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SIMULATION OF IMPACT, PERFORATION, AND FRAGMENTATION IN AUGMENTED FABRICS

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ABSTRACT

High strength, light weight, and flexibility have made fabrics the preferred material for use body armor, orbital debris shielding, and other impact protection applications. Recent research at the University of Delaware and the Army Research Laboratory has suggested that dissipative augmentation of conventional fabrics may improve their performance in ballistic protection applications. Research by the authors is in progress investigating the potential of dissipative augmentations to improve Kevlar impact performance in body armor and orbital debris shielding applications. This research includes experimental and simulation work on Kevlar treated with a shear thickening fluid (STF) or a magnetorheological fluid (MRF).

Current design work on fabric ballistic protection systems relies primarily on experiment. Conventional impact simulation methods were developed for application to structural impact and shock hydrodynamics problems, and are not well suited to model fabrics. As fabric impact protection systems become more complex, and more expensive materials are introduced, computation may play a more important design role. Hence this research is developing, and implementing in parallel new hybrid particle-element models of augmented fabric materials. The long term goal is to provide an experimentally validated simulation technique to assist in the computational design of improved fabric ballistic protection systems.

Computational work to date has developed and implemented in parallel new mesomechanical (yarn level) particle-element models of Neat, STF, and MRF Kevlar. The Neat Kevlar formulation models yarn crimp and rate-dependent yarn strength, as well as contact-impact, Coulomb friction, and viscous friction interaction between yarns and between fabric layers. The STF and MRF Kevlar formulations add a Bingham fluid model of viscosity effects and a mixture equation of state describing the STF (polyethylene glycol-silica) or MRF (hydrocarbon-iron) thermodynamics. Validation work to date shows good agreement with experimental data for different projectile types (fragment simulating projectile, disk, cylinder) and for both clamped and fixed-free boundary conditions. Additional validation work is in progress.