Extrusion Printhead for the Fabrication of Helical Shape Memory Polymer Artificial Muscles for Spaceflight

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Abstract

The zero gravity and microgravity environments astronauts must endure are made incredibly physically demanding by skeletal muscle atrophy caused by leaving Earth's gravitational field. Muscle strength and articulation is imperative for astronaut effectiveness and safety when aboard the International Space Station, traveling through deep space, or adjusting to gravity of terrestrial bodies beyond Earth. Polymer artificial muscles could be manufactured during missions and used in exoskeletons as muscular assistive devices for astronauts in strenuous situations. Currently, polymer artificial muscles are fabricated by twisting polymer fibers, a specialized labor-intensive process unsuited for astronauts during spaceflight. Therefore, the design and fabrication of a compact and lightweight printhead system is the objective of this research. The printhead design utilizes a fluted mandrel within the printhead to extrude helical shape memory polymers to act as artificial muscles without the required printing substrates or external supports of other printing methods. The printhead system was fabricated and tested by extruding, measuring, and contracting polylactic acid artificial muscles to verify the design. Average measurements of the artificial muscle diameter (3.51 ± 0.81 mm), thickness (1.28 ± 0.08 mm), and pitch (10.93 ± 0.80 mm) were compared to the respective geometries of the mandrel's flute, demonstrating how the printhead fabricates artificial muscles near the desired ideal geometries. From the measurement data found, it was determined that the difference in pitch between the printed muscles and mandrel will be mitigated by the lack of gravity when extruded in low gravity environments. Finally, a recovery ratio of 0.99 was determined from the artificial muscle contraction experiments, validating the effectiveness of helical polymer artificial muscle fabrication.