Jan 25, 2024

# Physics and Models for Liquid Crystal Elastomers


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## ABSTRACT:


Liquid crystal elastomers (LCEs) are a fascinating class of materials that display soft and semi-soft elastic behavior as well as a somewhat less explored viscoelastic behavior. These materials are composed of liquid crystal molecules and polymerizing agents to form a solid that behaves as an elastomer but also like a liquid crystal. The interaction of these two features provides for a wide and complex range of macroscopically observed phenomena, including for example optical actuation, extreme softness, pattern formation, and high damping to name a few. In this talk, I will present a general introduction to the physics of these unique materials at a microscopic as well as macroscopic scale. This will lead to insights into the long-standing well-established models that are used to understand their elastic behavior. Consideration will also be given to models that can account for time-dependent, i.e., viscoelastic, behavior – an aspect that is not well examined in the literature – as well as computational considerations.

In the presentation, I will mainly consider so-called mono-domain liquid crystal elastomers that possess both a viscous director response as well as a viscoelastic elastomeric network response. The modeling framework will be built from the continuum scale, utilizing the formal principles of invariance of expended power to develop the governing balance laws for such materials accounting for loads that can impose twist directly at the continuum level. This framework is combined with free-energy dissipation arguments to generate restrictions on the possible constitutive relations for LCEs based upon hypothesized functional dependencies of the free-energy function. This mathematical framework leads to natural choices for evolution laws governing the viscous kinematics that have an appealing and intuitive nature. We demonstrate the utility of the model by considering its capabilities in comparison to experimental data, while also learning some cautionary information about the application of such materials to engineering practice.


## BIOGRAPHY:

Sanjay Govindjee is a Distinguished Professor of Civil and Environmental Engineering and the Horace, Dorothy, and Katherine Johnson Endowed Professor at the University of California, Berkeley (1993-2006, 2008-present). His main interests are in theoretical and computational mechanics with an emphasis on micro-mechanics, shape memory alloys, and elastomers. Prior to joining Berkeley, he worked as an engineer at the Lawrence Livermore National Laboratory (1991-1993) in Livermore, California. He was also Professor of Mechanics at ETH Zürich (2006-2008) in Zürich, Switzerland. He obtained his Ph.D. and M.S. from Stanford University, 1991 and 1987. His S.B. is from the Massachusetts Institute of Technology, 1986.

Dr. Govindjee also serves as a consultant to several governmental agencies and private corporations. He is an active member in major societies such as the American Society of Mechanical Engineers and the US Association for Computational Mechanics, and he is a registered Professional Mechanical Engineer in the state of California. He is well-known for leading national failure analysis investigations in the automotive industry, contributions to commercial finite element programs and to the research software FEAP, as well as authoring several popular mechanics textbooks on solid mechanics.

Noteworthy honors include a National Science Foundation Career Award, the inaugural 1998 Zienkiewicz Prize and Medal, an Alexander von Humboldt Foundation Fellowship 1999, a Berkeley Chancellor's Professorship 2006-2011, and a guest Professorship at ETH Zürich 2008-2013. In 2015 he was named a Fellow of the US Association for Computational Mechanics, and in 2018 he received a Humboldt-Forschungspreis (Humboldt Research Award).