Development of Curling Actuations in HASEL Actuators

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Overview

Hydraulically amplified self-healing electro-static (HASEL) actuators are relatively new soft robotic actuators that have exhibited impressive actuation strain, speed, efficiency, and self-healing from dielectric breakdown. This work serves to harness the efficiency, speed, and self-healing characteristics in HASEL actuators to achieve biomimetic motion by mimicking curling and prehensile movements.

The work was split into four main stages:

- System configuration of high voltage amplifier, power supply, HASEL components, etc.
- HASEL shape and geometry design and experimentation.
- Strain-limiting layer design and experimentation.
- Design and early configuration of self-sensing circuit for complicated actuator designs.

This work will prove useful in robotic gripping applications because HASEL actuators accomplish soft curling movements. Execution of the dexterity of the human hand in robots is essential for NASA missions involving space exploration in environments threatening to human life.

Introduction

This work proves that designing actuator tails with a "scrunched" edge as opposed to a straight edge resulted in higher strain rates and tail tip deformations. Additionally, the plastic adhesive proved to be the most effective strain limiting layer. The work completed regarding the shapes and strain limiting layers can be used as a blueprint for incorporating HASELs into robotic grippers. Additionally, the efficiency of the designs in Fig. 2-3 can be used to further explore the self sensing capabilities in HASELs to manipulate the capacitance characteristics in the actuator. This work is significant because it provides design techniques to initiate curling movements in HASEL actuators.

Methodology

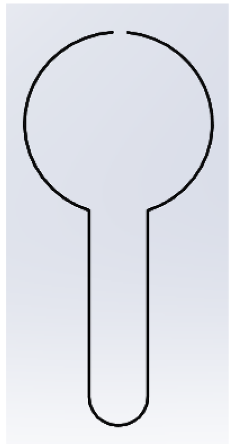

Figure 1: Straight tail design.

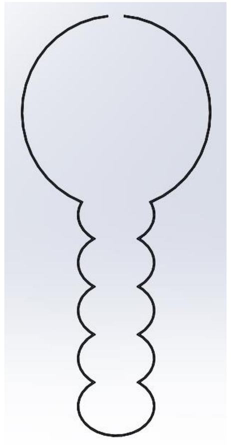

Figure 2: Scrunched tail design.

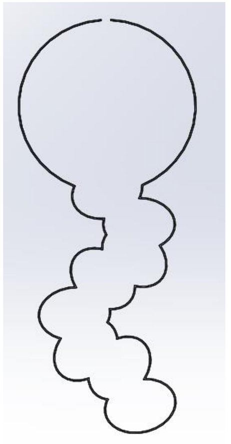

Figure 3: S-tail design.

- Three actuator shapes designed and refined in SOLIDWORKS.
- Actuator shapes outfitted with four strain limiting layers: scotch tape, duct tape, ecoflex-50, and plastic adhesive.
- Actuator deformations are measured, and shapes are modified based on effectiveness.

Experimentation

Figure 4: Straight tail actuator during experimentation

Figure 5: Straight tail actuator during experimentation

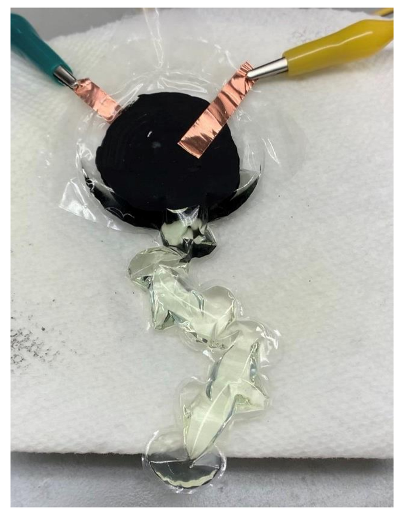

Figure 6: Straight tail actuator during experimentation

- Designs are heat sealed by 3D printer into biaxially-oriented polypropylene film.
- Actuators are filled with liquid dielectric, painted with carbon electrode paint, and outfitted with copper tape.
- A high voltage amplifier is connected to the system, and all experimentation was conducted at an applied voltage of 2kV.
- Strain-limiting layer acts as tendon to initiate curling movement of actuator tail.
- "Scrunched" geometry allows for tail to achieve better strain rates in conjunction with a strain limiting layer.
- Upon proof of concept in the self-sensing circuit that is currently being built, geometry may be modeled to achieve self-sensing.

Results

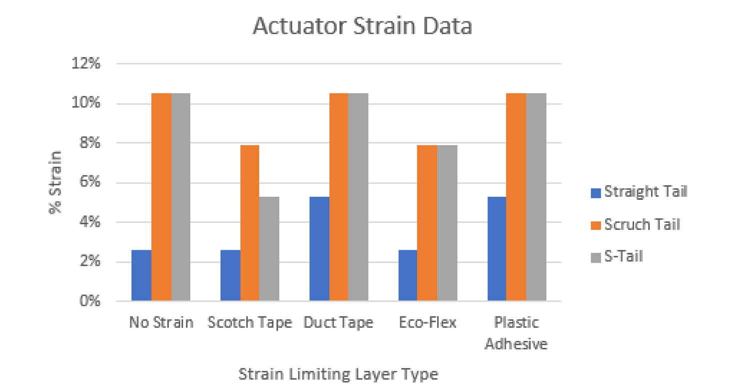

Figure 7: Strain data for the actuators with and without the four strain limiting layers.

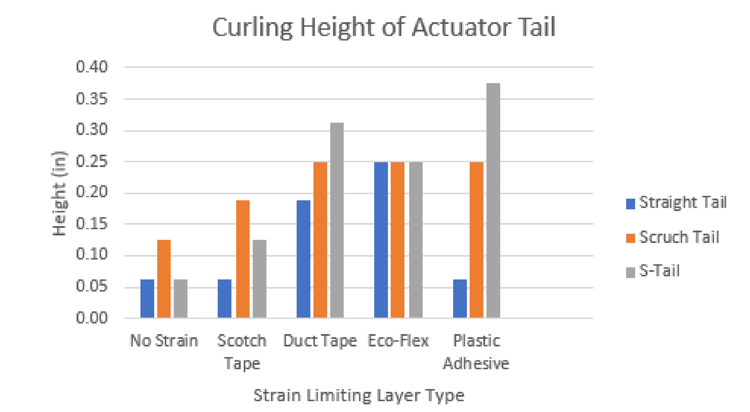

Figure 8: Height deformation data for the actuators with and without the four strain limiting layers.

- Tails with scrunched edge resulted in 8% higher strains than straight edged tails.
- Scrunched edge tails with plastic adhesive strain limiting layer had 25% higher height deformation at tail tip than straight edge tails.
- S-tails had 33% higher height deformation at tail tip than scrunched edge tails.
- S-tails had 50% higher height deformation at tail tip than straight edge tails.
- Self-sensing circuit is still in the process of being designed and assembled.

Conclusion

- Complicated actuator shapes take time to develop to increase accuracy and strain rates in actuators.
- Limited through application of high-voltage often shorting actuator before reaching maximum amplifier capabilities
- The s-tail design and plastic adhesive strain limiting layer were the most successful combination during experimentation
- Development of self-sensing capabilities will reveal more information about capacitance characteristics and more elaborate control of curling actuation.

References and Acknowledgements

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