How We Fit

Materials-by-Design Process

Mechanism-based Approach

• Experiments to see mesoscale damage mechanisms: matrix cracking, tow-tow debonding, tension-shear tow failure
• Modeling & simulation to understand mesoscale damage mechanisms

Key Goals

Collaboration: Experiments (tension, compression, punch-shear, impact): ARL, UD/CCM
• Damage mapping, characterization: visualization: MSU, ARL, UD/CCM
• Microscale modeling and material/constitutive inputs: JHU, UD/CCM

Meso-mechanical modeling:
• Tensile and punch-shear damage modes and energy dissipation as model input and validation
• Characterize elastic wave propagation and effect on mesoscale damage modes and energy dissipation
• Build and validate mesoscale model to predict energy dissipation and damage:
  • Tension (e.g., matrix cracking)
  • Punch-shear (e.g., punch-shear damage mode)
  • Tow pull-out (e.g., traction-separation, tow-tow debonding)
  • Impact (e.g., elastic wave propagation, back-face deflection, perforation)
• In materials-by-design framework, use model to evaluate novel composite material systems and lead to enhanced soldier protection and lethality

Technical Approach

• Macroscopic damage modes dissipate energy through:
  • Elastic strain energy (wave motion, vibration)
• Meso- and micro-mechanical damage mechanisms:
  • Matrix cracking, debonding, tensile fiber fracture, etc.
  • Isolate mechanisms that lead to damage modes (“See It”)
  • Single layer eliminates delamination mode, interlaminar stress field, nesting
  • Focus on perforation phase (eliminate penetration and transition)
• Isolate and characterize tension and shear damage modes and energy dissipation
• Characterize elastic wave propagation and effect on mesoscale damage modes and energy dissipation
• Systematically build up complexity of models (“Understand It”)
• Homogenized continuum plain weave properties
• Meso-mechanical plain weave model geometry with cohesive zone elements bonding constituents

Meso-mechanical modeling:
• Capture mechanisms occurring at mesoscale:
  • Axial wave speed
  • Transverse cone wave speed
  • Transverse tow cracking
  • Tow-matrix and tow-tow deboning
• Model damage and failure modes from understanding of mechanisms

Key Accomplishments

• Demonstrated perforation energy difference depending on impact location relative to a unit cell at mesoscale
• Damage characterization using CT scanning, confocal microscopy, and SEM showed how damage evolves from transverse matrix cracks to tow-tow debonding

Future Directions in 2018

• Refine model in terms of delamination response and transverse matrix cracking by evaluating/optimizing cohesive zone formulation, bilinear traction-displacement behavior, and predefined fracture planes.
• Conduct tension testing of 1, 2, and 3 inch wide PW tensile specimens, determine quasi-static tensile response of single-layer PW composite and using DIC identify strain levels at which transverse matrix cracks initiate and proliferate. Evaluate model tensile response in explicit FE code.
• Conduct quasi-static punch-shear testing of single-layer PW specimens at load levels increasing to failure to quantify damage and energy dissipation due to transverse punch-shear loading.
• Conduct low velocity impact experiments of single-layer PW specimens. Model the dynamic response using explicit FE code.

Impact

• Validated meso-mechanical plain weave composite model will be applied to woven composites of interest to the Army
  • In materials-by-design framework, model will be used to evaluate novel composite material systems in ballistic impact
  • Used in developing advanced composite armor systems for personnel and light vehicles, model will lead to enhanced protection for the soldier