Docket #: S15-122

Layered electroactive polymers for robust and reliable variable-stiffness suspensions in robotics, prosthetics and autonomous vehicles

Engineers in Prof. Mark Cutkosky's laboratory have developed patented electrostrictive elements that can support high loads over a long lifetime when used as variable suspension systems for robots, autonomous vehicles or prosthetics. Variable suspension systems can help mimic an important characteristic of animals: controlling the stiffness of their limbs through their muscles. This feature can be electrically manipulated and tuned through electroactive polymer suspensions (see Stanford Docket S12-067). To improve the basic suspension technology, the inventors developed manufacturing methods to easily fabricate uniform thin layers of electroactive polymer films on an expandable and contractible electrode. The multiple layers of the resulting electrostrictive element reduce stress concentration which then increases the overall force and stiffness of the suspension system while also improving reliability and lifetime. This technology could be used to control joints that can rapidly vary their stiffness to improve the capabilities of robots, prosthetics and other dynamically controlled devices.

Stage of Research

Elastomeric polymer suspension prototype: The inventors previously demonstrated the elastomeric polymer suspension with a prototype that changes stiffness by a factor of 10 in less than 10 milliseconds with a signal between 0 and 10 volts. (Stanford Docket S12-067)

Layered electrostrictive element prototype: The inventors fabricated a 20-layer device that supported a load of over 15 N at minimum stiffness and maximum voltage for displacements of +/- 7 mm and up to 138 N at maximum stiffness with a displacement of 20 mm. The multilayer devices have demonstrated 3 million mechanical load cycles (charging and discharging) and hundreds of thousands of stiffness variations.

Applications

- **Suspension/joint systems** that are electrically controllable/tunable, with end user applications such as:
  - robotics - biologically inspired robots for running, hopping, perching etc.
  - prosthetics - passive compliance to promote "fail safe" operation
  - autonomous vehicles

Advantages

- **High loads and lifetimes** - avoids stress concentrations with assembly of electrodes, reinforcing elements and frames
  - devices with multiple electroactive polymer layers have higher overall force and stiffness than previous designs
  - prototype with 20 layers supported a load of over 15 N at minimum stiffness and maximum voltage for displacements of +/- 7 mm and up to 138 N at maximum stiffness with a displacement of 20 mm
  - highly reliable - multilayer devices have demonstrated 3 million mechanical load cycles
- **Thin, uniform layers** - reliable, easy fabrication of thin, uniform layers that would difficult for skilled engineers to produce with conventional techniques
  - uses very soft silicone rubber with carbon particles and new application methods that enable control over the pattern of the electrode
  - ensures excellent conductivity
- **Advantages of elastomeric polymer** compared to mechanical systems:
  - fast tuning - can change stiffness by a factor of 10 in less than 10 milliseconds
  - compact and lightweight
  - low energy consumption
  - scalable - elastomeric polymer films can be stacked or connected to adapt force and displacement for the required application with hundreds of thousands of stiffness variations

    - combines electric actuation and viscoelastic load-bearing structure in a single material

Publications

- Orita, Atsuo, and Mark R. Cutkosky. "Scalable electroactive polymer for variable stiffness suspensions." IEEE/ASME Transactions on Mechatronics 21.6 (2016): 2836-2846.

Patents

- Published Application: 20160351784
- Published Application: 20160351790
- Issued: 9,871,183 (USA)
- Issued: 9,773,969 (USA)

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