Graduate Colloquium, Aerospace Engineering

Architected for Attenuation: Development of Novel Hierarchical Granular Metamaterial Architectures for Impact Mitigation

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Abstract: Granular metamaterials leverage the nonlinear properties of discrete, interacting grains to achieve exceptional acoustic behavior and enhanced energy dissipation. However, traditional architectures composed of monolithic grains are constrained by limited tunability in their bulk mechanical response. To overcome this limitation, we introduce a new paradigm of grain design featuring structural hierarchy embedded directly at the grain level. In the first part of this talk, we utilize a hybrid framework integrating high-strain-rate testing, finite element simulations, and physics-informed surrogate modeling to examine the behavior of these nonlinear systems across length scales. We demonstrate the exceptional mechanical filtering and amplitude-dependent energy dissipation mechanisms enabled by these architected grains. In the second part, we elevate this paradigm to include a field-driven, adaptive response by replacing the solid lattice struts with hollow channels infused with a magnetoactive fluid. Through computational modeling, we show that modulating an external magnetic field allows for the rapid, reversible tuning of the system's macroscopic impact response. Ultimately, this work establishes a quantitative link between the internal architecture of individual grains and the dynamic behavior of their assembly, providing a definitive roadmap for the next generation of lightweight, programmable impact protection devices.

Brief Bio: Prajwal Bharadwaj is a Ph.D. candidate in the Aerospace Structures and Materials Lab at Worcester Polytechnic Institute, under the supervision of Prof. Nikhil Karanjgaokar. His research focuses on the design and analysis of novel materials and structures, with a specific emphasis on mechanical metamaterials and experimental solid mechanics.