HASEL and HALVE actuators for artificial limbs and physical therapy aids

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In recent years, there have been massive breakthroughs in dielectric elastomers, specifically towards the self-healing aspect by introducing hydraulic elements into the elastomers. Even more recently, there have been breakthroughs in the power supplies typically used for hydraulically amplified self-healing elastomers (HASEL) actuators. Prior to hydraulically amplified low-voltage elastomers (HALVE) actuators, HASEL actuators were used with an input voltage of 10+ kV.

HALVE actuators are like HASEL actuators, but instead of requiring ranges of 10 kV to achieve strain rates of 18-24%, they can operate at $1/10^{th}$ the voltage. They achieve this by reducing the thickness of the material and/or increasing the permittivity of the dielectric material. HALVE actuators are constructed with polyvinylidene fluoride-trifluoroethylene- chlorotrifluoroethylene (PVDF-TFE-CTFE) at approximately 5 µm to achieve actuations with an input voltage of only 1.2 kV.

An interesting property with HALVE and HASEL actuators is that they self-detect their strain and the capacitance can be measured.[3][4] Our proposal is to use this mechanism either as a soft-body aid that may be used in physical therapy, or instead as a gripping mechanism that can partially be engaged by applying pressure to an object and detecting the capacitance at different ligaments.

Control systems for HASEL and HALVE actuators are in their infancy, due to the new nature of both actuators.[1] Another goal of this project is to investigate the different implementations of feed-forward and feedback control systems using the self-strain-detection of the actuators. Implementations include PID controllers that can have the error be a combination of a desired state and the current measured capacitance.

As HALVE actuators operate at a lower voltage, components such as MOSFETs, become more likely. However, because the actuation voltage still exceeds 1 kV, other solutions will have to be investigated, as MOSFETs rated for 1 kV are not a cost-effective solution. Current HASEL projects utilize optocouplers for switching, as HALVE actuators operating at max strain do not meet the sub-1kV threshold that would allow for the usage of transistors such as insulated-gate bipolar transistors (IGBTs), metal-oxide semiconductor field-effect transistors (MOSFETs), etc.

Combining these properties and the goal of the project, a skeletal frame can be constructed using materials such as ABS using additive-manufacturing. With the frame, a HALVE actuator would be run through the joint with a “weaved” pattern; that is, each joint of the skeletal frame will act as an idler, and additional HALVE actuator would be placed with a deformation pattern formed to mimic the 3 ligaments of a human finger, or 2 in the case of a thumb.

In summary, our project aims to combine the aspects of HASEL and HALVE actuators and investigate the control systems that can be implemented for both dielectric elastomers, and their interaction with the dynamics and kinematics of the system. Additionally, methods for switching, such as optocouplers, are to be investigated as well. To our knowledge, our work combines HASEL and HALVE actuators in a unique new way.

References:

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