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A Thermo-Electro-Mechanical Model for Predicting the Performance of Twisted and Coiled Artificial Muscles (TCAMs)

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Twisted and Coiled Artificial Muscles (TCAMs) have emerged as innovative structural actuators, renowned for their exceptional performance. Produced from nylon or other polymeric fibers, TCAMs combine affordability with significant displacement, high power output, and broad applicability, making them ideal for robotics and smart textiles. However, their recent development opened several challenges, like the deep understanding of their behavior or their effective integration into robotic and intelligent systems.
Previous studies investigated the thermo-mechanical behavior of TCAMs fabricated by three types of silver-coated nylon precursor fibers. The experimental analysis revealed the influence of production parameters, such as rotational speed and applied loads, on the displacement capabilities and mechanical stability. TCAMs produced with Shieldex 235/36x4 HCB fibers demonstrated superior performance in terms of contraction capacity and load-bearing capability.
In this work, a thermo-electro-mechanical model is proposed to complement the experiments, incorporating physics-based considerations. The proposed model is divided into a thermo-electrical and a thermo-mechanical model. Specifically, the thermo-electrical model determines the temperature increase of the artificial muscle based on the input power. Afterwards, by the temperature and the external load, the thermo-mechanical model allows to determine the TCAM's state variables (i.e. displacement and strain), according to geometrical considerations and by applying the Castigliano Second Theorem (CST). The model accurately predicts the displacement of TCAMs under various operating conditions, showing a good agreement with experiments.

Keywords: Twisted and coiled artificial muscle, twisted and coiled actuator, Artificial muscle, modeling, smart actuator

Autore principale: Sig. GAROFALO, Salvatore (Università della Calabria)

Coautore: Dr. MORANO, Chiara (Università della Calabria); Prof. PAGNOTTA, Leonardo (Università della Calabria); Prof. BRUNO, Luigi (Università della Calabria)

Relatore: Sig. GAROFALO, Salvatore (Università della Calabria)

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