ME Seminar

MECHANICAL ENGINEERING
INDIAN INSTITUTE OF SCIENCE

Mechanics of materials at the extremes: from protection materials to energy conversion

Dr. Vignesh Kannan, Mechanical & Process Engg., ETH Zürich

ABSTRACT

The rapid drive towards faster and efficient technology has pushed our knowledge of fundamental material behaviour to its limits. Specifically, the response of materials to high amplitude external stimuli at very short time-scales (microseconds and lower) have exciting future opportunities in fundamental research. Addressing the origins of material behavior at these extreme conditions involves a mechanism-based approach wherein physical mechanisms need to be probed at short length and time scales simultaneously. We will discuss two specific examples of high amplitude, short time-scale phenomena in materials. The first example will focus on the dynamic viscoplastic deformation of magnesium with applications in protection materials. With a density two-thirds that of aluminium, magnesium has been sought after as the next major industrial structural metal. In-situ experimental measurements at short length and time-scales indicate strong dependence of flow stress, strain hardening and microscopic mechanisms on loading rate. Using high-speed microscopy data, we will see that strain-rate-dependent strength of magnesium is due, in part to a transition in the dynamics of a specific deformation mechanism called 'deformation twinning'.

During the next part of the talk, we will briefly explore previously established ideas of rate effects and microscopic deformation mechanisms under multi-physical driving fields. Specifically, we will focus on ferroelectric materials, which are a class of non-linear electromechanical material systems with a wide range of applications from transducer technology to active structural control. Data from in-situ measurements reveal a non-linear dependence of electrical polarization switching kinetics on loading rate across time-scales spanning seven orders of magnitude. We will discuss the implications of these measurements from the perspective of the key microscopic mechanisms responsible for polarization switching called 'ferroelectric domains' and their kinetics. The ubiquity of microscale kinetics and their effects on macroscopic material behavior across material systems especially under dynamic loading conditions will be evident. Finally, a perspective on the future of mechanics research for material response at extreme loading conditions will be presented along with some examples of exciting open problems in the field applicable to material design for protection and energy generation.

ABOUT THE SPEAKER

Dr. Vignesh Kannan completed his undergraduate degree in production engineering from the National Institute of Technology Tiruchirappalli. In December 2018, he completed his doctoral degree in mechanical engineering from the Johns Hopkins University in Baltimore, U.S.A., specializing in the mechanics of materials at high strain-rates. Vignesh's doctoral research, under the mentorship of Prof. K. T. Ramesh, focused primarily on understanding plastic deformation mechanisms in magnesium and its effects on material strength under high strain-rate impact. He then moved to the ETH Zürich to start his post-doctoral research with Prof. Dennis M. Kochmann where he studies the electro-mechanical behavior of ferroelectric materials and develops experimental tools to characterize the static and dynamic behaviour of 3D-printed architected metamaterials. Vignesh is primarily an experimentalist by training, who continues to seek the unification of experiment and theory to understand material phenomena at the extremes. When not in the laboratory, you might find him watching south Indian comedy or injuring himself on the badminton court or more recently in the mountains.

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