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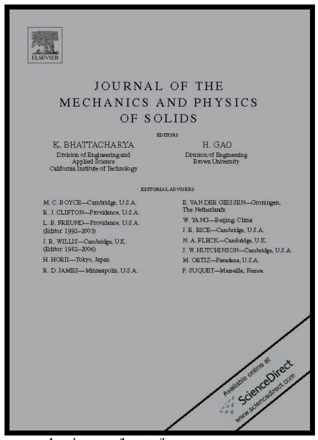

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A Top-down Multi-scale Modeling for Actuation Response of Polymeric Artificial Muscles

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Abstract

A class of innovative artificial muscles made of high-strength polymeric fibers such as fishing lines or sewing threads have been discovered recently. These muscles are fabricated by a simple “twist insertion” procedure, which have attracted increasing attention due to their low cost and readily availability, giant tensile stroke, record energy density, and easy controllability. In the present paper, we established a multi-scale modeling framework for the thermomechanical actuation responses by a top-down strategy, spanning from macro-scale helical spring analysis down to molecular level chain interaction study. Comparison between modeling results and experimental results exhibited excellent agreement. The effect of the micro-, meso- and macro-scale parameters on the actuation responses of the artificial muscle was further discussed through a parametric study per the validated model. This work helps understand the physical origin behind the remarkable tensile actuation behavior of the twisted-then-coiled polymeric artificial muscles and also provides inspirations for optimal design of advanced artificial muscles made by twist-insertion procedure.

Keywords: Artificial muscle; Multi-scale modeling; Actuation; Fiber; Top-down analysis.

1. Introduction

Artificial muscles are a class of biologically inspired materials or devices that can reversibly contract, expand, or rotate by external stimuli, such as voltage (Ohm et al., 2010; Pelrine et al., 2002; Zhang et al., 1998), pressure (Chou and Hannaford, 1996; Daerden and Lefeber, 2002), current (Baughman, 1996; Lima et al., 2012; Shahinpoor et al., 1998), or