ME Seminar

MECHANICAL ENGINEERING
INDIAN INSTITUTE OF SCIENCE

Two Problems in Nonlinear Mechanics: Instabilities in Soft Solids and Chemo-mechanics of Energy Storage Materials

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ABSTRACT

Soft solids can undergo large deformations often exhibiting complex patterns ranging from spatially uniform to highly localized configurations under different mechanical loads. Examples of such patterns are ubiquitous in nature: folds and creases on the cerebral cortex, wrinkles on skin to mention a few. One of the major challenges in studying the mechanics of soft solids is that these solids can have several equilibrium configurations at a given loading condition due to their strongly nonlinear behaviour. A commonly used recipe for such problems in existing computational frameworks relies on introducing ad-hoc imperfections which help in biasing the system towards a desired configuration. Such trial-anderror based imperfection methods prove to be non-reliable, and in fact can lead to wrong conclusions. In the first part of the talk, an imperfection-free approach based on the application of bifurcation theory coupled with numerical path-following and group-theoretic techniques will be presented. Motivated by the celebrated Biot problem of surface instability in hyperelastic solids under compression, the methodology is applied to study the evolution from unstable periodic wrinkles to stable localized deformations such as folds and creases. By systematically following different bifurcation paths, detailed global bifurcation diagrams are constructed and the routes to complex deformation states are uncovered.

The second part of the talk will focus on the newly emerging Nickel-rich energy storage materials for cathodes in Lithium-ion batteries (LIB). These materials have a layered crystal structure which facilitates high energy density for LIBs. Among all the Nickel-rich materials, the alloy $LiNi_{0.8}MN_{0.1}Co_{0.1}O_2$ (NMC811) has received increased attention due to high storage capacity and low cost. With the broader objective of understanding various failure mechanisms in storage particles during actual operating conditions, a thermodynamically consistent chemomechanical analysis for single crystal NMC811 is presented. The primary interest is the transport of Li^+ and the associated levels of mechanical stresses generated in storage particles with realistic material properties, sizes and charging rates. Several nonlinearities and anisotropies associated with the chemical potential, diffusivity of Li^+ and lattice intercalation strains have been included in the analysis. Maps showing peak stress levels generated in storage particles under fast charging of the battery will be discussed.

ABOUT THE SPEAKER

Shrinidhi Pandurangi is a postdoctoral research associate in the Department of Engineering at the University of Cambridge. Shrinidhi received a Ph.D. in Theoretical and Applied Mechanics from Cornell University in August 2020. Before joining Cornell, he worked with GE India Technology Centre in Bangalore for two years. Shrinidhi received a Master's degree at IIT Bombay and a Bachelor's degree at the University of Pune, both in Mechanical Engineering, in 2013 and 2011 respectively. His research interests broadly span the areas of: Bifurcation Theory, Mechanics of Soft Solids, Nonlinear Elasticity, Continuum Mechanics, Energy Storage Materials, Multiphysics problems in Chemo-mechanics and Thermomechanics.

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