Microstretch modeling of liquid crystalline elastomers

Aishwarya Kasarla*[1] and Krishnendu Haldar*†[1]

[1]Indian Institute of Technology Bombay – India

Abstract

Liquid crystals (LCs) exhibit a state between crystalline solids and liquids and can deform under the influence of an external electric or magnetic field. Also, the birefringent response of the LCs to the light is being primarily studied and utilized in many applications, such as LCDs, actuators, sensors, etc. Liquid crystal elastomers (LCEs) are elastomers with liquid crystalline molecules (mesogens) as part of the polymer chains. They can change their shape whenever the orientation of these mesogens undergoes changes due to external stimuli like electric, magnetic field, or temperature.

For liquid crystalline elastomers, that is elastic liquid crystalline polymers, Bladon, Terentjev, and Warner developed a non-linear theory for nematic elastomers by extending the classical Gaussian network theory of rubber elasticity to allow for anisotropic distributions of the end-to-end vector between two crosslinks, also known as neo-classical theory. However, in this theory, they assumed the molecules to be 'rigid rods' which is not the case for polymeric liquid crystals. The theory also assumes 'affine deformation' for the end-to-end distance vector of the polymer chain. As a result of these limitations, this theory fails to agree with some significant experimental results. This motivates us to go for the generalized microstretch continuum theory by E.C.Eringen.

In the microstretch continuum, a material point has macro-deformation given by three translations, and micro-deformation given by three microrotations and one microstretch of the three deformable directors. To start with, we extend the existing model for a special neo-Hookean type elastic energy with mixed invariants of macro and micro deformation gradients. We aim to develop a theoretical model for the static behavior of liquid crystalline elastomers to derive the stress responses following the thermodynamic laws. We calibrate the model parameters for

*Speaker

†Corresponding author: hkrish@iitb.ac.in

the proposed free energy function using the experiments reported in the literature and verify the model with the widely accepted neo-classical theory for liquid crystalline elastomers in the
cases of uniaxial stretching and simple shear.