Effects of Varying Porous Structures of an Airfoil

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Introduction

In my lab we are studying how porous holes affect lift and drag of an airfoil. The goal of the porous holes is to decrease separation between the airfoil and fluid and to increase laminar separation which will help increase lift and decrease drag.

Objectives & Parameter Design

Our main objective was to reduce drag and increase lift in order to produce more efficient wings, which would decrease the amount of fuel needed to fly. To do this, we varied two parameters of the holes: the spacing and the angle of the holes. For spacing, we modified the gap between holes as a function of the length of the airfoil:

s = 10%, 15%, and 20%

For the angles, we drilled holes that would appear horizontal when the airfoil was at angles of attack:

AoA = 3°, 6°, 9°, and 12°

We tested all of this on a NACA 0012 airfoil that was 10cm long. We kept our experiment at $Re = 5 \times 10^4$ to keep it consistent with a previous paper. The formulas used to determine lift was:

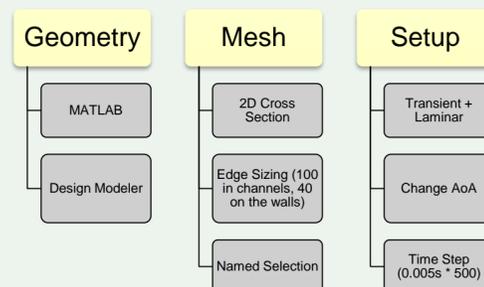$$C_l = \frac{L}{0.5\rho \cdot U^2 c}$$

$$C_d = \frac{D}{0.5\rho \cdot U^2 c} .$$

These formulas produce non dimensional numbers, which allows for our research to be applied to larger scales.

Methods and Results

Simulations

Method:

Geometry → MATLAB → Design Modeler

Mesh → 2D Cross Section → Edge Sizing (100 in channels, 40 on the walls) → Named Selection

Setup → Transient + Laminar → Change AoA → Time Step (0.005s * 500)

Our simulation process mainly took place in Ansys with the help of MATLAB and Excel. Ansys is a simulation process which conducts an experiment in a computer. To create this experiment in Ansys, we started with the first step which was geometry. In geometry, we designed the model of the airfoil with the help of MATLAB to create the porous holes. We tested a 2Dcross-section of the airfoil because in the same amount of data points we can have higher resolution and it's less expensive. After the geometry, we started the next step which was Meshing. Meshing indicates the exact points that are getting tested by using face meshing. We also used name selection in Fairfield to differentiate the different sides the air is coming from which we named inlet and outlet. Finally, we went on to the setup of the experiment. We made the experiment transient which is time-dependent because of the porous holes. Changing the angle of attack of the airfoil was also done in setup by changing the direction of the air using trigonometry.
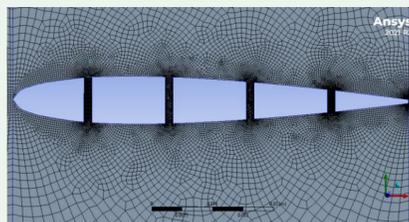
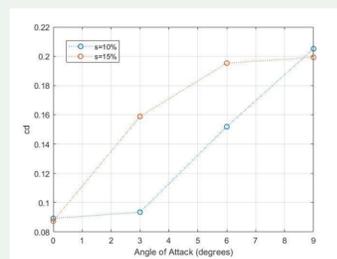**Figure 1. Mesh for s = 10%**

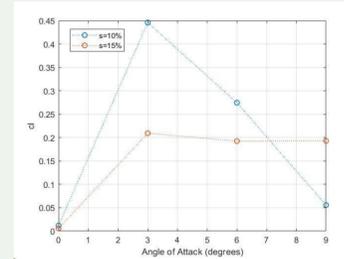**Results:**

Figure 2. Graphs of Cd vs. AoA at spacing=15%, 20%

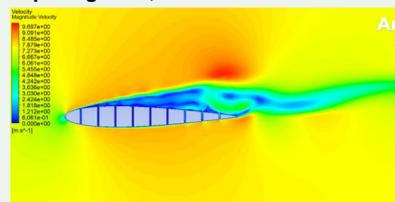**Figure 3. Graphs of Cd vs. AoA at spacing=15%, 20%**

Figure 4. Velocity Contour for s = 10% and AoA = 6°

Experiments

Method:

We used SolidWorks which is a 3D CAD software used to create the models of different types of porous airfoils that needed to be tested. There were five configurations that needed to be tested but each configuration was too big to be built in the 3D printer at once so we split each configuration into two parts and put them together at the end. After a certain part of the airfoil was done with 3D printing it went into an ethanol cleaning bath and a heating machine to clean up any leftover residue on the airfoil. Finally, we sanded each part of the airfoil to decrease frictional drag and then attached the two separate parts of each airfoil together with a hot glue gun and sanded them together afterward.
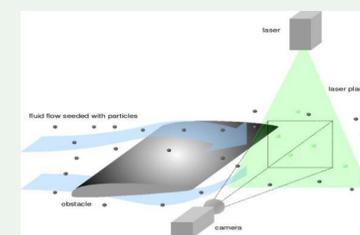
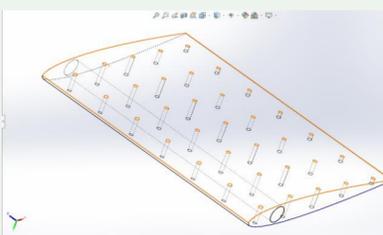**Figure 5. Experimentation Setup Design**
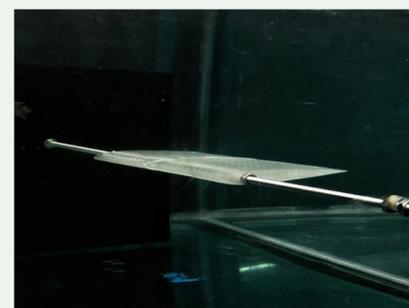
Figure 6. 3D CAD Model for s = 20%

Figure 7. Airfoil fixture within water channel

Everything was now ready to test each configuration. We started experimenting by using the water channel of USC. We used lasers to capture a 2D portion of the airfoil and a high-speed camera to capture certain particles in the water channel flowing through the water.
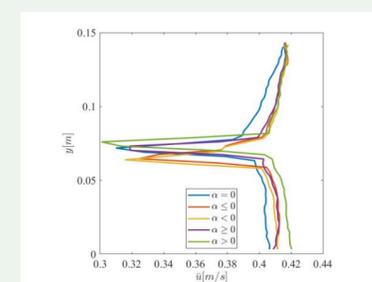
Results:

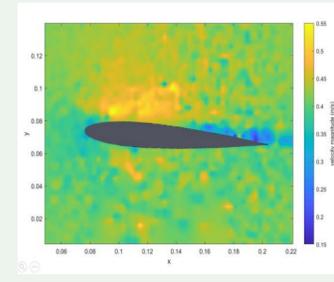**Figure 8. Horizontal velocity profile at trailing edge in y direction**

Figure 9. Velocity magnitude contour at s = 10%, positive AoA.

Skills Learned

Ansys

SOLIDWORKS

MATLAB

Conclusion

Overall, SHINE has been very educational and has allowed me to gain a lot of experience in Aerospace Engineering. Furthermore, I plan to major in Aerospace and hope to make a career in the field.

Acknowledgements