INVESTIGATION OF STRENGTH AND SURFACE MORPHOLOGY OF UHMW PE FIBERS EXTRACTED FROM FATIGUED PANELS

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Introduction

Materials

- Consolidated Panels (HW)
  - Each panel consists of multiple layers of consolidate UHMW (Ultrahigh molecular weight) PE unidirectional 0-90 cross plies. Two types of consolidated panels were evaluated:
    - Baseline panel – 0 cycles
    - Fatigued panel – 250K cycles

- Unconsolidated Panels (SB)
  - Each panel is made from multiple sheets of unconsolidated 0-90 cross plies stitched together at the corners. Two panels were evaluated:
    - Baseline panel – 0 cycles
    - Fatigued panel – 500K cycles

Objectives

- To quantify the strength of UHMW PE fibers due to cyclic fatigue loading
- To identify the failure modes/damages appeared on the fiber surface before after cyclic fatigue loading.

Problem Specification

- Successfully demonstrate filament extraction without causing damage to the fibers.
- Specify types of damage/failure mode on microscales caused by cyclic fatigue loading on two types of UHMW PE based shoot packs.
- Correlate the failure modes / damage to strength degradation.

Methodology

Microscopic Analysis

- Laser Confocal microscopy to map crease surface
- Measure crease dimensions
- Observe any signs of layer deconsolidation
- Analysis of filaments in damaged areas
- SEM to determine failure modes
- Develop a method to remove resin matrix and extract individual filaments

Fiber Extraction

- Remove a strip of fibers from a single layer of the shoot pack
- Soak in THF for 24 hours
- Periodic agitation and rinsing
- Perform solvent exchange every 1-2 hours
- Remove fibers from solvent to dry

Tensile Testing

- Fiber wrapped around the capstan.
- Tensile testing was conducted on fibers (from base line and fatigued panels) at gauge length of 25 mm and 5 mm/min cross-head speed.

Results and Discussion

Microscopic Analysis

- Insignificant differences in diameter between SK99 (10-13 µm) and extracted fibers (9-17 µm)
- THF-based extraction did not damage the fibers

Tensile Testing

- Strength-displacement behavior
- Most unconsolidated (SB) fatigued panel fibers failed at 3-4 GPa, while most consolidated (HW) fatigued panel fibers failed at 2-3 GPa
- Average strength and kink band spacing

- Fatigue loading caused fiber strength degradation of 36% for the fatigued HW panel and 20% from the fatigued SB panel
- Fibers from the fatigued HW panel exhibit significantly lower kink band spacing than those from the fatigued SB panel

Summary and Conclusion

- Fatigue cycling induces damage in the form of kink bands, fiber splitting, and fibrillation for both consolidated and unconsolidated panels
- Average failure strengths of filaments pulled from the baseline panels are essentially identical
- Fatigue cycling reduces the average tensile strength of filaments in both consolidated and unconsolidated panels
- The effect has a significantly greater impact on consolidated panels

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