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A simple calculation model for a robotic gripping finger driven by zipping actuators

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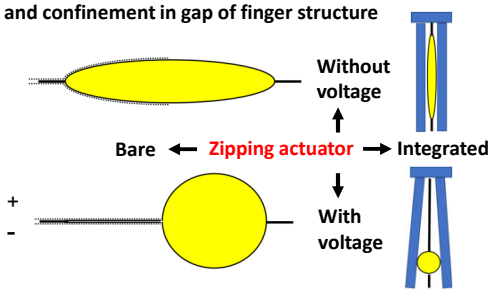
Abstract

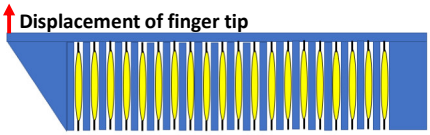
In Hydraulically Amplified Self-healing ELectrostatic (HASEL) zipping actuators, a high voltage applied between two electrodes on a polymer pouch leads to a zipping effect and displaces the oil to the pouch region without electrodes. This oil displacement generates a strong actuatoric deformation of the pouch [1]. A series of HASEL actuators can be used to cause a bending displacement of a flexible and soft robotic gripping finger structure printed with TPU (Shore A 95). The performance of the single HASEL actuator and the gripping finger depends on various geometrical and material parameters. In order to optimize the actuation performance, a simple mathematical model was established to calculate the dependence of the stroke and force of the HASEL actuator as well as the bending angle and blocking force of the gripping finger on the applied voltage. This model was used to predict the performance of HASEL actuators consisting of different polymer materials. The calculated data was compared with the results of experimental investigations on corresponding HASEL actuators and related gripping fingers giving valuable information on the requirements on the actuator materials and the finger structure.

Single HASEL actuator

Polymer pouch with electrodes and filled with oil and confinement in gap of finger structure



Gripping finger with HASEL actuators



Parameters in calculation model

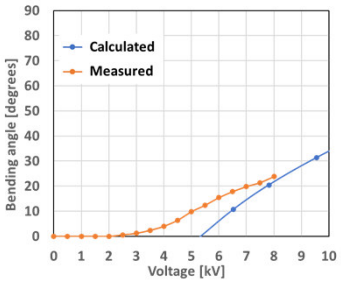
- Geometrical parameters (HASELs and finger)
- Polymer film permittivity
- Polymer film stiffness
- Bending stiffness of finger structure
- Weights of components (HASELs and finger)
- Finger orientation

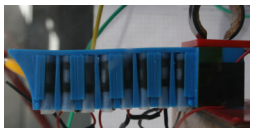
Calculation procedure

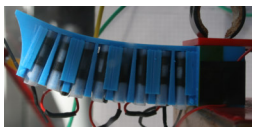
1. Calculation of the deformation of single HASEL actuators depending on the applied voltage
2. Transfer of the HASEL deformation to the finger structure
   HASEL deformation → Finger bending angle
   HASEL force → Finger tip force
3. Inclusion of the stiffness of the finger structure
4. Inclusion of the weights of the components (HASEL and finger structure) according to finger orientation
5. Calculation of the force equilibrium gives the bending angle depending on applied voltage

Validation of the calculation model

Gripping finger with 16 HASELs with polyethylene terephthalate (PET) films 30 µm



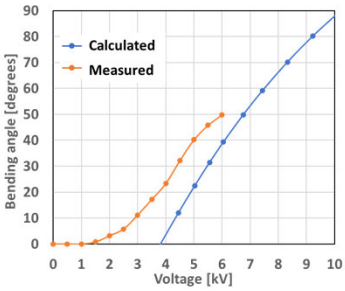

Without voltage

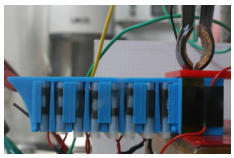

With 8 kV

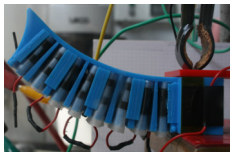
⇒ Achieved bending angle 24° at 8 kV

Validation of the calculation model

Gripping finger with 16 HASELs with thermoplastic polyurethane (TPU) films 50 µm




Without voltage


With 6 kV

⇒ Achieved bending angle 50° at 6 kV

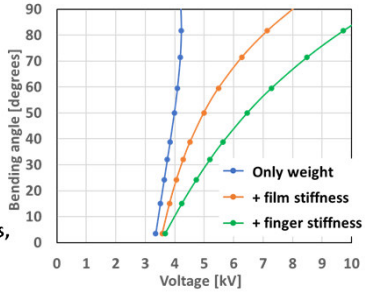
Prediction of the impact of various material effects

Gripping finger with 20 HASELs with PET films 30 µm

The bending angle of the finger depending on the applied voltage results from the equilibrium between the active torque of the HASELs and the passive torque of various material effects.

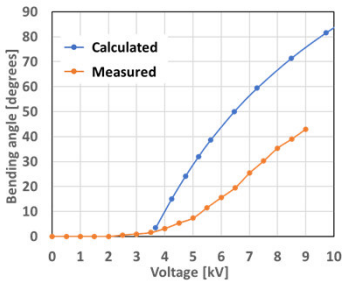
Additional impacts on torque equilibrium by

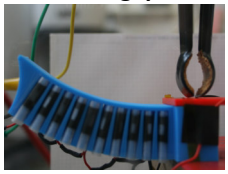
- weight of HASELs and finger components,
- stiffness of polymer film (PET) and
- bending stiffness of finger structure

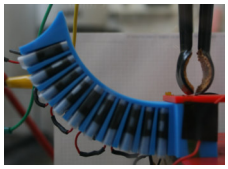


Improvement of finger performance with reduced gap width

Gripping finger with 20 HASELs with PET films




Without voltage


With 9 kV

⇒ Larger bending angle with improved TPU finger structure (42° at 9 kV)

Conclusions

- Results of the calculations for gripping finger with zipping actuators with the model exhibit satisfying agreement with experimental data.
- The model predicts the influence of various geometrical and material effects on the actuator performance.
- The calculation model supports the optimization of the gripping finger with HASEL zipping actuators.

Acknowledgement

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Reference

[1] E. Acome et al., Science 359 (2018) 61-65