Design and Development of an Actuation System for Morphing Flaps

Nate McWilliams, Kavan Hazeli Ph.D. and Konstantinos Kanistras Ph.D.

Overview
Wings with a continuous contour do not experience flow stream fluctuations during flight, and consequently provide better aerodynamic characteristics compared to wings with conventional flaps. Internally actuated morphing wing structures that are able to change their shape smoothly to adapt to different loading conditions can be capable of achieving near-optimal lift and drag profiles throughout all flight phases. The main goal of this study is to design and develop a lightweight actuation system for a morphing flap capable of sustaining a smooth operation under aerodynamic loads and enhance the aircraft aerodynamic performance.

Conceptual Framework
The proposed morphing flap will be internally actuated using shape memory alloys (SMA) (Fig. 1) [1]. Flexinol wires, which are small in diameter and made of nickel-titanium, contract like muscles when electrically driven are used in this study. An experimental test-bed is set to test the SMA wires performance, based of those used by Kennedy (Fig. 2) [2]. This ability to expand or contract is characteristic of certain alloys that dynamically change their internal structure at certain temperatures. They are lightweight when compared to other actuator systems, deform naturally and thus an ideal candidate for use in morphing wings.

Key Findings
Three Flexinol wires with diameters of 0.003", 0.006", and 0.012", respectively, were tested. Figure 3 shows the response of the wires when actuated at different current inputs. Fig. 4 & 5 show the temperature strain variations during actuation and cool down. The results plotted in Fig. 4 & 5 are from test A1 as shown in Fig. 3. The amount of plotted iterations in Figures 4 & 5 are 5, 8, and 5 for the 0.003", 0.006", and 0.012" respectively. The recorded strain values were between 3.5% and 4% at near the max safe pre-stresses for each wire. The power consumption was approximately 0.83 watts, 1.40 watts, and 1.19 watts for the 0.003", 0.006", and 0.012" diameter wires respectively. The next step is the development and testing of a Proportional Integral Derivative (PID) control system to control the current and temperature during actuation.

Impact
The aviation industry is already facing the challenge to develop a new generation of air vehicles characterized by high performance and low environmental impact. A morphing “adaptive” wing will allow for mission adaptability and improved aerodynamic efficiency.

References

Acknowledgements
- The authors would like to thank the National Science Foundation and Alabama Louis Stokes Alliance for Minority Participation for funding my research.
- The authors would also like to thank the RCEU staff, UAII Office of the Provost, UAII Office of the Vice President for Research and Economic Development and the Alabama Space Grant Consortium.