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A vacuum-powered soft linear actuator strengthened by granular jamming

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Vacuum-powered Soft Pneumatic Actuators (V-SPAs) are considered to be fail-safe, because, their maximum forces and displacements are restricted by environmental pressure from actuating. However, their performances are significantly influenced by the selection of materials. V-SPAs fabricated by materials with low modulus of elasticity might fall short of output forces for many tasks. This article proposes a novel approach aiming to improve the performance of V-SPAs. A new vacuum-powered soft linear actuator strengthened by granular jamming is proposed to achieve better mechanical properties without sacrificing their compliance. For simplicity, we call these structures jamming-strengthened vacuum-powered soft linear actuators and abbreviate them with the acronym J-VSLAs. The new J-VSLA changes the stiffness partially and it can lift about 4 times of weight (at 20% of strains) compared to its no-granule version (called as VSLA). We also investigate the thermodynamic and mechanical efficiencies of the new J-VSLAs. Although more energy is consumed on the particles in operation, there is still more energy converted to effective work since the energy converted to elastic potential energy is reduced. A four-wheeled walker actuated by the J-VSLAs is demonstrated to illustrate the potential of the J-VSLAs for soft robotic applications. Our results highlight the effectiveness of J-VSLAs for improving the mechanical properties of soft actuators and reducing the material selection constraints on the performance of V-SPAs. This partial stiffness changing design can be applied to other types of V-SPAs, which is conducive to expanding the application of soft robotic system.

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