A continuum model for novel electromechanical-instability-free dielectric elastomers

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Abstract

Traditional dielectric elastomers exhibit an unstable response when the electric field reaches a certain threshold, known as electro-mechanical instability, which significantly limits the broad application of these soft active materials. Recently, a bimodal-networked dielectric elastomer has been designed without suffering from the electro-mechanical instability due to a clear strain stiffening effect in the median strain regime. In this work, we develop a constitutive model to fully describe the mechanical and electro-activated response of this novel dielectric elastomer. The free energy density consists of a time-independent hyperelastic component, time-dependent viscous components and an electrical component. A hyperelastic function dependent on both the first and second strain invariants is proposed to fully capture the stress response. The form of ideal dielectric elastomers is adopted for the electrical free energy. With further incorporation of viscous effects, the model is able to describe both static electro-actuated behavior as well as the frequency-dependent actuation performance upon a square wave voltage loading. The model is also implemented for finite element analysis to design tubular actuators which have been extensively used in the area of soft robotics.

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