Development and Iterative Design of Multistable Multi-Material Compliant Mechanisms

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Compliant mechanisms move via the deflection of flexible members, allowing them to be designed with a reduced part count, fewer points of failure, and increased durability. Bistable devices are compliant mechanisms characterized by two stable fixed positions separated by an unstable equilibrium position. Complex bistable devices can be developed by modularizing mechanisms into individual components, improving testing timelines and technology accessibility. With the advent of commercially available 3D printing technologies, chains of bistable mechanisms (modular linkages) have created the opportunity for more complex actuation profiles. In this investigation, a modular, multi-material, multistable mechanism was designed and tested. The bistable mechanism was investigated for its ease of manufacture and reduced design-iteration timeframe. The mechanism acted as a spring with a nonlinear spring constant, such that it had several stable positions along its travel length. A linear actuator attached to a force sensor was used to measure the restoring force of the mechanism at a given displacement from the mechanism’s natural length. Restoring force as a function of distance was measured for devices with different spacings between flexible units (defined as the intermediate arm length). Testing revealed that restoring force increased as intermediate arm length increased. Moreover, the modular system was durable, with force vs. displacement profiles staying similar over more than three hundred tests. Bistable linkages require no energy input when not in the actuation phase, and the units developed during this study were quite flexible and durable. Therefore, these systems could be used for robotics applications, allowing low energy movement and navigation of complex terrain.