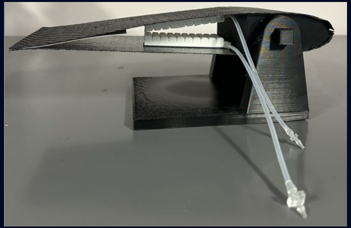
Fluidically Actuated Aerodynamic Surface Technology (FAAST)



ME 193 – Printable Robotics

Team 7: Chris Yen, Raaj Pednekar, Saurabh Pal

Problem

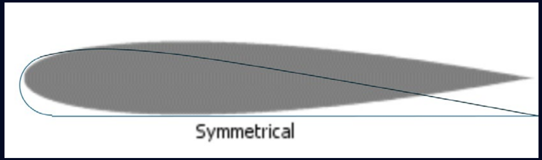
Rigid airfoils have a fixed camber, and can only produce lift in one direction. Dive planes and sails used in AUVs and solar cars must be symmetrical, rotating about one axis. They thus produce lots of drag when turned.

[1] AUV: autonomous underwater vehicle

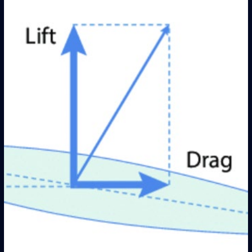
Approach

Create a camber-morphing airfoil. 3D print bending actuators and attach to an airfoil-shaped rigid skin so it can bend in either direction.

Testing will be performed with a weigh station and/or strain gauges.



(Anticipated) Results



The airfoil will be neutral by default. One actuator can be turned on to morph the camber to one side.
Morphing is symmetrical.
Morphing the foil downwards causes a lighter weight on a weigh station and vice versa.

Impact

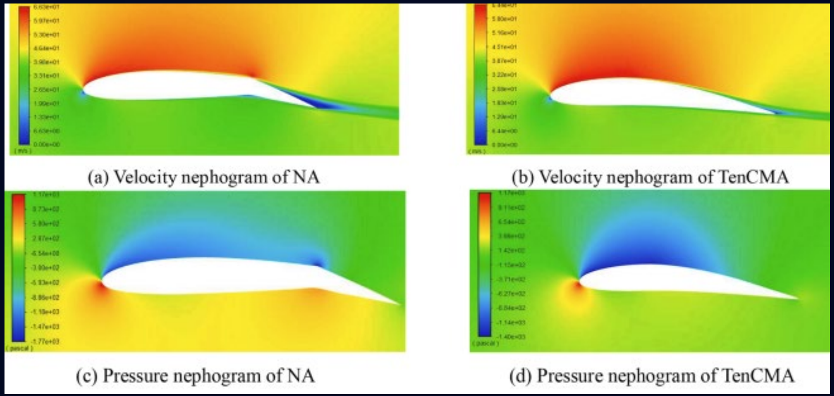
This will provide an avenue for increased aero/hydrodynamic efficiency, making robots and solar cars more energy-efficient for crosswind/current operations.

Ideation and Research

Papers:

- Smooth surface bending actuator using symmetrical chambers is possible but has limitations[4]
- Data for the effect of external pressures and insight into how pressure affects PneuNet actuation[5]
- Changing the surface contour of the airfoil is still a viable option and leads to substantial benefits[6]

[3] Zhou, Wen, et al.. "Modeling and Experimental Evaluation of Dynamic Behavior of a Soft Bending Actuator with Symmetrical Fluidic Chambers," *Science and Actuators A: Physical*, 2023.
[4] Sun, Enlai, et al., "An Experimental Study of Bellows-Type Fluidic Soft Bending Actuators under External Water Pressure," *Smart Materials and Structures*, 2020.
[5] Xie, McGovern, et al., " ," *Advanced Engineering Materials*, 2015.



(a) Velocity nephogram of NA

(b) Velocity nephogram of TenCMA

(c) Pressure nephogram of NA

(d) Pressure nephogram of TenCMA

Inspiration: Innoptus Solar Racing Team

Design Iterations Snapshot

Idea

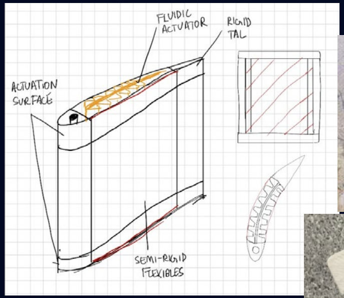
Design and simple airfoil and paste actuator in it

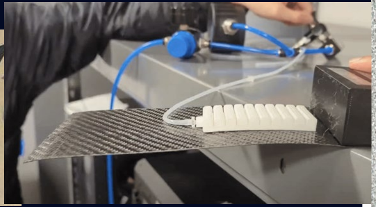
Refine the prototype

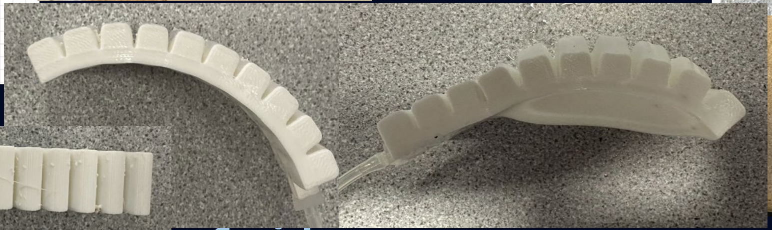
Get more bending, improve skin quality

Add second side

Skin-skin connection too rigid. Iterate with thinner bar







Final Design!

Create 1 side prototype

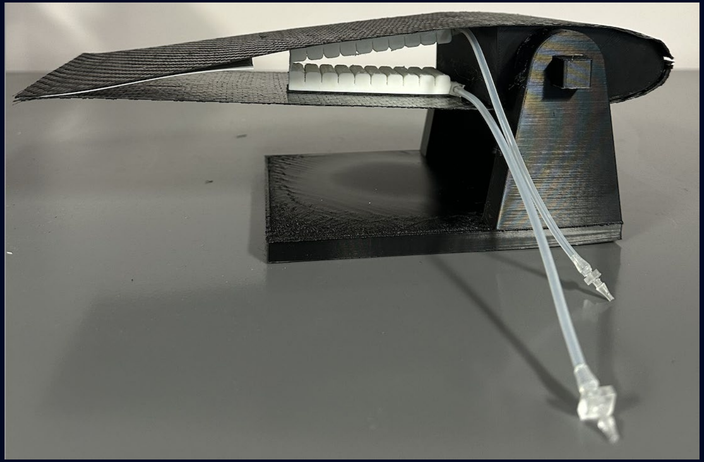
Initial actuator is was not airtight and too flimsy and initial skin too thin

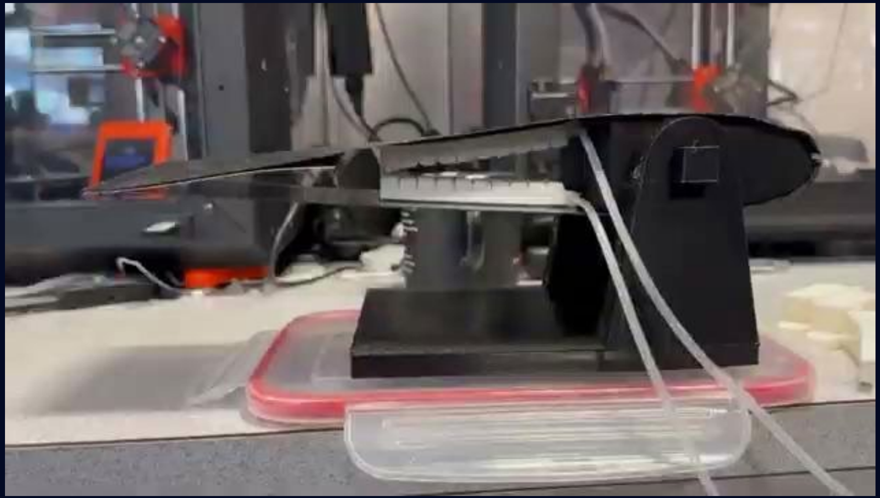
Add PLA attachments

Skin too inflexible. Find different adhesive methods, reduce friction

Final Design

- Two carbon fiber skins
- Coupled bending actuator with the ability to go either direction
- Slick, flexible material at trailing edge
- Stand for affixing



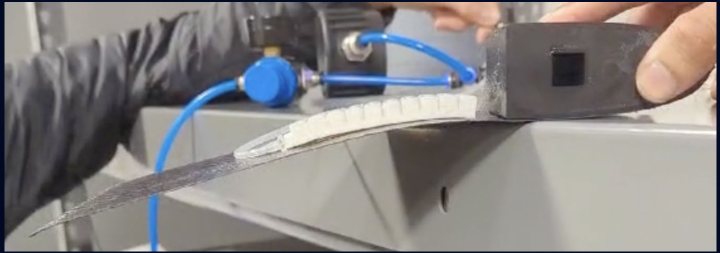


Takeaways

Design Optimization for Soft Robotics:
Explored unique geometries through iterative testing, balancing overly flimsy and overly stiff prints. Refined channel and chamber designs for optimal performance.

Mastering 3D Printing Challenges:
Gained experience debugging 3D printers, optimizing slicing settings, and incorporating insights from research papers. Used different filaments for various aspects of the device.

Leveraging New Tools and Materials with 3D Printing:
Developed carbon skins, manipulated PET plastics, and integrated non-printed components into the design and testing process.



Thank you!

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[1] AUV: autonomous underwater vehicle
[2] Brito, Griffiths, Challenor, "Risk Analysis for Autonomous Underwater Vehicle Operations in Extreme Environments," *Risk Analysis*, 2010.
[3] Zhou, Wen, et al.. "Modeling and Experimental Evaluation of Dynamic Behavior of a Soft Bending Actuator with Symmetrical Fluidic Chambers," *Science and Actuators A: Physical*, 2023.
[4] Sun, Enlai, et al., "An Experimental Study of Bellows-Type Fluidic Soft Bending Actuators under External Water Pressure," *Smart Materials and Structures*, 2020.
[5] Xie, McGovern, et al., "Elastomeric Actuators on Airfoils for Aerodynamic Control of Lift and Drag," *Advanced Engineering Materials*, 2015.