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Development of a Trailing Edge Flap Using a Compliant Mechanism

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Overview

The focus of this project is the construction of a morphing wing with a trailing edge (TE) flap using an internally actuated compliant mechanism to achieve a smooth flap deflection. A compliant mechanism is a mechanism that relies upon the inherent flexibility of the material in order to achieve motion. An adapted cross-axis flexural hinge is implemented in order to achieve the desired deflection (fig 2)[1]. This mechanism then needs to be actuated internally, which is done using a servomotor and fishing line.

Conceptual Framework

A trailing edge (TE) flap is a device that deflects downward in order to artificially increase the camber line slope of the wing. This causes the wing to produce higher lift at lower velocities and lower angles of attack [3]. However, this also increases drag. The contour of a conventional TE flap has discontinuities that increase drag. Thus, a smooth contour decreases drag while also delaying the separation of the laminar boundary layer. This would increase the Lift/Drag ratio leading to a reduction in fuel consumption [3].

Results

A TE flap was successfully developed that implemented an internally actuated compliant mechanism (fig 1). At the TE, there are two of these mechanisms. Fishing line is secured at the tip and ran to the servo mounted towards the leading edge (fig 2). When the line is in tension, the mechanism deflects (fig 4), causing the flap to return to equilibrium once tension is released (fig 3). A flexible skin material is attached to the flexure. As the flap deflects, the skin moves into slits on the wings upper and lower surfaces as needed. The design was able to achieve a maximum deflection of 40˚ (fig 4).

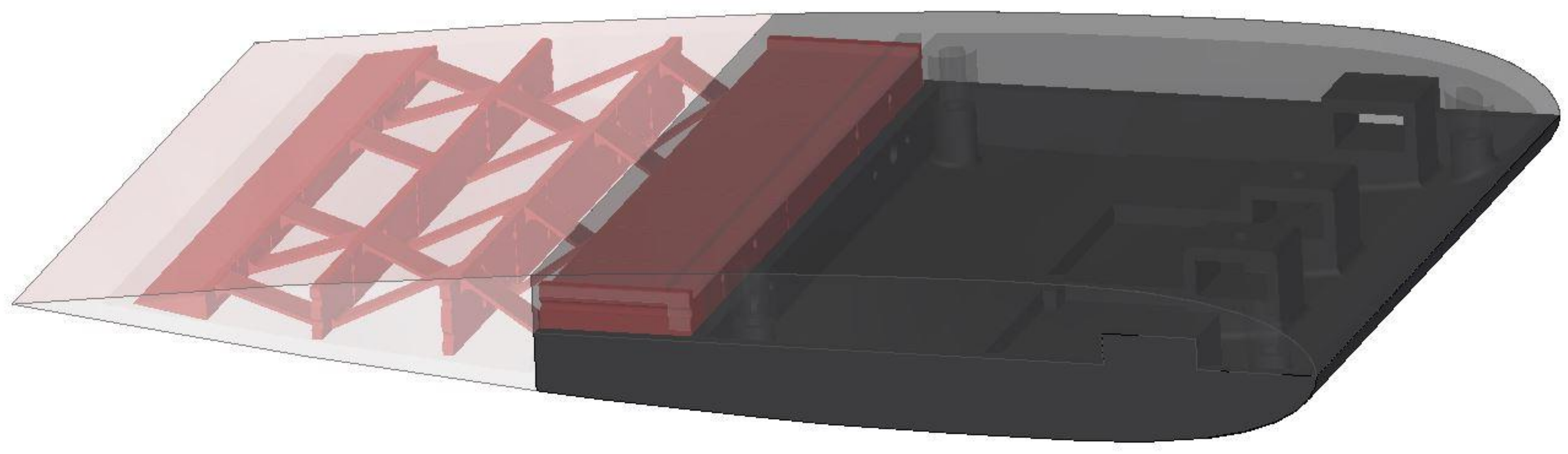

Figure 1: CAD model of wing

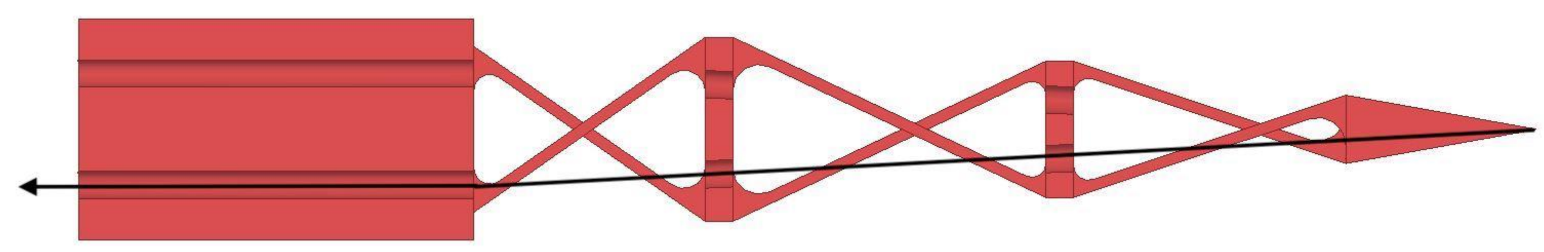

Figure 2: Adapted cross-axis flexural hinge mechanism

Figure 3: Undeflected wing

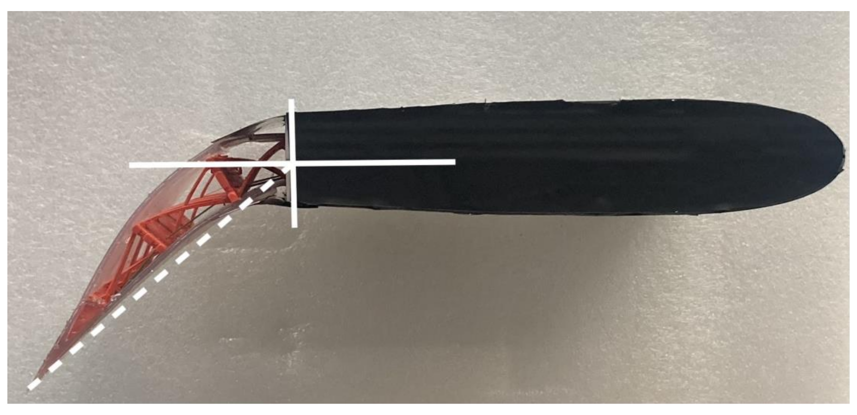

Figure 4: Wing deflected to ≈ 40˚

Impact

Compliant mechanisms can be printed in one piece which increases manufacturability [2]. The smooth geometry of the airfoil impacts the efficiency by decreasing drag. This decreases fuel consumption. The design could also be used during cruise to increase controllability mid-flight.

Project Continuation

In the future, a flexible material designed for cyclic loading will be used for the flexure. Lifecycle analysis simulations will be performed. An ANSYS framework to parameterize the flexure design has already been created [2]. This framework will use a mechanical simulation to investigate the optimal dimensions needed to achieve a specific required contour through stress and lifecycle analysis.

References

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2. Jensen, B. D., & Howell, L. L., *The modeling of cross-axis flexural pivots,* Mechanism and Machine Theory, 2002
3. R. Pecora, *Morphing wing flaps for large civil aircraft: Evolution of a smart technology across the Clean Sky program,* 2021

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