Meso-Mechanical Modeling of Canonical Perforation Experiments

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Key Goals and Technical Approach

See it

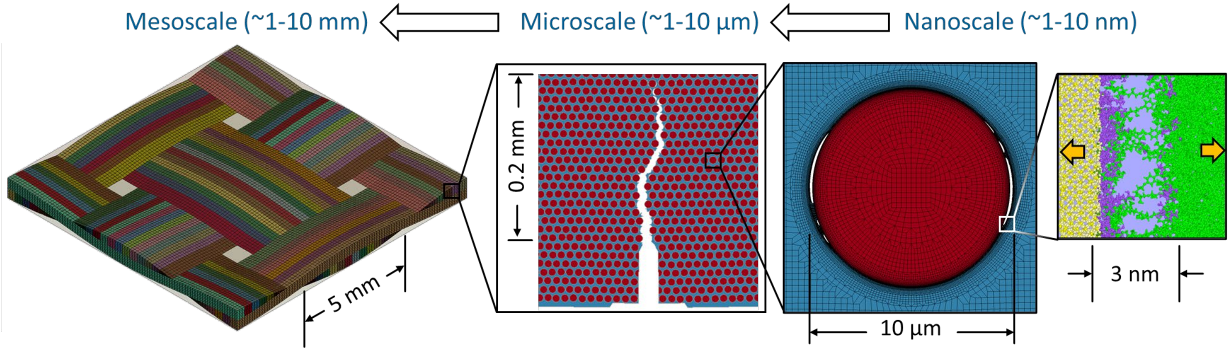
- Conduct ballistic perforation experiments on single-layer, plain weave S-2 glass/epoxy composites, determine $V_I - V_R$, V_{50}

Understand it

- Develop multiscale models including realistic geometry and rate-dependent material behavior
- Validate mesoscale model with canonical perforation experiments

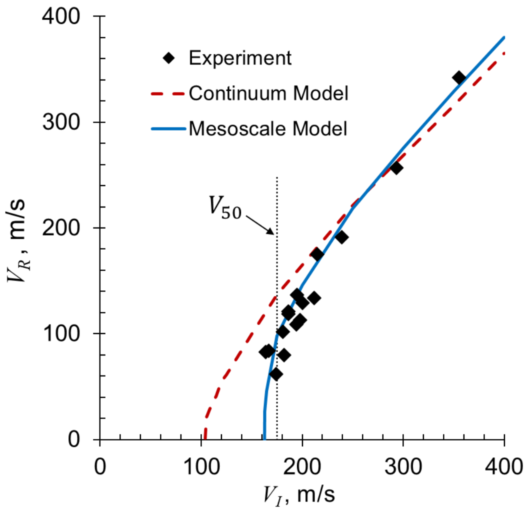
Materials by Design

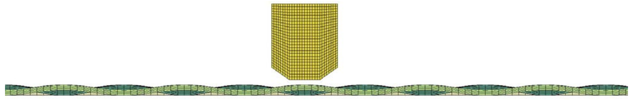
- Use mesoscale model to partition energy dissipation, to investigate important deformation and damage mechanisms, and to identify areas for optimizing the material, design, or processing to enhance penetration resistance



Major Results, Key Accomplishments

- Developed micro-to-mesoscale model to determine traction separation laws and bridge length scales with the J-integral method
- Developed meso-to-macroscale model of perforation experiments
- Demonstrated improved predictive capability over state-of-the-art continuum model
- Approximated energy dissipation: 13% matrix, 63% composite fabric, 24% coupled mechanisms including tow-tow delamination, tow tensile elongation, tow pullout and frictional sliding
- Enhanced performance can be achieved by using better resins, higher fiber volume fraction, better fibers, better fiber-matrix interface





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Transitions (materials, codes/tools, legacy publications)

1. **Micro-to-Mesoscale Crack Evolution for Traction Law Prediction**
   - Tool to determine cohesive traction-separation laws for fiber-matrix micro-cracking
   - Applied to a materials-by-design framework to bridge cracks from microscale to mesoscale with input fiber-matrix interface properties
2. **Mesoscale Composite Model for Penetration Mechanics**
   - Tool to predict $V_I - V_R$ for ballistic penetration of plain weave composites for thin or thick composites
   - Applied to a materials-by-design framework to partition energy absorption and predict important mechanisms for improved penetration resistance
3. **Select Journal Publications**

1. Meyer CS, O'Brien DJ, Haque BZ, Gillespie Jr. JW, Mesoscale modeling of ballistic impact experiments on a single layer of plain weave composite, Manuscript submitted for publication, 2021.
2. Meyer CS, Haque BZ, Gillespie Jr., JW, Bridging length scales from micro to mesoscale through rate-dependent traction-separation law predictions, Compos Part B, 2022.
3. Meyer CS, Catugas IG, Gillespie Jr. JW, Haque BZ, Investigation of normal, lateral, and oblique impact of microscale projectiles into unidirectional glass/epoxy composites, Defense Technology, 2021.
4. Bhaduri A, Meyer CS, et al., Probabilistic modeling of discrete structural response with application to composite plate penetration models, J. Engrg. Mechanics, 147:11, 2021.
5. Meyer CS, Bonyi E, Drake K, et al. Automated detection and quantification of transverse cracks on woven composites, Journal of Reinforced Plastics and Composites, 2021.
6. Bonyi E, Meyer CS, et al. Assessment and quantification of ballistic impact damage of a single-layer woven fabric composite, Intl J Damage Mechanics, 28:2, 2019, 249-269.
7. Meyer CS, Haque BZ, O'Brien DJ, et al. Mesoscale ballistic damage mechanisms of a single-layer woven glass/epoxy composite, Intl J Impact Engrg, 113, 2018, 118-131.

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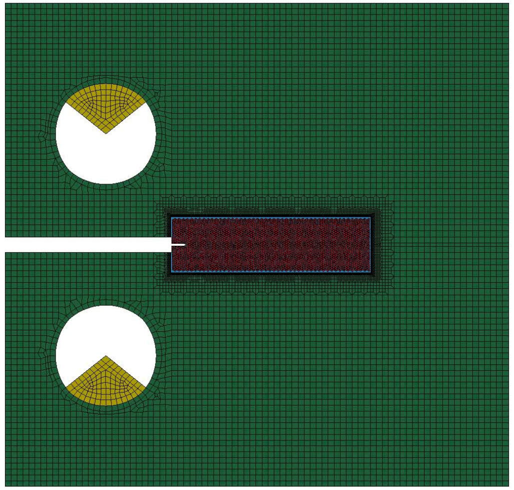
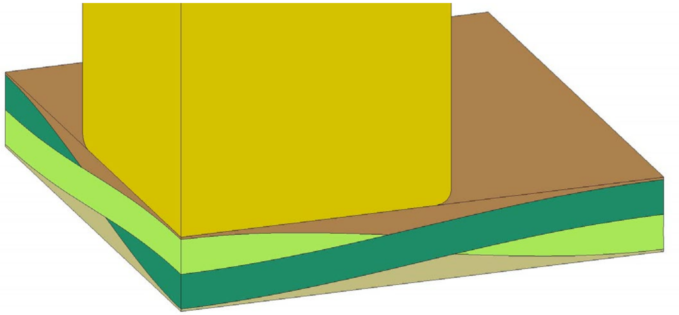
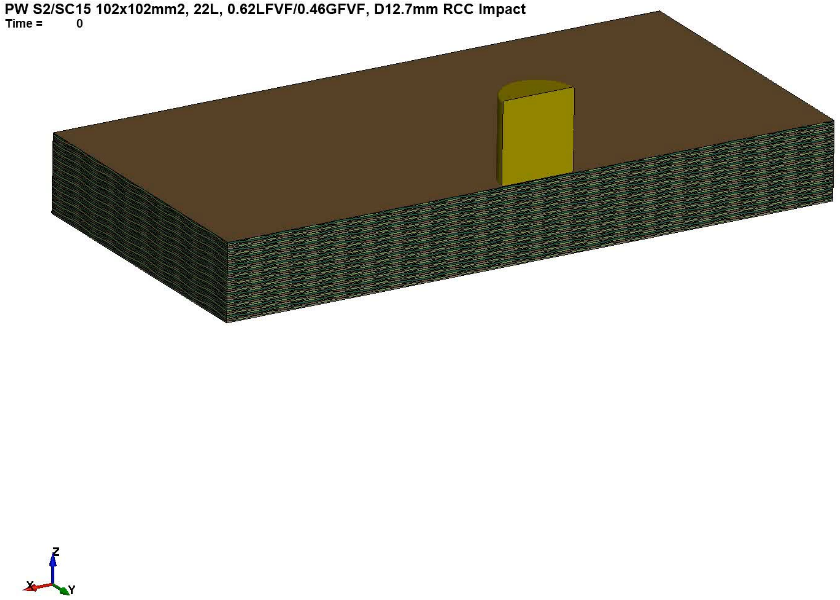
Multi-scale Models of Impact and Fracture

Compact Tension
Microscale Fracture Model



V_I = 200 m/s Impact
Local Tow-tow Delamination and Cone Wave Initiation





V_I = 932 m/s Impact on 22 Layer Plain Weave Glass/Epoxy Composite