Experimental Study of an Untethered Magnetorheological Elastomer based Phase Change McKibben Actuator

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Abstract

McKibben actuators are a type of pneumatic artificial muscle (PAM) actuators which consists of an elastomeric bladder encapsuled within a braided mesh. The elastomer is pressurized and the radial expansion of the tube is translated into axial contraction due to the geometric constraint of the braided mesh. These actuator are renowned for their exceptional power-to-weight ratio (10 kW/kg (1)) when the weight of peripheral components is excluded. However, their reliance on heavy peripheral systems, such as compressors, valves, and pressurized gas tanks, limits their application in lightweight, portable systems like exosuits or wearable robotics. To address this challenge, this work explores a phase-change-based actuation mechanism designed to minimize peripheral weight.
The proposed mechanism involves a magnetically induced liquid-to-gas phase transition of a low boiling-point fluid to generate the pressure required for actuation. The actuator consists of a magnetorheological elastomer (MRE) tube filled with the engineered fluid, which is infused with suspended magnetic particles. This tube is enclosed in a braided shell that restricts axial elongation, ensuring efficient force generation. The actuator is placed inside an induction coil, causing it to heat which triggers the phase transition, causing a rapid volumetric expansion of the fluid. The combined effect of the phase transition and mechanical constraints produces sufficient pressure to actuate the artificial muscle.

The use of a low boiling-point fluid enables faster cyclic actuation, while the induction coil facilitates untethered power transfer without significantly increasing the system's weight. The fabricated actuator achieves impressive performance, lifting a maximum load of 4.5 kilograms while weighing only 23 grams. This novel approach offers a lightweight and efficient solution for portable robotic applications, advancing the integration of artificial muscles into wearable systems.

References:

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