Technical Approach & Major Results

- Developed and validated a fiber-level FE modeling framework to capture the dynamic effects of a single fiber break while relaxing the inherent assumptions in theoretical shear lag models
- Identified influential non-dimensional parameter, \( R_{shear} \), which gives insights into micromechanical damage mechanisms and demonstrated the need to tailor the matrix and interphase as a system
- Extended the scope of SFFT using in-situ visualization of fiber break progression
- LabView script to track the locations of each fiber break in SFFT and index them
- In-situ observation of interfacial debond growth accompanying fiber breaks

Key Accomplishments

- Developed novel experimental method (Continuous Fiber Bending Experiment) to characterize spatial distribution of critical defects in the fiber
- Designed and manufactured precision fiber-placement fixture(a) to create precisely controlled multi-fiber microcomposites(b) for FE model validation

Technical Approach

Materials-by-Design Process

- Brittle S-glass fibers, have gage-length dependent stochastic distribution of strength
- Cannot be modeled using RVEs
- Dynamic Localization and clustering of fiber breaks leads to catastrophic failure

Mechanism-based Approach

- To experimentally determine the statistical distribution (size and spatial) of Critical defects in S-glass fibers
- Interaction with composites CMRG tasks
- Experimentally determine the statistical distribution (size and spatial) of Critical defects in S-glass fibers

Key Goals

- Tensile strength along the fiber direction (XT) is one of the key properties identified in the Materials by Design Process
- Brittle S-glass fibers, have gage-length dependent stochastic distribution of strength
- Dynamic Localization and clustering of fiber breaks leads to catastrophic failure

Randomness in fiber packing
Fiber diameter variations
Fiber strength distribution

OBJECTIVE FUNCTION

\[ F(\lambda, W_{def})_{max} = F(F_{c}(\theta), XP, XPCS, XPSS) \]

Mean = 9.89 microns
Std. Dev = 0.45 microns
CV = 4.5%

Critical defect distribution in S-glass fiber
derived from SFFT

Single Fiber Fragmentation Test (SFFT)
- Single S-glass fiber embedded in DER330-Epoxy Dogbone
- Saturated fragment length of 365 microns (defects spaced within this length are shielded)
- Extrapolation of fiber tensile test data leads to over-estimation of mean strength by ~25%

Measuring Critical Defect Distribution: Continuous Fiber Bending Experiment

Sandwich specimen is moved over a distance of 25 mm to ensure that all cross-sections of the fiber are subjected to the same radius of curvature within this gage length

- Bi-modal Wibull distribution
- S-glass Cumulative Strength distribution
- at 365 microns

Impact

- Generation of a defect-distribution based model capable of predicting progression of fiber breaks under a range of applied strain rates
- Framework for tailoring interface and matrix to enhance tensile properties and energy absorption in the composite
- Study the interaction of micromechanical damage mechanisms inside a realistic composite system
- Generation of a defect-distribution based model capable of predicting progression of fiber breaks under a range of applied strain rates
- Multi-scale modeling of tensile behavior
- Will also provide direct input to dynamic Punch-shear models (Dr. Haque, UDel)