ME Seminar

Design of protective overlayers for extreme environment applications

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ABSTRACT

The development of next-generation energy technologies and space launch capabilities relies on materials which can perform under extreme heat-flux conditions, thermomechanical loads, and corrosive environments. Protective oxide scales and coatings enable the protection of the base materials against severe chemical and mechanical degradation. However, the same extreme conditions can also cause these films/coatings to fail. Physics-based modelling of failure mechanisms is essential to designing new materials for these applications. In this talk, I will present two representative examples of my work in this field. First, I will present a novel approach to model the anomalous periodic oxidation behavior of zirconium alloys, which are used extensively as a cladding material for fuel rods in pressurized water reactors. These alloys show periodic acceleration in their oxidation while the oxide layer remains adhered to the substrate. This results in an increase in hydrogen entering the zirconium alloy, accelerating hydrogen embrittlement which ultimately limits the fuel burn-up in the reactor. In this talk, I will show how the application of Turing's theory of pattern formation unveils the mechanism behind this detrimental anomaly, which had remained unexplained for the last four decades. The second part of my talk will focus on the development and fracture analysis of a novel ductile phase-toughened protective coating for the turbine of an oxygen-rich turbopump in a staged combustion rocket engine. The proposed coating protects Ni-based superalloy parts from potential metal fires, driven by a high-pressure, hightemperature gaseous oxygen environment. However, extreme thermal transients in a rocket engine make the coatings susceptible to delamination. Here, I investigate the driving force for thermomechanical delamination of this coating under a notional flight cycle for a reusable boost-stage engine. I will discuss the design criteria for the coating's composite architecture such that it exhibits a fracture toughness large enough to resist delamination.

ABOUT THE SPEAKER

Isha Gupta is a postdoctoral associate in the MIT Aerospace Materials and Structure Laboratory, working with Prof. Zachary Cordero in the Department of Aeronautics and Astronautics. Her research focuses on developing an environmental barrier coating to mitigate the risk of metal ignition in high-pressure oxygen environments of staged combustion rocket engines. Isha received her PhD in Mechanical Engineering from the University of Michigan under the guidance of Prof. Michael Thouless and Prof. James Barber. In her PhD thesis, she developed a novel approach for modeling the anomalous periodic oxidation behavior of zirconium alloys, which are widely used as fuel rod cladding material in pressurized water reactors. Isha's research interest lies in developing environmental-barrier materials for next-generation energy, space launch, and aerospace technologies, where materials will be subjected to extremely hostile operating conditions. Her work leverages multi-physics modeling of failure coupled with advanced material processing and damage characterization techniques to develop material design strategies for safe operation in extreme environments.

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