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

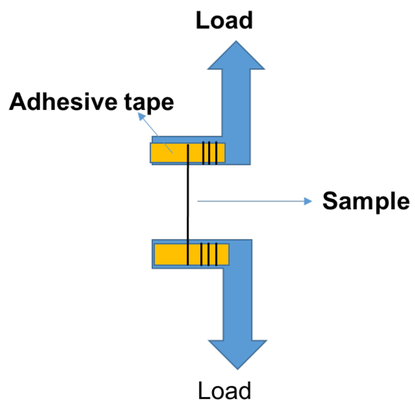
- Laser Confocal microscopy to map crease surface
  - Measure crease dimensions
  - Observe any signs of layer deconsolidation
- Analysis of filaments in damaged areas
  - SEM to determine failure modes
  - Develop a method to remove resin matrix and extract individual filaments

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

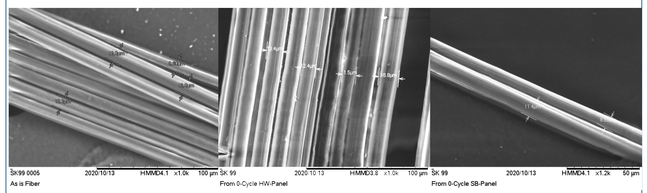
- Fiber wrapped around the capstan.
- Tensile testing was conducted on fibers (from base line and fatigued panels) at gauge length of 25 mm and 5 mm/min cross-head speed.



Results and Discussion

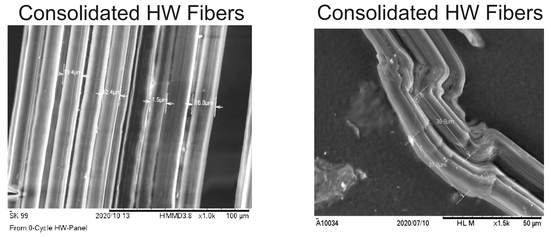
Microscopic Analysis

Virgin SK99 Fibers | Consolidated HW Fibers | Unconsolidated SB Fibers

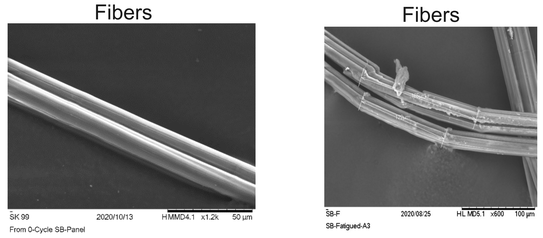


- Insignificant differences in diameter between SK99 (10-13 µm) and extracted fibers (9-17 µm)
- THF-based extraction did not damage the fibers

Unfatigued Consolidated HW Fibers | Fatigued Consolidated HW Fibers



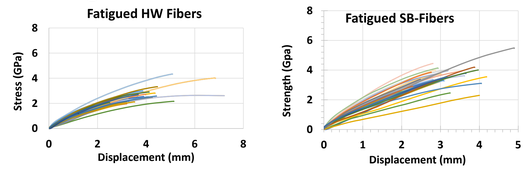
Unfatigued Unconsolidated HW Fibers | Unfatigued Unconsolidated HW Fibers



- Fibers from fatigued HW panel exhibit kink bands, fiber splitting, and fibrillation.
  - It is believed that damage is initiated with fiber kinking and that fiber splitting/fibrillation occur subsequently
- Fibers from the unconsolidated panel (SB) experienced less damage than the fibers extracted from the consolidated (HW) panel

Tensile Testing on Fibers

- 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

Fiber	Mean (Gpa)	Strength degradation (%)	Average Kink Band Spacing (µm)
Dyneema SK 99-Version Fibers	4.30±0.71	-	0
Unfatigued HW	4.08±1.01	-	0
Fatigued HW (250k cycles)	2.61±0.67	36	54
Unfatigued SB	4.53±1.14	-	0
Fatigued SB (500k cycles)	3.62±0.63	20	136

- 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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