STRENGTH AND SURFACE MORPHOLOGY OF UHMWPE FIBERS EXTRACTED FROM FATIGUED POLYETHELYNE BASED COMPOSITES

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Introduction

Materials

- Consolidated Sheets
  - Each sheet consists of Polyethylene fibers unidirectional 0-90 cross plies.
  - Two types of consolidated panels were evaluated:
    - Baseline Sheet - 0 cycles
    - Fatigued Sheet - 11,160 cycles at RT and at -20°C

Objectives

- To quantify the strength of fibers extracted from fatigued consolidated sheets.
- To identify the failure modes/damages appeared on the fiber surface before and 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 the consolidated fibers at RT and at -20°C.
- Correlate the failure modes / damage to strength degradation.

Cyclic Fatigue Procedure

- A specially developed fatigue setup was utilized along with an environmental chamber.
- The consolidated sample was folded at midplane, then mounted in the cyclic fatigue setup.
- Consolidated samples were exposed to cyclic fatigue loadings for 8hrs (11,160 cycles) at RT and at -20°C.
- The cross plies were extracted from the fibers in order to get samples to run fatigue testing.

Methodology

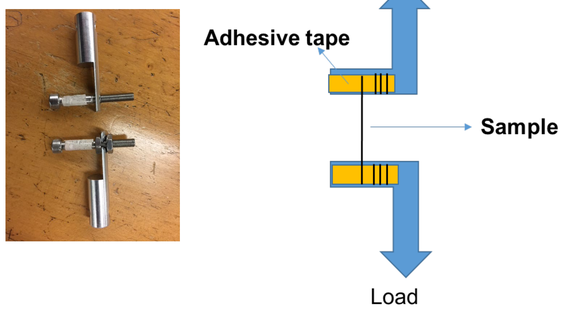
- A high-resolution camera (100 MP camera) was used to measure crease dimensions induced by fatigue.
  - SEM microscopy was conducted to determine failure modes in the filament due to fatigue.
  - Develop a method to remove resin matrix and extract individual filaments

Fiber Extraction Process

- Remove a strip of fibers from a single layer of the sheet 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 baseline and fatigued sheets) at gauge length of 25 mm and 5 mm/min cross-head speed.
  - The Fatigued /folded region was always at the middle of the gauge length of the sample during tensile loading.
  - Prior tensile testing, each fiber diameter was measured.

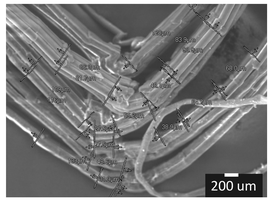


- Schematic sketch for tension test setup applied.

Results and Discussion

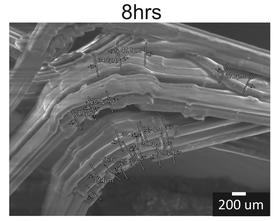
SEM Images

Prior fatigue @ RT



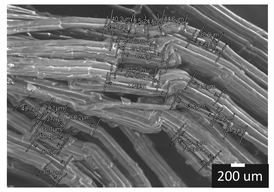
- Fibers exhibit kink band spacing on average ~69±37µm.

After cyclic fatigue @ RT for 8hrs



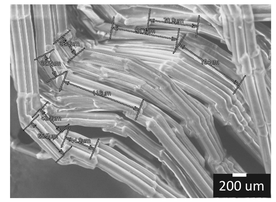
- Fibers exhibit kink band spacing on average 50±21µm .

Prior fatigue @ -20°C



- Fibers exhibit kink band spacing on average ~65±28µm .

After cyclic fatigue @ -20°C for 8hrs

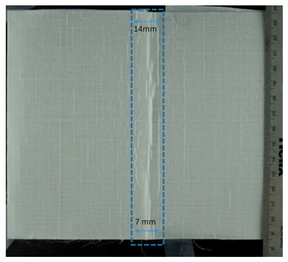


- Fibers exhibit kink band spacing on average ~61±29µm .

- Kink band spacing tends to have lower values due to fatigue at RT and -20°C.

Images of Fatigued Surfaces

After Fatigue @ RT



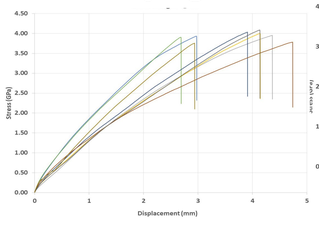
- Vertical crease show ~15µm in length and ~1.4 in width.

After Fatigue @ -20°C

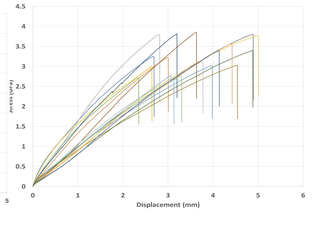
- Vertical crease show 20µm in length and ~1.4 in width.

Strength-Displacement Behavior

After Fatigue @ RT



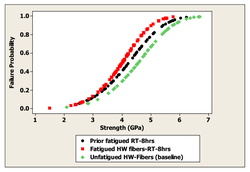
After Fatigue @ -20°C



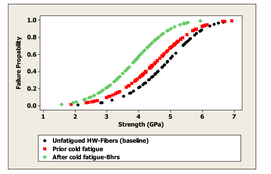
- Fibers exhibited a strength ranging from 3.8 to 4.0 GPa after fatigue at RT for 8hrs. For fibers fatigued at -20°C, the strength ranges from 2.7 to 3.7 GPa.

Failure Probability Distributions

After cyclic fatigue at RT for 8hrs



After fatigue at -20°C for 8hrs



- With respect to unfatigued fibers, prior fatigued and fatigued fibers at RT for 8hrs exhibit shifts to lower strength levels for failure probability above 25%.
- With respect to unfatigued fibers, the shifts to lower strength levels obtained from cold fatigued fibers are significantly higher than those obtained from unfatigued fibers.

Average strength and kink band spacing

Condition	Mean (GPa)	Strength degradation	Average kink bands spacing (µm)
Unfatigued HW fibers (baseline)	4.80±1.00		0
Prior RT fatigue	4.19±0.97	13%	69±37
After RT Fatigue for 8hrs	3.97±0.84	17%	50±21
Prior cold fatigue	4.46±0.95	7%	65±28
After cold fatigue for 8hrs	3.77±1.07	22%	61±29

Summary and Conclusion

- Cyclic fatigue at RT and -20°C reduced the dimensions (length and width) of the creases appeared on surface of the fatigued samples.
- Cyclic fatigue induces damage in the form of kink bands and fiber splitting.
- Strength degradation caused by cold fatigue is larger than that obtained for the fibers after fatigue at RT for 8hrs.

Acknowledgements

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