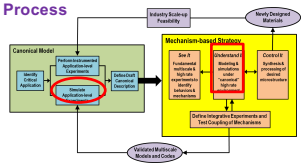
Transverse Impact of Fibers and Yarns

Subramani Sockalingam (USC), Sanjib Chowdhury (UDel), John W. Gillespie Jr. (UDel),
Travis Bogetti (ARL), Tusit Weerasooriya (ARL), Daniel Casem (ARL)

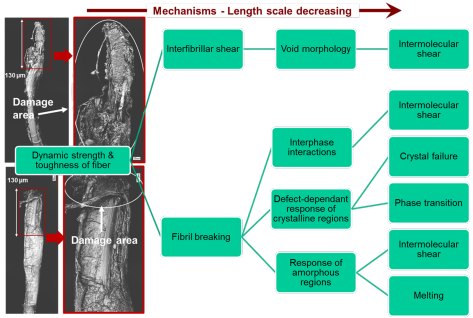
Enterprise for Multi-scale Research of Materials

How We Fit

Materials-by-Design Process

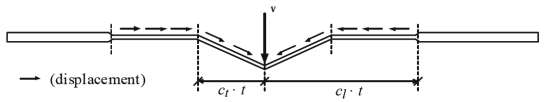


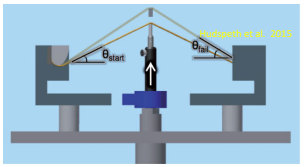
Mechanism-based Approach

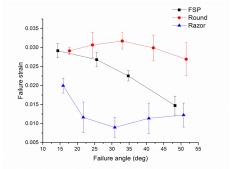


Key Goals

- Fundamental understanding of fiber response and fiber-level mechanisms during impact with Kevlar KM2 as model material
- Investigate the role of multiaxial loading during impact

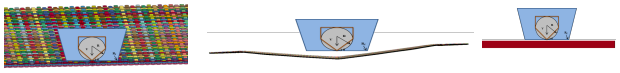




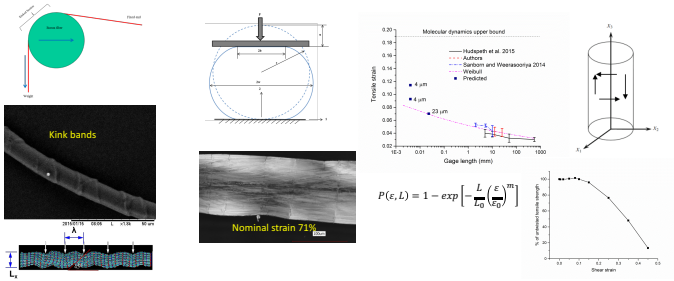


Technical Approach

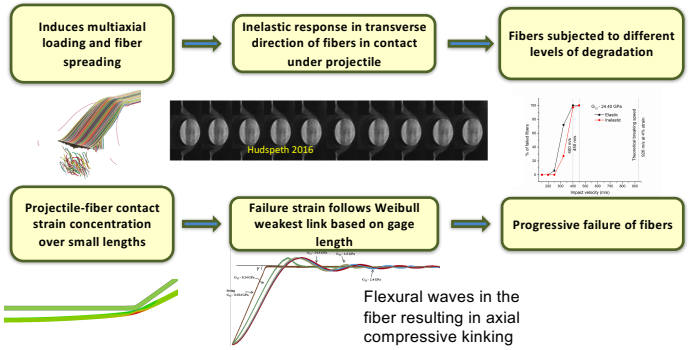
Fiber-scale 3D FE models of single fiber and yarn transverse impact



Validated constitutive and failure model for single fibers



Major Results

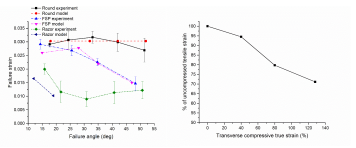


Multiaxial loading failure criterion

$$\frac{\varepsilon_{3,max}}{\varepsilon_{3,fail}} = 1 \qquad \varepsilon_{3,max} = SCF \times \varepsilon_{3,avg}$$

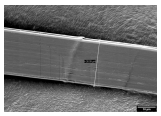
$$\varepsilon_{3,fail} = \varepsilon_3(L_c, ACr, TCr, ILSr)$$

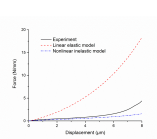
$$\varepsilon_{3,fail} = \varepsilon_3(L_c) \times (1 - ACr) \times (1 - TCr) \times (1 - ILSr)$$

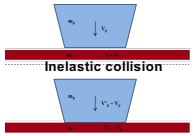


Key Accomplishments

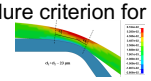
- Developed validated constitutive model for KM2 single fibers in transverse compression. Applied to UHMWPE up to 25% true strain





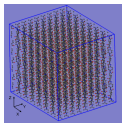


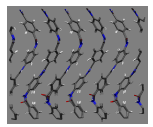
- Developed multiaxial loading failure criterion for single fibers with degradation experiments



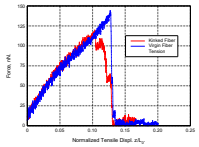
- Developed fiber-scale 3D FE models of yarn impact

- MD modeling of multiaxial loading





Kevlar chain buckling



Axial tensile response with and without compression kinking

Future Directions in 2017

- Extend to larger strains for UHMWPE constitutive models
- Apply failure theory to UHMWPE multiaxial loading
- Fibril-scale modeling of multiaxial loading experiments
- High strain rate behavior of single fibers in transverse compression

Impact

- Improved understanding of energy absorbing mechanisms during impact
- Will lead to improved protection materials while decreasing the cost and time for development of new lightweight energy absorbing materials

CMEDE CENTER FOR MATERIALS IN EXTREME DYNAMIC ENVIRONMENTS

UNIVERSITY OF DELAWARE | CENTER FOR COMPOSITE MATERIALS Internationally Recognized Excellence