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Variable Camber Wings using Compliant Mechanisms

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Introduction

Wing morphing is the manipulation of a wing shape to influence aerodynamics. Wing morphing has significant aerodynamic advantages over traditional flaps, including increased efficiency and control. The USU Aerolab specializes in morphing aircraft and is currently working with the Air Force Research Lab on morphing straight wings [1-4].

The purpose of this project is to identify methods for applying morphing technologies to swept-wing aircraft. These methods are then used to create a morphing wing aircraft to demonstrate the efficiency and control of morphing flight with a swept wing.

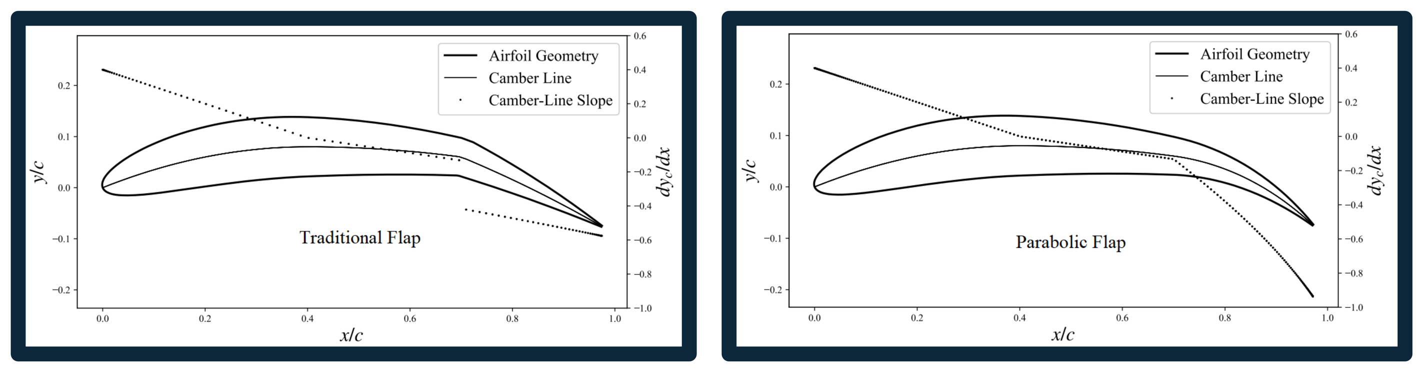

Figure 1 A traditional flap vs. a parabolic flap [4]

Methods

The USU Aerolab is a research group which specializes in computational aerodynamics. The student first learned how to manufacture RC aircraft. Though the process was difficult to create, the student has developed a repeatable process for designing, building, and testing concepts along the research path.

The student uses this general process to test different concepts for the research project. The first step involves determining whether the concept is feasible. This requirement means the concept must be possible to create using available equipment and machinery. Similarly, the concept must not have an exorbitant cost or be mechanically complex.

The second step involves modeling the concept to determine the compliant characteristics of the concept. This step often includes multiple iterations to perfect the use of the concept. Such characteristics include deflection angle, compliance to deflection, load support stiffness, and material/concept weight. These characteristics were tested using mini digital servos as actuators. As a final demonstration of the concept they are tested in near flight conditions out the window of a car.

The final step was to evaluate the ease of manufacture. As several iterations are expected for the concept development, if the concept is not easy to remake, it is discarded. Such processes as additive manufacturing greatly enhanced this step.

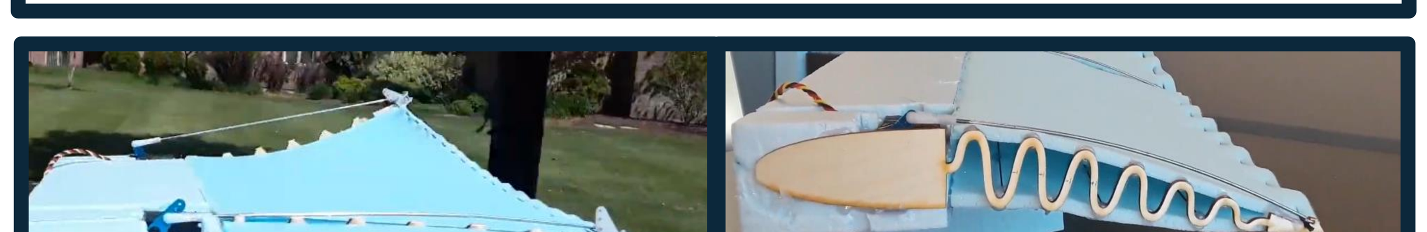

Figure 4 Deflection and trailing edge interpolation shown on early concepts

Results

The student evaluated concepts for variable camber wings from three requirements. These requirements are that the wing design must be feasible, the design must be modeled and tested, and the manufacturing process must not be complex. The design that holds best is a 3D printed concept that relies on inherent compliance of the material to deflect in flight.

Feasibility

The student has tested several concepts to determine feasibility. The student includes here some key points which have characterized the most proficient design. The design :

- Can be modeled in a CAD software and 3D printed
- Must be buildable using equipment owned by USU or the AeroLab
- Must be buildable by the undergraduate student

Figure 3 Morphing wing C4V10 deflected

Modeling and Testing

The following characteristics were determined as the designs were iterated upon. The design :

- Must not flutter at the trailing edge when in flight
- Must deflect $\pm 10°$
- Material must withstand aerodynamic loading without buckling
- Actuation must deflect the flap without buckling or bulging
- Actuator mini digital servo must be able to deflect the wing without overstraining the motor
- Must have comparable density to non-morphing model made from blue DOW foam -- $\rho = 14.79\,\frac{kg}{m^3}$, PLA -- $\rho = 1{,}250\,\frac{kg}{m^3}$, Fishbone -- $\rho = 188.5\,\frac{kg}{m^3}$, Current concept -- $\rho = 40.51\,\frac{kg}{m^3}$.
- Skin must be continuous
- The trailing edge must interpolate between actuators

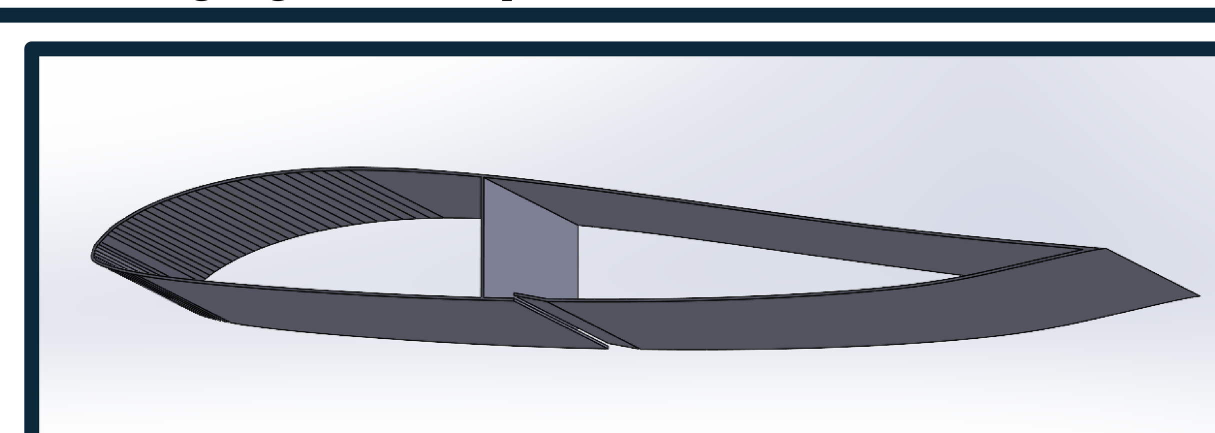

Figure 4 Current concept involving a flexible material trailing edge

Manufacturability

Through the iterative testing mentioned above, the student found the best manufacturing method to be 3D printing. This method has the following characteristics :

- Concept can be made within 48 hours after modeling is complete
- A repeat design takes less time
- Easiest method for an iterative approach to research

The final designs which meet the previously described requirements are 3D printed. Due to the compliance of the material, they deflect enough to morph during flight while being stiff enough to withstand aerodynamic loading. The 3D printing process is a streamlined manufacturing process that requires little to no monitoring once the print is started. When a final design is chosen, the 3D printing process will be the simplest to perform for a student new to the project.

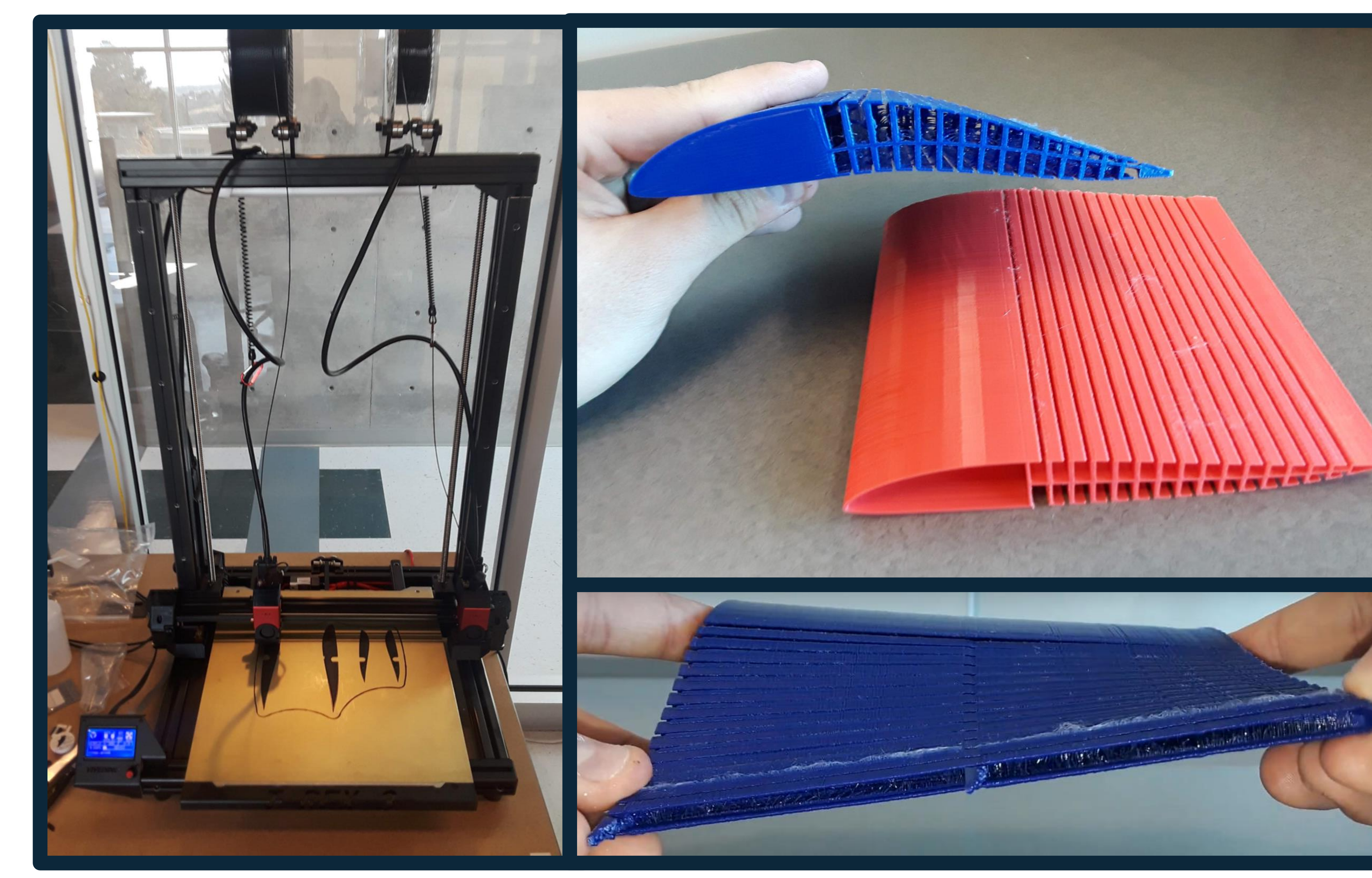

Figure 5 3D printed concepts best employ morphing wing characteristics

Conclusion

The student had to learn manufacturing techniques for designing and building RC aircraft. Through learning these techniques, the student has developed an iterative process to manufacture wing concepts. The tactics the student has learned continue to develop his understanding of morphing wing requirements.

This project continues to examine the best morphing wing design for creating a small morphing-wing RC aircraft. 3D printing has proved to be the simplest and quickest manufacturing process. The student currently examines the use of flexible materials to utilize inherent compliance. The results of such structures support the continued use of flexible materials.

Further testing will examine skin requirements as well as locating the actuation mechanism internally.

References

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