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Design and Experimental Study of Shape Memory Alloy (SMA) Spring as Actuators in Wrist Exoskeleton

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Abstract

This paper presents the design, modeling, and experimental assessment of a wrist exoskeleton actuated by Shape Memory Alloy (SMA) springs to support flexion-extension and radial-ulnar deviation of the wrist. A dynamic model based on the Euler-Lagrange formulation was developed and simulated to estimate the joint torque requirements, which ranged from 0.26–0.32 Nm for standard wrist movements. A prototype is fabricated and tested incorporating four SMA spring actuators fixed on an arm splint, with targeted actuation for generating different wrist motion. Experimental findings revealed that the prototype delivered torque values surpassing simulation requirements for flexion (0.332 Nm) and extension (0.328 Nm) motions, whereas lower torque was observed for radial and ulnar deviations, likely due to actuator placement and frictional losses. The actuation cycle frequency for flexion-extension was measured to be 0.018 Hz, primarily constrained by the thermal characteristics of the SMA springs. Another important observation is enhanced speed during SMA reversal motion (from extension to flexion) resulted from antagonistic actuation of the SMA. To further improve the torque and speed generation, an optimal SMA actuator with reduced thermal mass (thinner diameter, bundle configuration) and active cooling can be designed. Overall, the SMA-driven wrist exoskeleton exhibits promising potential as a lightweight, wearable system for effective wrist joint assistance.

Author keywords

actuator; artificial muscle; flexion-extension; radial-ulnar deviation; Shape memory alloy; wrist exoskeleton

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