Material Extrusion Manufacturing of Artificial Muscles Using Printhead with Helix Channel

Muscle atrophy is one of the main complications for astronauts since they have to work in low-gravity environments for extended periods of time. Development of wearable exercise devices is one of the potential solutions, which are lightweight, compact, and inherently compliant and safe. Artificial muscles are the core components in wearable exercise devices with the working mechanism similar to that of biological muscles, which can generate straight contractions/elongations under external excitations. Helical filament structures are the main form of artificial muscles. Currently, the mainstream technique to make artificial muscles is to mechanically twist fibers into a helical shape, which needs a complex and time-consuming fabrication process, making it difficult for untrained astronauts to rapidly fabricate replaceable artificial muscles in space. In this work, we developed a material extrusion method to manufacture artificial muscles using a printhead with a helix channel. Polymer melt was injected into the helix channel in the printhead. By accurately controlling the temperature distribution, polymer melt was solidified and prototyped at the exit of the printhead to form a filament with helical morphology. Poly(lactic acid) (PLA), a shape memory polymer, was selected as the build material, which can contract and elongate at different temperatures. Thus, the extruded PLA helical filament was able to function as an artificial muscle driven by temperature change. Herein, numerical simulation was performed first to determine the geometries of the printhead. Then, extrusion experiments were conducted to investigate the effects of key operating conditions on the filament morphology. Finally, by changing the ambient temperature, the extruded PLA helical filament presented desired contraction and elongation, validating the effectiveness of the proposed method to fabricate artificial muscles in a quick and easy-to-use way.