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PROCEEDINGS

4D Printing of Polylactic Acid Hinges: A Study on Shape Memory Factors for Generative Design in a Digital Library Framework for Soft Robotics

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ABSTRACT

The emergence of 4D printing introduces stimuli-responsive, shape-changing capabilities through additive manufacturing (AM) and smart materials, has advanced the field of soft robotics. However, there are currently lack of methods or tools that capable of aiding in the generative design of 4D AM structures. The current generative design procedure for 4D AM structures often lacks transferability among various structures due to limited understanding of shape memory material behaviors for soft robotics. To develop such a digital library, investigation of fundamental elements, such as material properties of shape memory materials, geometry parameters of design primitives, and 4D printing process parameters are necessary. (1) Material properties of shape memory materials, including shape memory effect, thermal characteristics, and mechanical behaviors, are critical for the material selection of targeted 4D AM structures in soft robotics. (2) Geometry parameters of design primitives, including shape, size, and motion capabilities, are essential to the foundation for creating different morphing systems and programmable structures in the digital library for soft robotics design. (3) Printing process parameters, including infill density, layer thickness, and temperature control, are important for optimizing the fabrication of shape memory components with desired properties and functionalities in soft robotics. As one of the important digital library design primitives, the hinge structure plays a pivotal role in enabling controlled movement and flexibility in 4D AM structures, crucial for soft robotic joint functionality. The designed hinges enable articulation and bending, thus facilitating shape changes and dynamic responses for the generative design of soft robotic morphing systems. In this study, the hinge structures will be fabricated using conventional polylactic acid (PLA) filaments, which exhibit shape memory effects and offer low infill density through fused filament fabrication 4D AM process. (1) To characterize material properties of the PLA filament, such as glass transition temperature, tensile strength, modulus of elasticity, and elongation at break, through dynamic mechanical analysis and static tensile test. (2) To implement the Taguchi method and factorial design of experiment approach to systematically vary hinge geometry parameters, including shape memory properties, such as thickness, width, length, and curvature, for the digital library. (3) To establish the property-structure-process relationship for the 4D printed PLA hinges through the measurement of bending angles and recovery rate. This study will lay the foundation for the creation of an extensive digital library based on various shape memory materials and design primitives for 4D generative design, with a specific focus on soft robotics.

KEYWORDS

Soft robotics; 4D printing; additive manufacturing; generative design; shape memory effect

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