Bio-Inspired Connective Granular Jamming for a Robotic Limb

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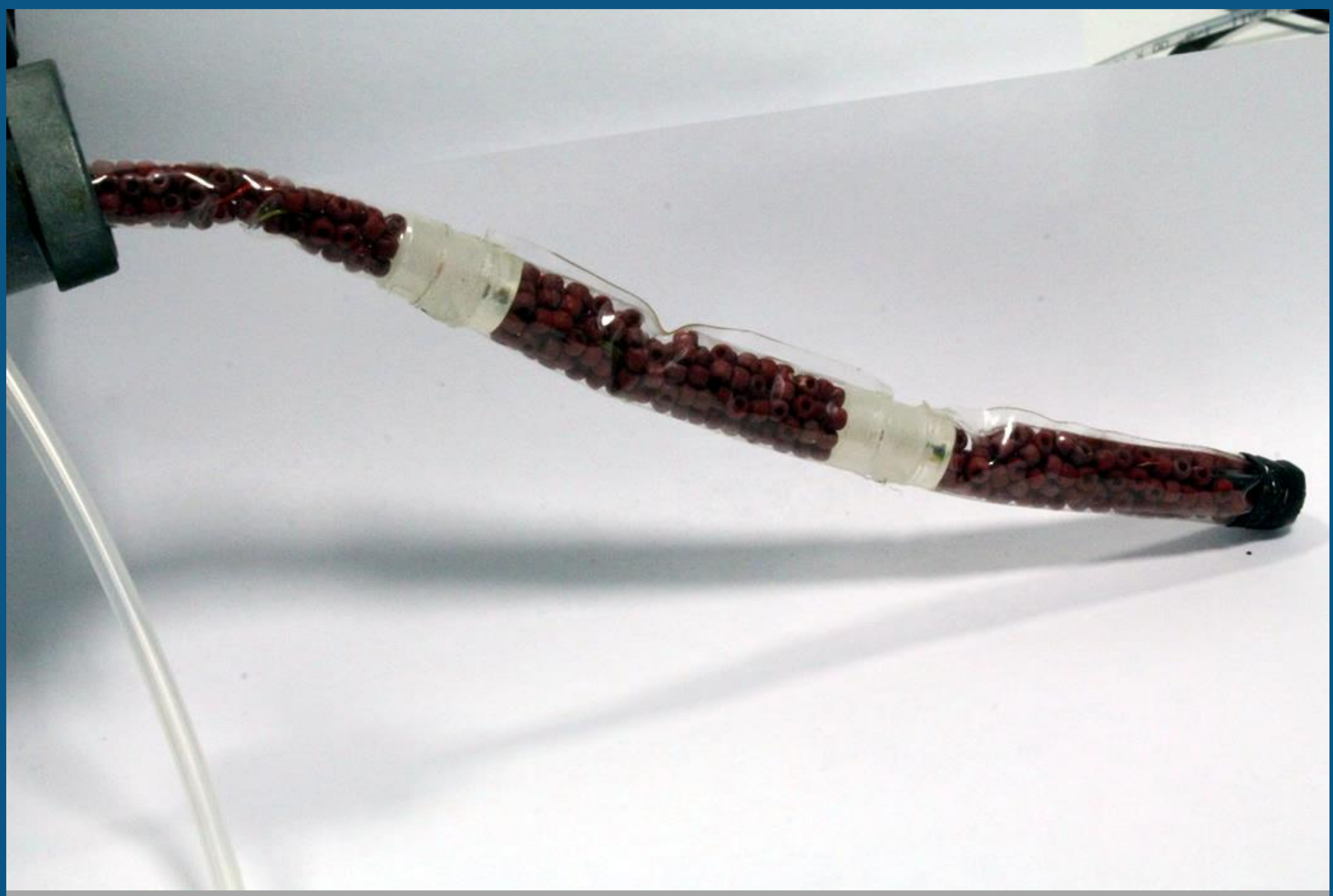

Figure 1. The Core-Snake, a granular jammed robotic limb for endoscopy. Current works on jamming have not examined the effect of coupling particles together, akin to connective tissue in animals. We present a study which provides a comparison between coupled and decoupled granules when jammed for a dexterous robotic limb.

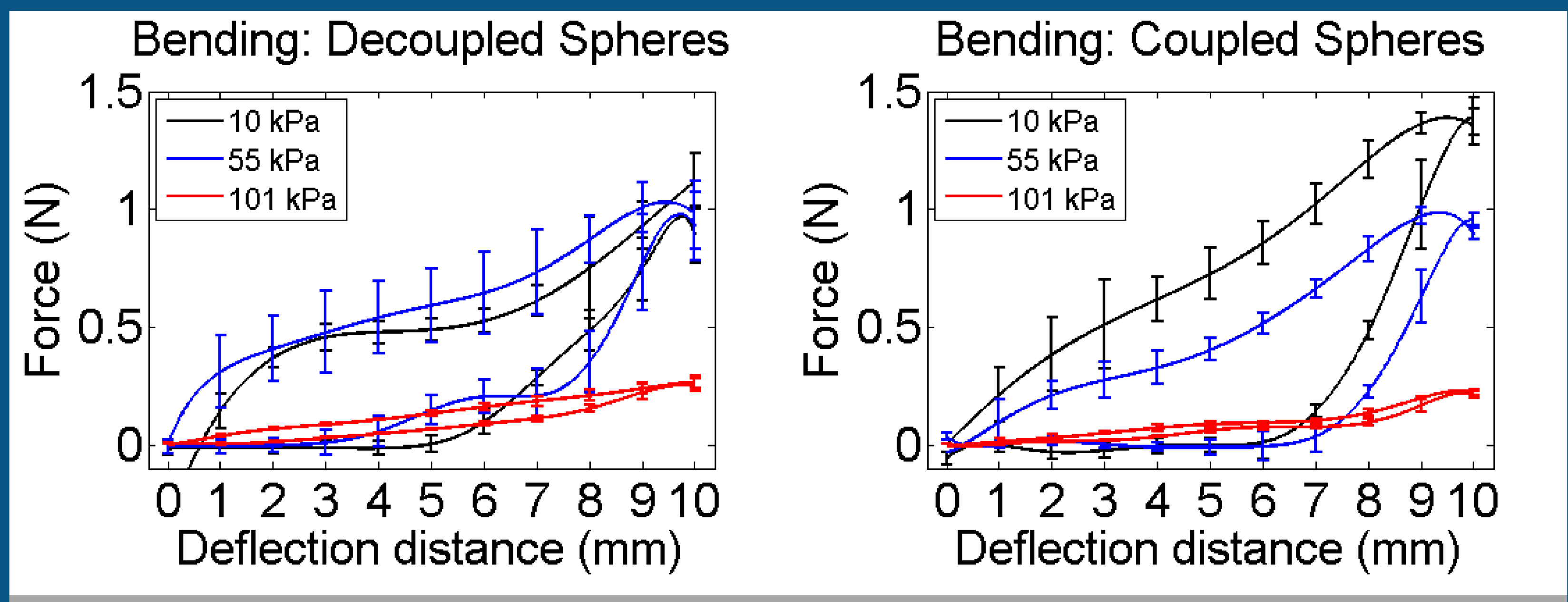

Figure 2. Comparative results in stiffness between decoupled and coupled granules during bending.

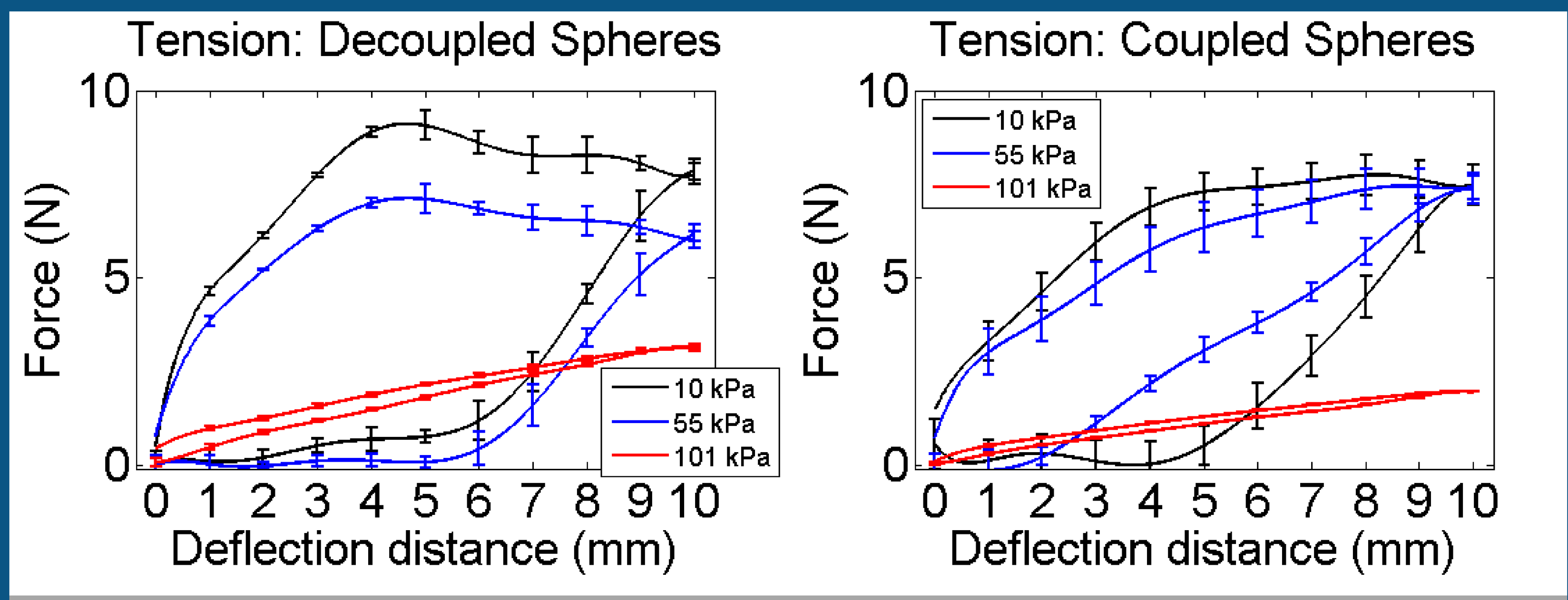

Figure 3. Comparative results in stiffness between decoupled and coupled granules during tension.

Introduction

To vary their body stiffness, invertebrates have a hydrostatic skeleton which consists of fluid-filled cavities that resist muscle contraction. These counteracting forces stiffen the body or limb [1]. Similarly, granular jamming consists of applying an external stress on loose particles [2], such as particle-filled chambers contracted by vacuum. While able to change from a soft to rigid state, the range of stiffness granular jamming can achieve is dependent on the size, shape, and material of the granules [3]. Previous studies have examined the relationship between achievable stiffness and particle properties, but only examine decoupled granules—granules which are distinct and independent.

This paper presents the use of coupled granules, in which particles are linked together by a flexible strand. The bio-inspired coupling of the granules simulates the connective tissue fibers within muscles which help increase the stiffness [4]. By increasing the stiffness range of granular jamming, the usability of a flexible, variable stiffness manipulator increases as well, such as the endoscope in Fig. 1. This benefits the dexterous robotic community, as current designs lack the sufficient stiffness without the addition of external systems, such as tendons [5].

Method

To test the effect of coupling granules, two experiments (bending by 10 mm perpendicular deflection and tension by 10 mm axial stretching) were performed on a 15 mm dia by 40 mm long latex chamber. This chamber is representative of one segment of a flexible manipulator. The decoupled granules are 1.5 mm dia spheres, as seen in Fig. 4. These granules were coupled by connecting them via a string, Fig. 5. Coupled granule strings were placed in longitudinally and in parallel to the chamber.

Results

In bending, as seen Fig. 2, decoupled spheres behaved similarly at moderate and full vacuum. However, in coupled spheres, the string connecting the granules together increased the required load force by 50%.

In tension, as seen in Fig. 3, coupled spheres exhibited similar peak loads as decoupled spheres. However, the coupled spheres had improved hysteresis and better load profile.

Conclusions

This paper introduces the use of bio-inspired, coupled granules in granular jamming to improve the variable stiffness of a robotic mechanism. Our results in Fig. 2 and 3 show coupled granules increase the bending stiffness and improve tensile hysteresis. This opens new field of research in granular jamming and bio-inspired robotics.

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Figure 4. Uncoupled granules

Figure 5. Coupled granules

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