ME Seminar

MECHANICAL ENGINEERING
INDIAN INSTITUTE OF SCIENCE

Next generation damage tolerant materials for extreme environments

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ABSTRACT

Discovering structural materials that can withstand extreme environments is crucial, especially for aerospace, hypersonic, nuclear, and sustainable energy applications. For these applications, structural materials are required to be lightweight, withstand extreme temperatures (4 K-1873 K), and perform in corrosive environments. The metals and alloys suitable for these applications can be broadly divided into two classes- (i) alloys with face-centered cubic (fcc) crystal structure (primary phase)—they can withstand extremely low temperatures, and (ii) body-centered cubic (bcc) alloys comprising largely refractory elements—suitable for high-temperature applications. Historically, the selection and design of materials for these extreme environment applications have been challenging because of the conflict between their strength and fracture toughness. The fcc and bcc alloys represent the opposite ends of the spectrum in this conflict of material's damage tolerance. While the fcc alloys show exceptional fracture toughness at room temperature and cryogenic temperatures, they have relatively lower resistance to plastic deformation; the bcc refractory alloys have excellent thermal stability and high compressive yield strength at temperatures above 1073 K but suffer from poor resistance to fracture in tension and oxidation resistance at these temperatures. This presentation will highlight the challenges in the discovery of materials for these extreme environments and the utility of emerging technologies and concepts such as additive manufacturing and high entropy alloys in resolving the conflict of strength and toughness for the accelerated discovery of next-generation damage-tolerant materials—notably the role of additive manufacturing in tailoring the microstructure to generate damage tolerance. Moreover, in refractory high entropy alloys, the elements are mixed at the atomistic level to form a single phase, in some cases altering the deformation mechanisms and generating fracture resistance.

ABOUT THE SPEAKER

Punit Kumar is a postdoc at the Lawrence Berkeley National Lab and the University of California, Berkeley. He received bachelor's and master's degrees in Metallurgical and Materials Engineering from the National Institute of Technology, Rourkela. He did his Ph.D. thesis research on the fracture and fatigue behavior of additively manufactured Ti-alloy at the Materials Engineering department, IISc Bangalore. For the research work published during his Ph.D., he was awarded "The Acta Student Award 2019." As a postdoc at the School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore, he investigated the mechanical properties of various conventional structural alloys produced by laser powder bed fusion, directed energy deposition, and electron beam melting processes. As a postdoc at the Berkeley Lab, he investigates the fracture behavior of high entropy alloy systems in extreme environments, i.e., in the temperature range of 77 K to 1873 K. These high entropy alloys are produced by conventional arc melting and additive manufacturing processes. He was invited for the keynote presentation during the "International Conference on Fracture 2023" in the symposium on "The Fracture Behavior of Additively Manufactured Alloys."

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