MODELING THE IMPACT OF FLEXIBLE TEXTILE COMPOSITES THROUGH MULTISCALE AND PROBABILISTIC METHODS

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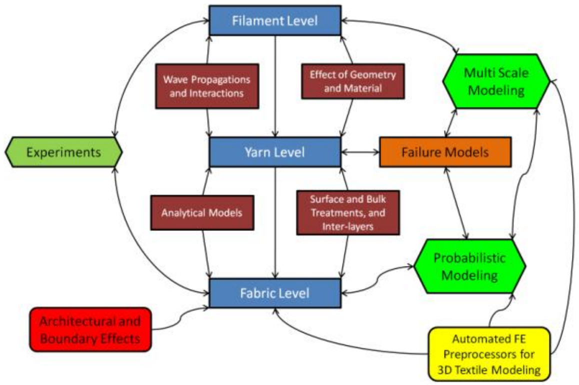
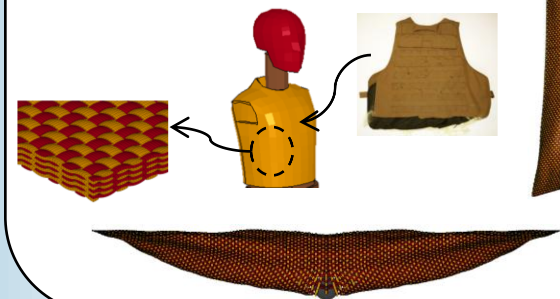
RESEARCH OVERVIEW



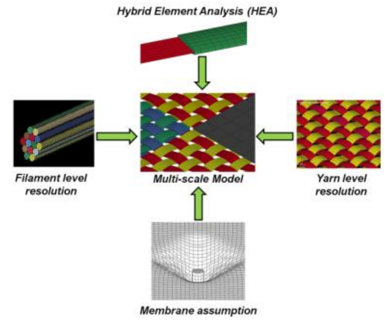
COMPUTATIONAL MODELING OF FABRIC IMPACT

- Fabric system studied: *plain weave Kevlar S706 fabric*
- Understand energy dissipating mechanisms: *momentum transfer, internal energy, frictional interactions*
- Investigate interactions: *yarn-yarn, projectile-fabric, fabric layer-layer*
- Finite element analysis using LS-DYNA
- Fabrics modeled using a yarn-level architecture



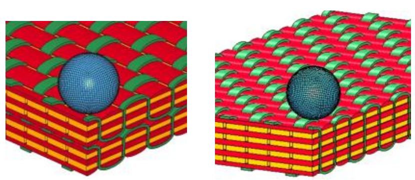
MULTISCALE MODELING OF FABRIC IMPACT

- Massive savings in the computational requirements of the FE model
- Enables simulation of large dimensioned multi-layer fabric panels
- Yarns modeled using both solid and shell elements
- 3 modeling levels – filament, yarn, membrane



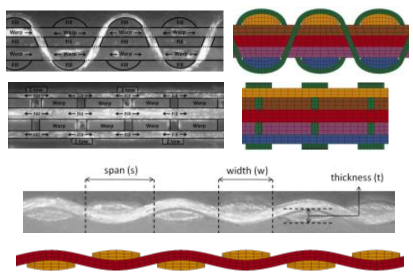
ROLE OF MATERIALS AND ARCHITECTURE ON IMPACT PERFORMANCE

- 2D Vs. 3D architecture
- Role of structural stitching and Z-tows
- Effect of tow geometry and undulations
- Effect of material properties (e.g. modulus, strength)

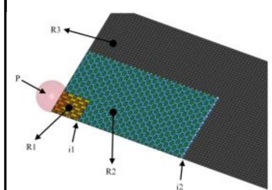


SETUP OF 2D AND 3D FABRIC FE MODELS

- Micrographs used as input to DYNAFAB™
- Output is a FE model with a yarn level architecture



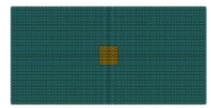
MULTISCALE MODELING USING THE HEA METHOD



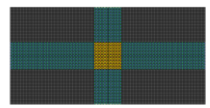
P	Projectile
R1	Local region, solid element yarns
R2	Local region, shell element yarns
R3	Global region, homogenized shell elements
i1	Interface #1
i2	Interface #2

Hybrid Element Analysis (HEA) is defined as '*the finite element analysis of a structure by combining different finite element formulations at both a single and multiple scales of modeling*'

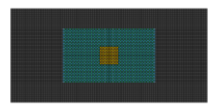
SAMPLE HEA CONFIGURATIONS



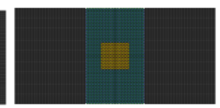
Single Scale HEA



Center Cross HEA



Central Patch HEA



Center Strip HEA

Impedances matched across all interfaces to prevent interfacial reflections of the longitudinal strain wave

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(Continued)

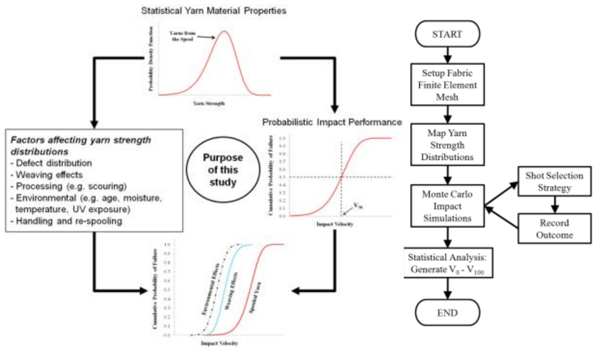
PROBABILISTIC NATURE OF FABRIC IMPACT PERFORMANCE

- Parameters such as V_0, V_{50}, V_{100} used to describe impact performance
- Probabilistic impact performance arises from two sources of variability:
  Intrinsic: *filament geometry (diameter) and packing, fabric architecture, yarn material properties (modulus, strength, frictional coefficient), et cetera.*
  Extrinsic: *experimental equipment (gas gun, projectile, backing material), statistical techniques (Neyer-D, Langlie), testing conditions (fabric slippage, impact location), et cetera.*

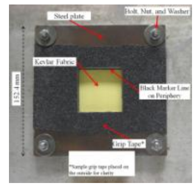
IMPORTANT QUESTIONS

- What is the relation between the statistical nature of yarn strength and the fabric probabilistic impact performance?
- How do the characteristics of the yarn strength distribution (*mean, width, shape*) affect the impact performance?
- What are the effects of weaving and scouring strength degradations on the impact performance?
- What are the effects of projectile characteristics (*size, shape, trajectory*) and fabric architecture (*plain weave, structural stitching, 3D fabric*) on the probabilistic impact performance?

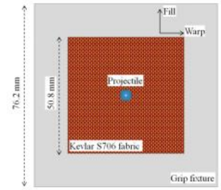
OVERVIEW OF PROBABILISTIC FRAMEWORK



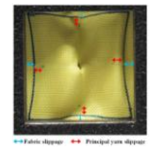
EXPERIMENTAL AND NUMERICAL SETUP



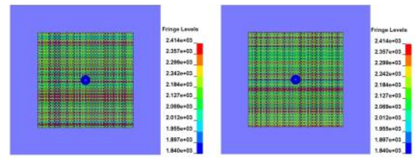
Experimental setup



Numerical setup in LS-DYNA



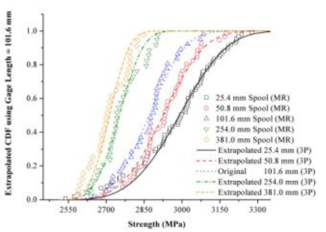
Experimental Fabric Slippage



Sample strength mappings in two fabric samples. Each yarn assigned to a strength based on the statistical strength distribution.

Numerical Fabric Slippage

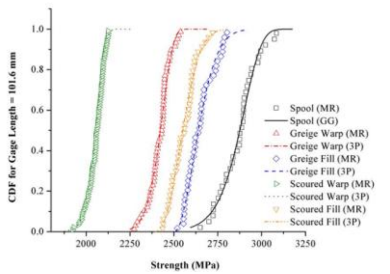
EXPERIMENTAL CHARACTERIZATION OF YARN STRENGTH – LENGTH SCALE EFFECTS



Cumulative Distribution Function (CDF) for a 3-parameter Weibull distribution with parameters $\boldsymbol{\sigma_o}$ (scale), $\boldsymbol{m}$ (shape), $\boldsymbol{x}$ (threshold), length scale parameter $\boldsymbol{\alpha}$ (α_1 for $L < L_0$; and α_2 for $L > L_0$)

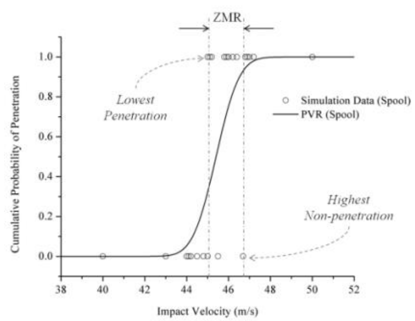
$$F(\sigma)=1-\exp\left(-\left(\frac{L}{L_0}\right)^{\alpha}\left(\frac{\sigma-x}{\sigma_0}\right)^{m}\right)$$

EXPERIMENTAL CHARACTERIZATION OF YARN STRENGTH – WEAVING EFFECTS



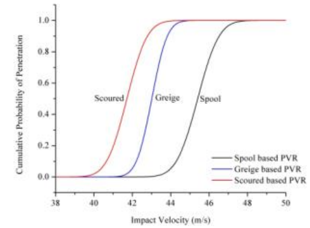
- 3-parameter Weibull and G-Gamma distributions used for the CDF
- Weaving and scouring processes cause tensile strength degradations
- Warp yarns are degraded to higher levels than the fill yarns

NUMERICAL V_0-V_{100} PREDICTIONS



2in. x 2in. Kevlar S706 fabric with spool based strength mappings held on four sides (zero slippage) and impacted by a 0.22 caliber spherical projectile

NUMERICAL V_0-V_{100} PREDICTIONS



ACKNOWLEDGEMENTS

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