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Magnetically Assisted Rotational Bistability

Alireza Seyedkanani[1], Abdolhamid Akbarzadeh[1,2*]
[1]Department of Bioresource Engineering, McGill University, Montreal, Canada
[2]Department of Mechanical Engineering, McGill University, Montreal, Canada
[*]Email: hamid.akbarzadeh@mcgill.ca

ABSTRACT

Employing mechanical instabilities in the material architecture has led to the emergence of a new class of architected metamaterials with different stable configurations, often referred to as shape reconfigurable materials. Repeatable switching between these stable states is possible; indeed, it originates from local bistable deformations and, therefore, relies on reversible changes in the geometry of utilized mechanical elements with negative stiffness, such as tilted beams or bistable shells. Shape reconfigurable materials can have distinctive multiphysical properties at each stable configuration, which is one of the main motivations to develop materials with tunable properties. Furthermore, due to potential energy differences at different stable configurations, these materials can also be used as deployable structures. Apart from these advantages, one of the issues of utilizing mechanical instabilities to induce shape reconfigurability is their susceptibility to variations in geometric parameters and boundary conditions. This adversely affects the tunability of shape reconfigurable materials and their engineering applications due to limitations in adjusting their mechanical responses. Moreover, using these materials in applications requiring a form of rotational input is challenging since most of the previously proposed architectures rely on translational inputs. Herein, we first show that magnetic interactions can be exploited to induce negative torsional stiffness and obtain rotational bistability. Subsequently, we demonstrate how this strategy can compensate for the aforementioned limitations encountered when mechanical instabilities are utilized. This is realized by embedding permanent magnets in 3D printed parts that can rotate with respect to each other and to form a rotationally bistable cell. By adopting a simplified computational model corroborated with a detailed finite element analysis and a series of experiments, we show that the mechanical response of the developed cell can be easily tailored by changing the air gap between the magnets, by adjusting the position of the magnets, or by changing the magnetic poles orientation of facing magnets.