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Extensional and torsional coupling in spiders silks: modeling and experiments

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Abstract

Environmental conditions have a significant impact on the mechanical response of spider silk, and must be accounted for when interpreting experiments and designing silk-inspired materials [1, 2, 3]. In particular, changes in relative humidity may trigger supercontraction and a concomitant torsional response. These effects have not been sistematically esperimentally and theoretically analysed. In particular, a macromolecular-scale interpretation of humidity-driven twist and its interplay with loading history remains incomplete. We perform experiments under controlled environmental conditions to quantify the coupled evolution of axial deformation and torsion during humidity-driven supercontraction and mechanical loading. The experiments are interpreted with a micromechanically-based model, inspired by the dual Poynting effect for fiber-reinforced cylinders [4], to link humidity-induced axial shortening to the observed torsional response. Moreover, we measure the emergence of residual strain during cyclic tests and its concomitant effect on torsion, indicating that loading history can modify

the subsequent twist evolution during humidity cycles. The modeling framework is therefore extended to provide an interpretation of the coupling between residual deformation and torsional response. Overall, the combined experimental evidence and modeling provide a unified view of the coupled effects of environment and loading history on spider silk, and supply transferable tools for hygroscopically active fibers and bioinspired actuators.

Keywords:

Spider silk Supercontraction Humidity-induced torsion dual-poynting effect Residual strain Cyclic loading

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