma load cell system and save the data to output files

3D printing (Prusa I3 3D printer)
- used SolidWorks to design the hemispheroids

Laser Doppler Velocimeter (MSE 2D miniLDV)
- used to measure the velocity of the flow

Fluid Mechanics Concepts
- lift and drag
- Bernoulli's principle
- wake region



Arduino Uno. PC: Jacklyn Oldoerp

Acknowledgements

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