

Clutching with High Force, High Bandwidth, Low Mass, and Low Energy Consumption using Electrostatics

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1 Introduction

Electrostatic clutching offers lightweight, energy-efficient, and fast controllable force transmission for exoskeletons and walking robots. Clutching is achieved by charging two electrically-conductive clutch plates with micrometer-scale thickness separated by a thin dielectric insulating layer. Because the clutch acts like a capacitor, power is only required while changing states, not to maintain an engaged or disengaged state. The clutch can employ flexible conductive elements (Fig. 1), such as aluminum-coated polymers, enabling use in applications that require conformability, such as soft exosuits.

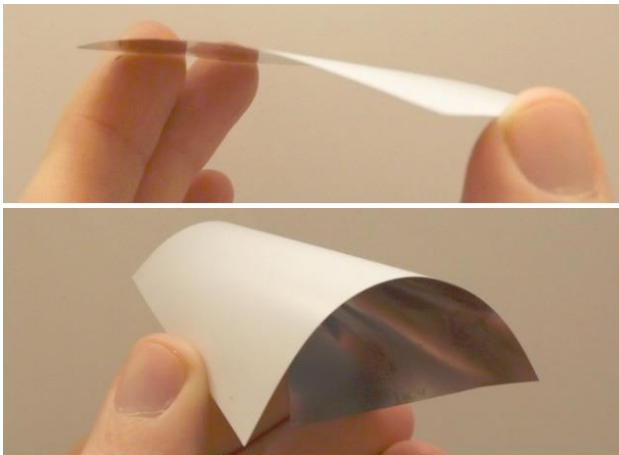


Figure 1: Dielectric-coated flexible clutch plate.

2 Methods

We tested a variety of polymer and ceramic-polymer composite materials as the dielectric insulator. The maximum clutch holding force was determined by engaging the clutch and increasing force until slipping occurred between the clutch plates. Release and engage times were evaluated by high speed camera and force data.

3 Results

We have identified polymer-ceramic composites that dramatically outperform dielectrics previously used for actuation and clutching by increasing the dielectric constant (Fig. 2). A clutch using a promising composite material has exhibited shear pressures greater than 15 kPa, corresponding to a holding force of 150 N over a 10cm x 10cm area. An electrostatic clutch of that size has a mass of ~1 g, and requires ~0.01 J to engage. These results show a 100X reduction in mass compared to a 6 watt, 30 N holding force

electromagnetic clutch used in a knee prosthesis [1]. The electrostatic clutch is also 100X lighter than a similarly capable clutch used with a spring to make walking more efficient in robots [2]. Our clutch has shown a release time of less than 6 milliseconds, implying a maximum bandwidth of more than 160 Hz.

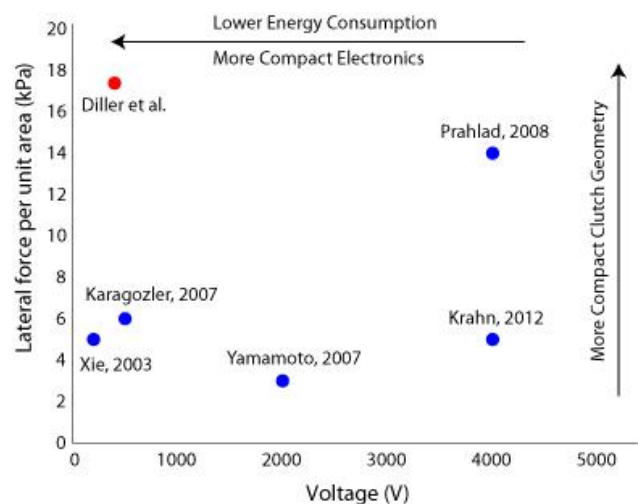


Figure 2: Maximum shear force reported using electrostatics, plotted against the activation voltage.

4 Future Work

Theory and literature data suggest that similar adhesion forces can be achieved at ~10 V by further decreasing the thickness of the dielectric layer. We will achieve these thinner dielectric layers by improving the manufacturing techniques used to create the clutch. At the conference in July, we will present the results of systematically varying the dielectric thickness and the clutch plate stiffness, as well as clutch characteristics including bandwidth, wear lifetime, and energy consumption.

5 Implications for Bipedal Locomotion

Incorporation of an electrostatic clutch could improve the performance of soft exosuits [3] and exoskeletons with clutched passive springs [4] by reducing distal mass and allowing more precise control of actuation timing. Electrostatic clutching could also allow the introduction of controllable spring elements into walking robots at minimal weight and electricity cost. Finally, this electrostatic design could be adapted as a controllable variable damper for use in exoskeletons or walking robots.

Acknowledgements

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References

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