Lattice meta-materials: mechanics, simulation, and optimization

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Refreshments at 3:30 pm, Upson Hall Lounge

ABSTRACT
Lattice meta-materials achieve exceptional stiffness- and strength-to-weight ratios and can strongly attenuate shock loading. Furthermore, certain lattice topologies demonstrate mechanical properties not found in nature, such as negative Poisson's ratio and acoustic band gaps. Additive manufacturing technologies can now assemble lattices with structural scales ranging from nanometers to millimeters with build areas greater than one square meter, meaning these meta-materials will soon find industrial applications.

This presentation describes a series of models for the mechanical response of lattice meta-materials for conditions ranging from quasi-static and linear elastic to the extreme plastic volume change and high strain rates associated with shock propagation. The objective of these models is not only to support the design of shock absorbing materials for applications like armor and helmets, but also to begin to explore lattice materials as a framework for designing materials specifically tailored for particular applications.

Towards the goal of material design, the presentation describes a framework for optimizing a lattice microstructure for a particular objective – for example, isotropic stiffness or minimum negative Poisson's ratio. Future work will focus on optimizing more complicated and non-linear properties of the materials – such as fracture toughness and vibrational attenuation and dispersion – as well as moving from microstructural optimization to optimization of a component as a whole, including both macroscale and microscale topology.

BIOGRAPHICAL SKETCH
Mark Messner earned his Ph.D. at the University of Illinois at Urbana-Champaign. His dissertation, supported by an NDSEG fellowship, examined delamination fracture in aluminum-lithium alloys using multiscale crystal plasticity models. He is currently a postdoctoral researcher at Lawrence Livermore National Laboratory, focusing on additively manufactured meta-materials for shock mitigation applications and on developing new multiscale constitutive models for the behavior of hexagonal closed packed metals at extreme temperatures, pressures, and strain rates.