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Simulation of a Trailing Edge Flap Using a Compliant Mechanism

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Overview

This study focuses on the conceptual development of a trailing edge (TE) flap that utilizes compliant mechanisms it its rib framework to provide smooth flap deflection. A compliant mechanism is a specific mechanism that replaces multiple moving joints with a fluid, continuous geometry to achieve motion by relying on the flexibility of the material it is constructed with. For this TE flap, half of the large-displacement, monolithic compliant mechanism, Flex-16 (Fig. 1), was used in the rib geometry [1]. By integrating three half Flex-16's in each rib, the TE flap will provide a smooth curvature when it is deflected using the gear train (Figs. 2 & 3).

Conceptual Framework

Trailing edge flaps are utilized in nearly all real-world wings due to their ability to deflect downwards, allowing for more lift to be garnered at low velocities. However, during cruise flight, the wing must be as streamlined as possible to reduce the amount of drag produced, therefor the flap that was once used to create high lift must be returned to its original position. A smooth curvature of this TE flap allows the airflow to adhere to the flap for longer than a flap that has an abrupt change due to the Coanda effect [3]. This increased adherence in the flow is crucial in delaying the point at which the flow transitions from laminar to turbulent, improving the Lift/Drag ratio of the wing. A better Lift/Drag ratio corresponds to numerous improvements in the overall aircraft performance, such as: reduction of fuel consumption, shorter takeoff distance, and a greener interaction with the environment.

Key Findings

Originally, the project was first conceptualized with the intent of having a Shape Memory Alloy (SMA) integrated as the TE flap actuator, the mechanism that pulls the flap downwards. An SMA is an alloy that undergoes a specific crystal structure transformation when heated, resulting in the shrinkage of the alloy [3]. However, upon testing the SMA, the data collected showed a strain in the .006 in diameter wire of 3% when heated to its transition temperature. These experiments (Fig. 5,6) proved that using them as actuators would be too challenging as gaining a tip deflection of 30° would require a complex arrangement of the wires and excessive amounts of power to heat them.

Impact

Compliant mechanisms can greatly benefit the manufacturing process as they offer a faster production due to the material uniformity and not requiring assembly. The smooth curvature TE flap can be used on a wing to increase aircraft performance by delaying the point of flow separation on the wing.

References

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2. Anderson, J. D., *Fundamentals of Aerodynamics*, Boston: Mc-Graw Hill, 2001.
3. Almeida, Thais & Santos, Osmar & Otubo, J.. "Construction of a Morphing Wing Rib Actuated by a NiTi Wire." Journal of Aerospace Technology and Management. Volume 7, 2015. Pages 454-464.

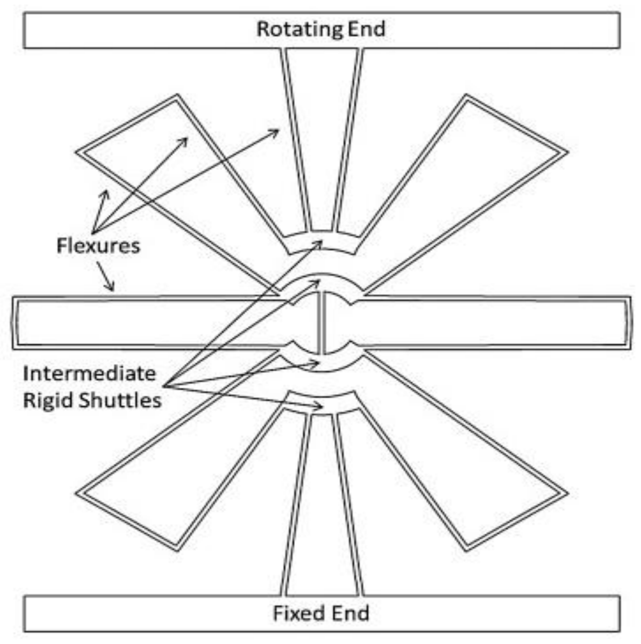

Fig. 1 – Schematic of a Flex 16 Compliant Mechanism.

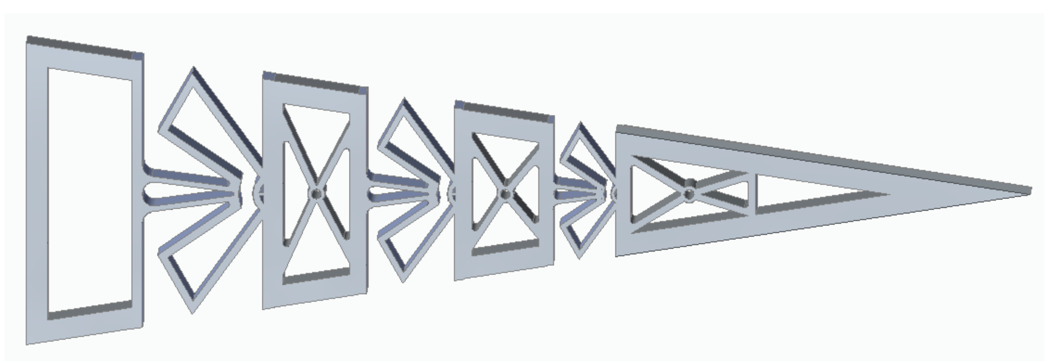

Fig. 2 –CAD model utilizing half Flex-16 geometry.

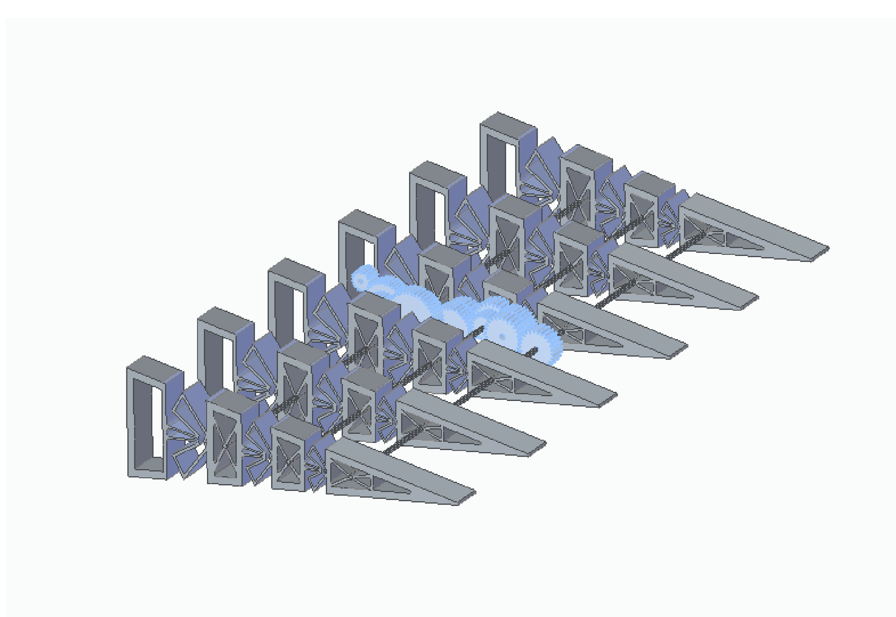

Fig. 3 - Gear train actuation mechanism.

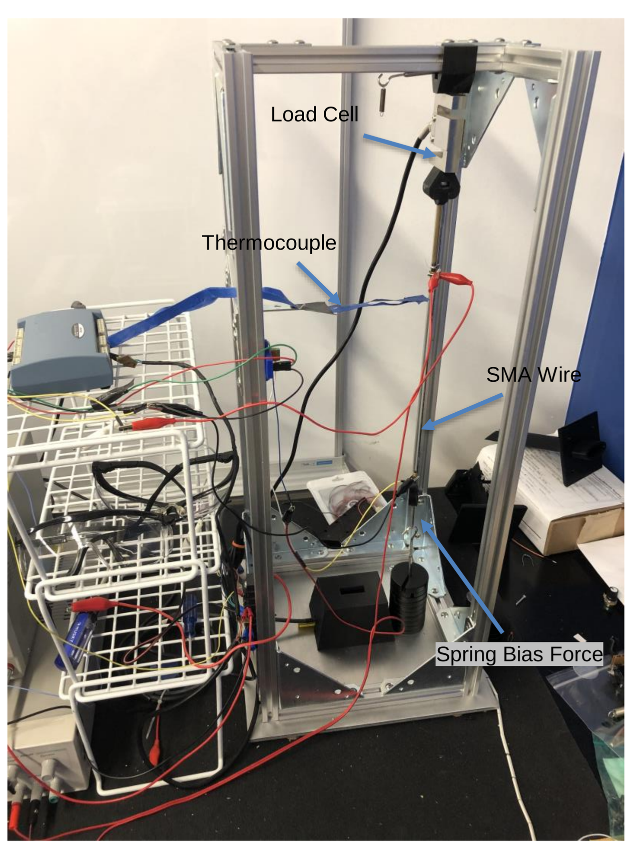

Fig. 4 – SMA test bed setup.

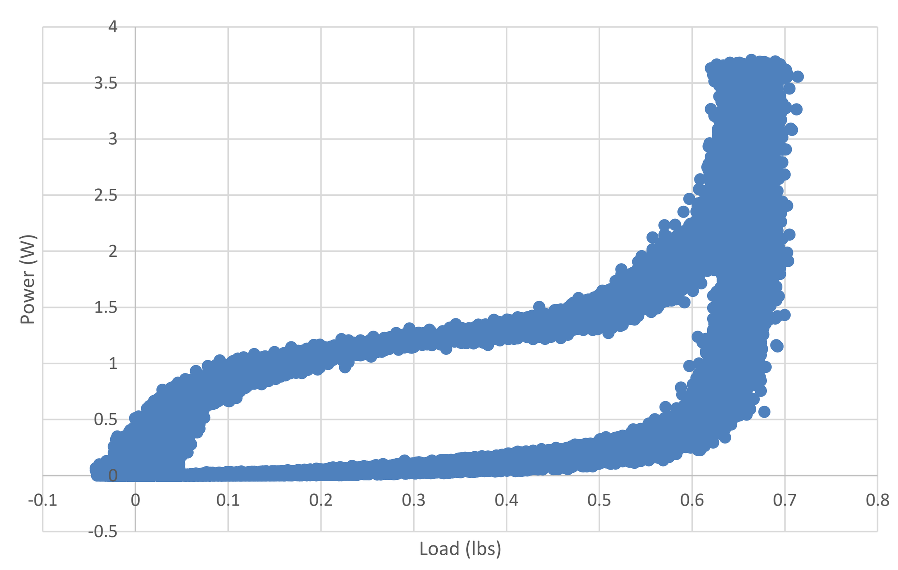

Fig. 5 – Power (W) vs. Load (lbs.) for SMA wire of .006 in diameter cycled every 10 seconds

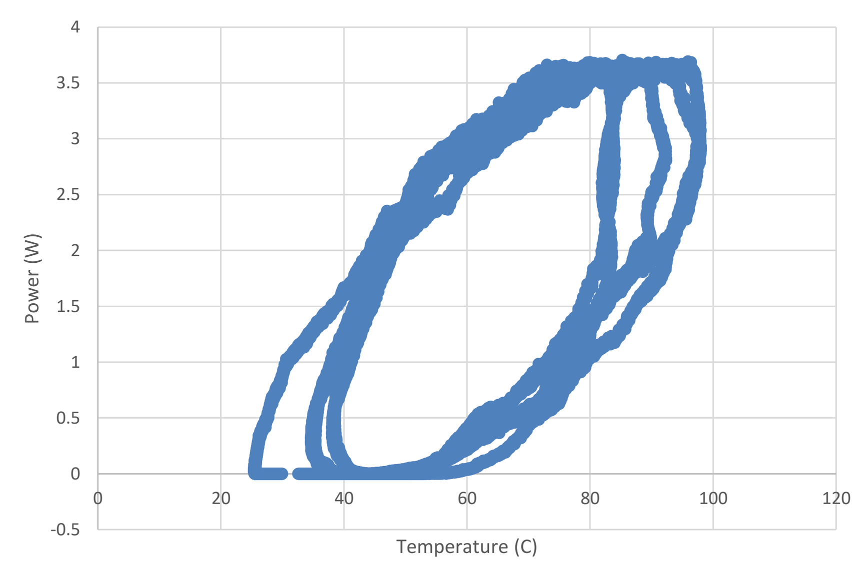

Fig. 6 – Power (W) vs. Temperature (C) for SMA wire of .006 in diameter cycled every 10 seconds

Project Continuation

The next step in the design process is to determine the material to use in the fabrication of the TE flap. Research will be conducted to analyze the benefits of different materials used in the construction of wing flap rib geometries. Stress analysis and cycle life analysis simulations will be performed using the rib geometry and implementing the different materials' properties. After the analysis of the geometry is complete and the material is decided, the gear train will need to be corrected to output the respective moment that causes a 15° deflection in each of the three actuation members. A 15° deflection in each member translates to a 30° tip deflection. Finally, the actualization of the flap will then take place, such as, fabricating the ribs and gear train, programming a stepper motor to provide the calculated torque to the gear train, and determining the best skin to use to cover the ribs.

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