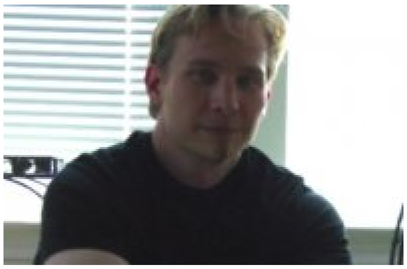
Department of Civil Engineering and Engineering Mechanics
Columbia University

Tuesday, April 3, 2012 (2:30-3:30 pm)
644 Mudd

MICROMECHANICAL FINITE ELEMENT ANALYSIS FOR DEVELOPMENT OF COMPOSITE MATERIAL DESIGN CAPABILITIES



Dr. Ryan Karkkainen
Army Research Laboratory
Weapons and Materials Research Directorate
Aberdeen Proving Ground, MD 21005

(Host: Prof. Haim Waisman)

Structural robustness, impact resistance, and enhanced lethality each represent important ongoing objectives of Army research for ordnance, vehicle structures, and protection system applications. Improvement of material system performance to achieve these ends can be accomplished through traditional design methods utilizing existing materials, failure theories, and optimization procedures, or more recently, methods are being developed for proactive design of material microstructures to achieve desired properties and system performance. In this case, detailed simulation of material microstructures is employed to determine material responses such as failure behavior on the fundamental scale of active mechanisms. Parametric study can effectively map out the microstructure-to-property response. Once this knowledge base is developed, a material can then be proactively designed through controlled manipulation of material microstructure to achieve the desired ends in material performance.

As examples, polymer composite materials exhibit great flexibility in the manipulation of ply layup specifications, and in the case of textile architectures, additional flexibility is introduced in terms of fiber tow microgeometry and constituent properties. In metallic materials, manufacturing processes allow for design of meso-scale grain structures which can tailor the properties to specific needs, and multi-modal material systems with controlled variation in grain size have shown great capacity for improvement through proactive material design. For the so-called material class of metamaterials, active manipulation of high density inclusions in a polymer can show frequency mitigation effects essential to protection systems. Lastly, detailed study of fracture mechanisms in nanoparticulate reinforced polymers including effects of interface properties and particle distribution can yield actionable information in design of energy absorbing materials.

Results herein will be presented which illustrate the capacity for finite element micromechanical modeling to accurately predict strength and stiffness properties of textile composite materials, with subsequent utilization to perform parametric studies which map out the effects of stitch density on various mechanical properties. Methods for development of a rate dependent adhesive interface failure model are shown, along with incorporation into a dynamic micromechanical investigation of textile composites. An overview of preliminary work in impact of structural reactive metals and fracture of nanocomposite materials will further be presented.

http://www.civil.columbia.edu