EFFECTS OF PROCESSING PARAMETERS ON MECHANICAL AND THERMAL PROPERTIES OF DYNEEMA FIBERS

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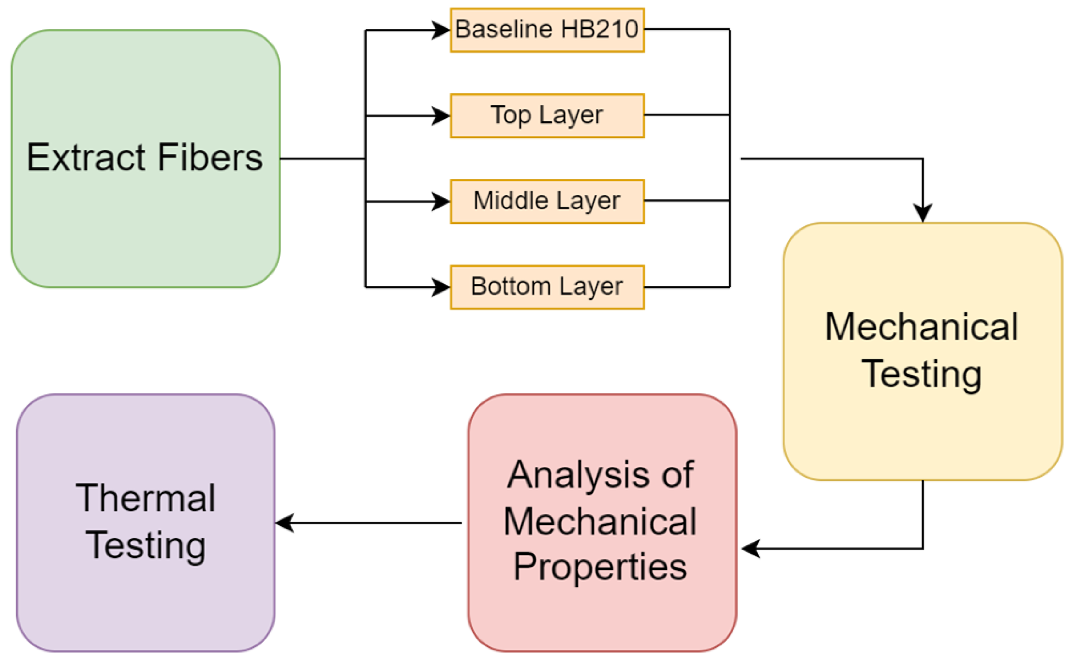
Introduction

Motivation

- Identify change in mechanical and thermal properties for layers of multilayer composite due to processing at different conditions

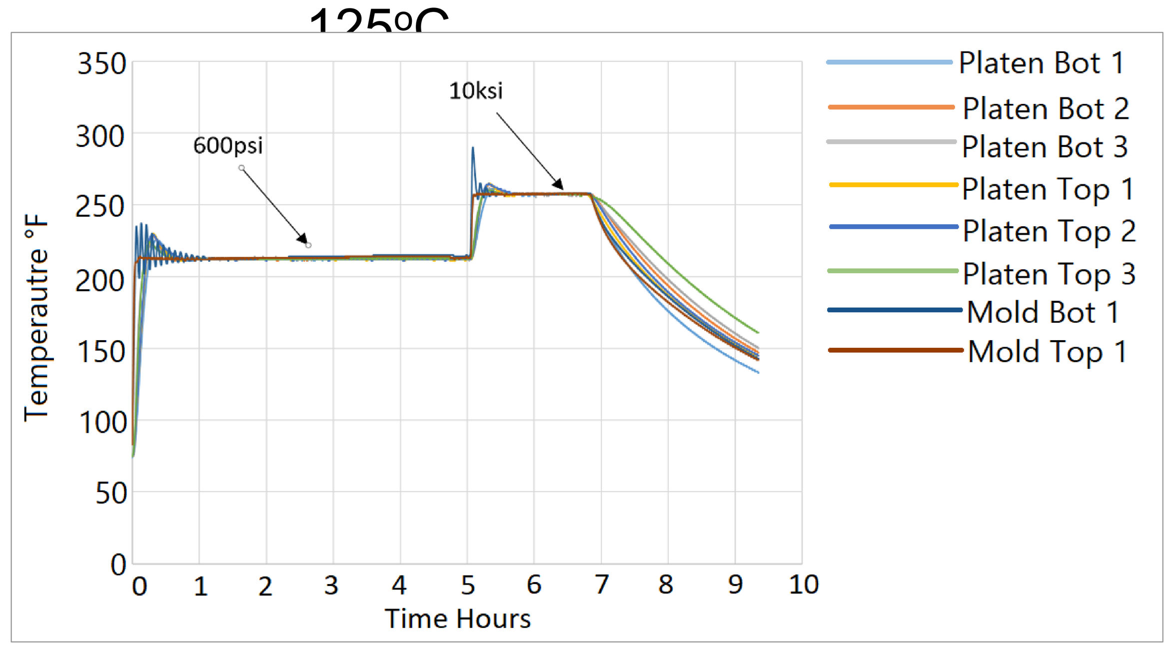
Objectives

- Quantify and compare changes in the strength of Dyneema fibers due to processing
- Observe the images of fibers due to effects of the processing
- Identify the thermal properties and transitions of layers of fibers to support the mechanical testing result



Material

- A UHMWPE fibers based composite panel. The panel was processed according to following cycle:
  - Isobaric at both 0.6 and 10 ksi
  - Isothermal at both 100 and 125ºC

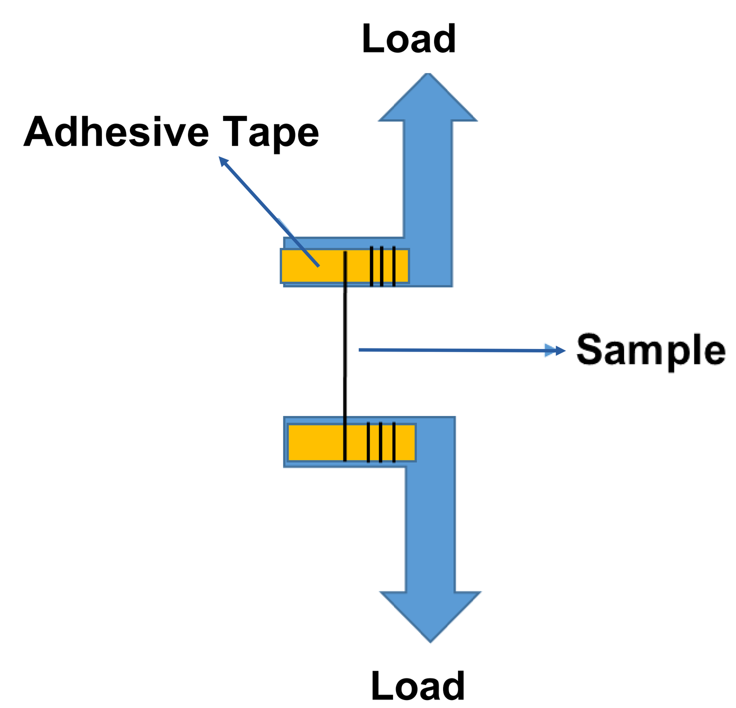


Extraction Procedure

- Sample of 0.5"x0.5"x6" was cut from the processed panel and immersed in Tetrahydrofuran (THF) for 15 days
- Top, Middle, and Bottom layers of the composite were separated and immersed in THF again to break down remaining resin
- Fibers from single layers were extracted carefully with tweezers after time in THF to prevent damage
- Fibers → 4 - 6" long

Mechanical Testing

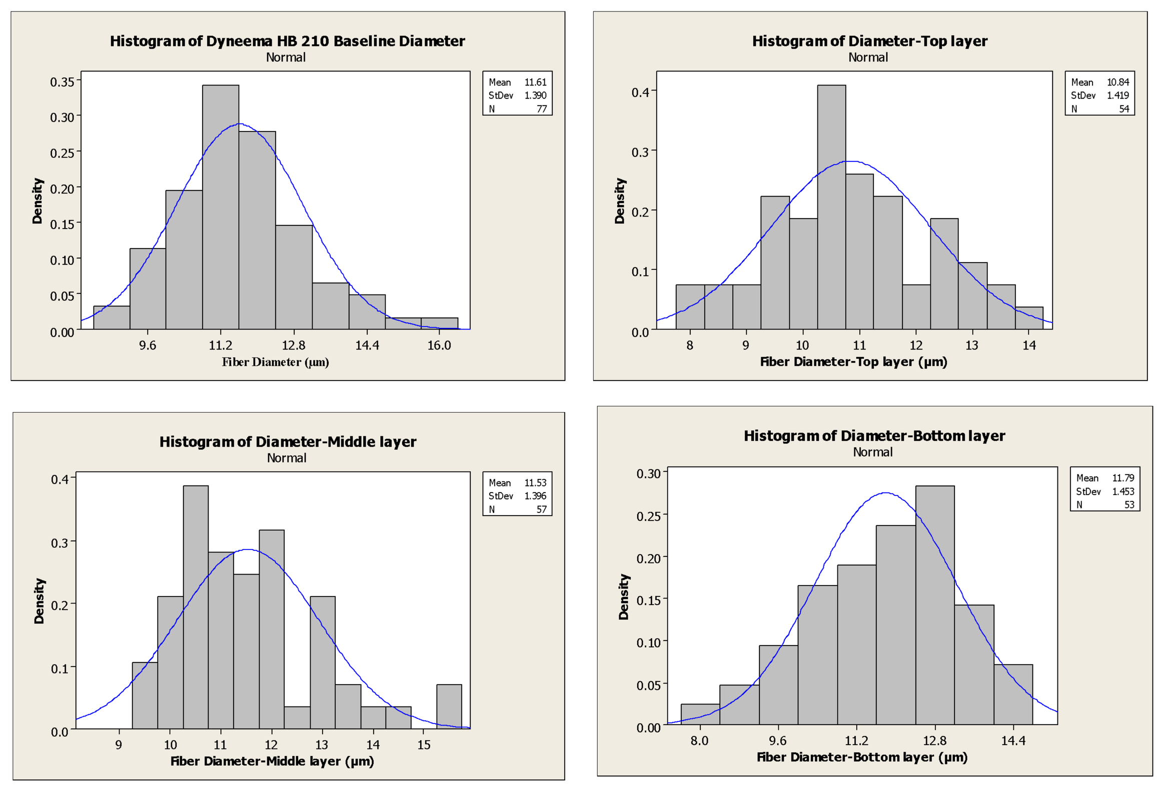
- Tensile testing was conducted using the micro-mechanical test frame (Instron) to quantify the maximum failure load for each fiber
- "Winding" method was used as apparatus for the tensile test
  - Gauge length 25 mm
  - Cross-head speed 5 mm/min



- Prior testing diameter for each fiber was measured to calculate failure strength
- Minimum of 60 filaments were tested for each composite layer

Fiber Diameters Analysis

- At high resolution, diameters of fibers extracted from different layers of the panel were measured and their distributions were generated.



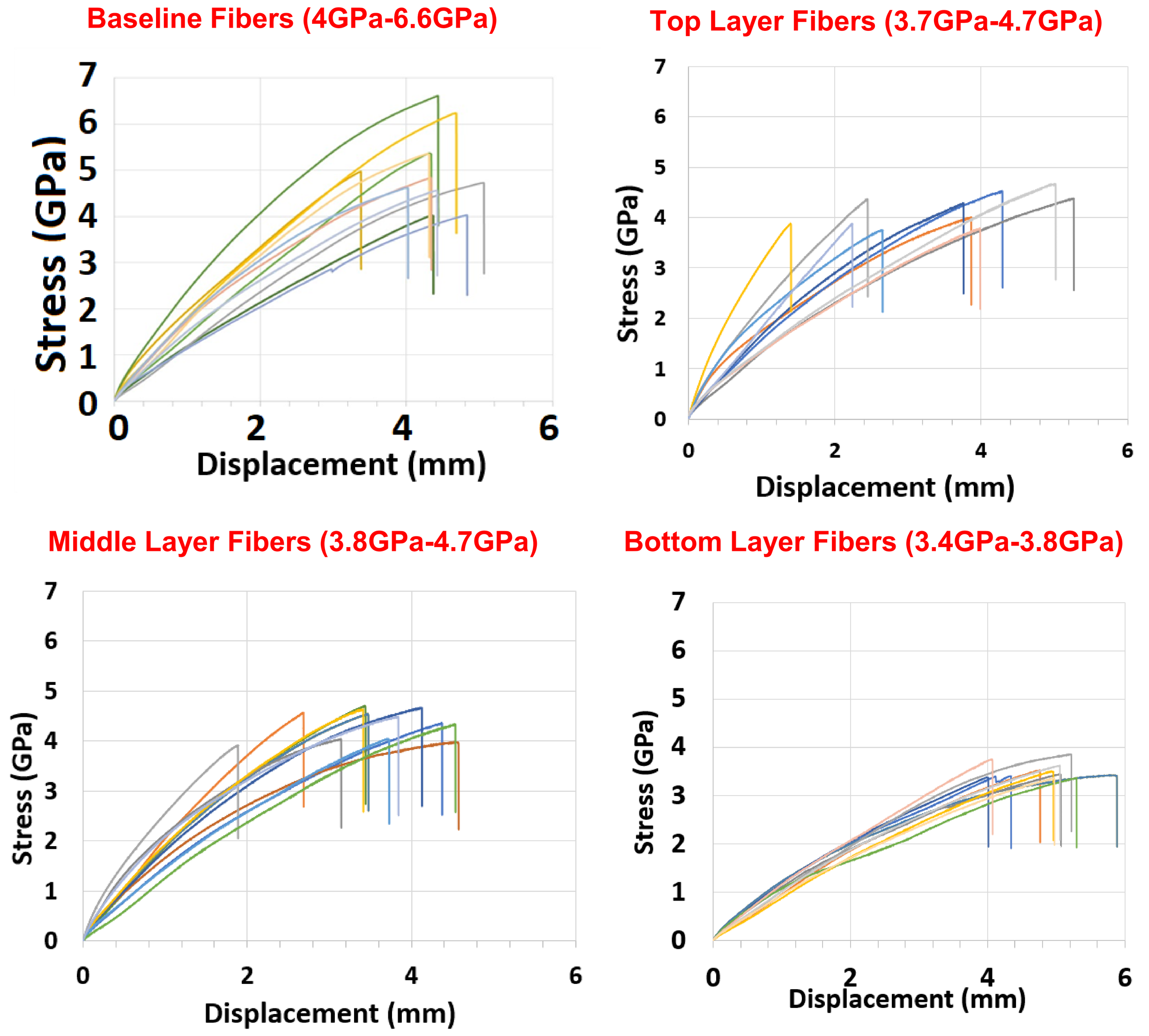
Mean Diameter (μm)

Fiber	
Dyneema HB 210-Baseline	11.61±1.39
Top layer	10.84±1.42
Middle layer	11.53±1.40
Bottom layer	11.79±1.45

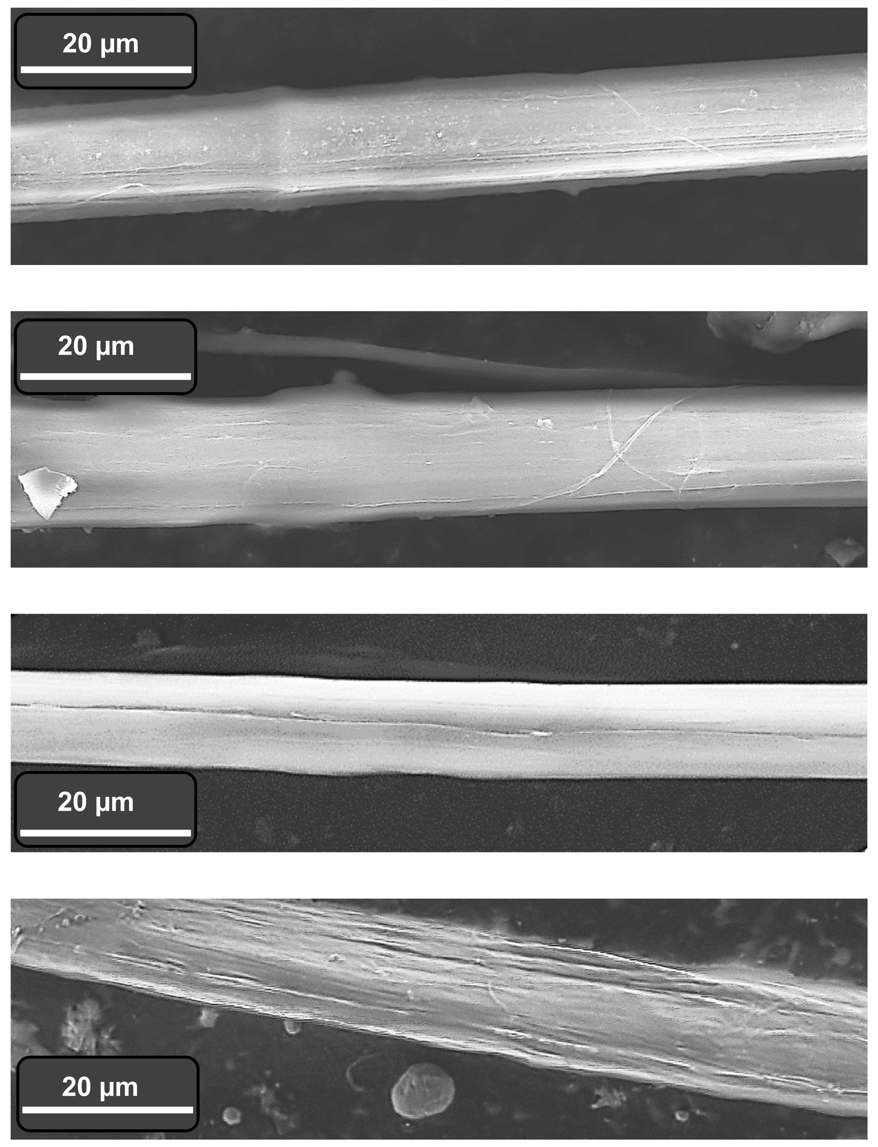
- Fibers from top layer tend to have lower mean diameters than fibers from middle and bottom layer.

Mechanical Testing Results and Discussion

Repetitive stress-strain curves for fibers from each layer

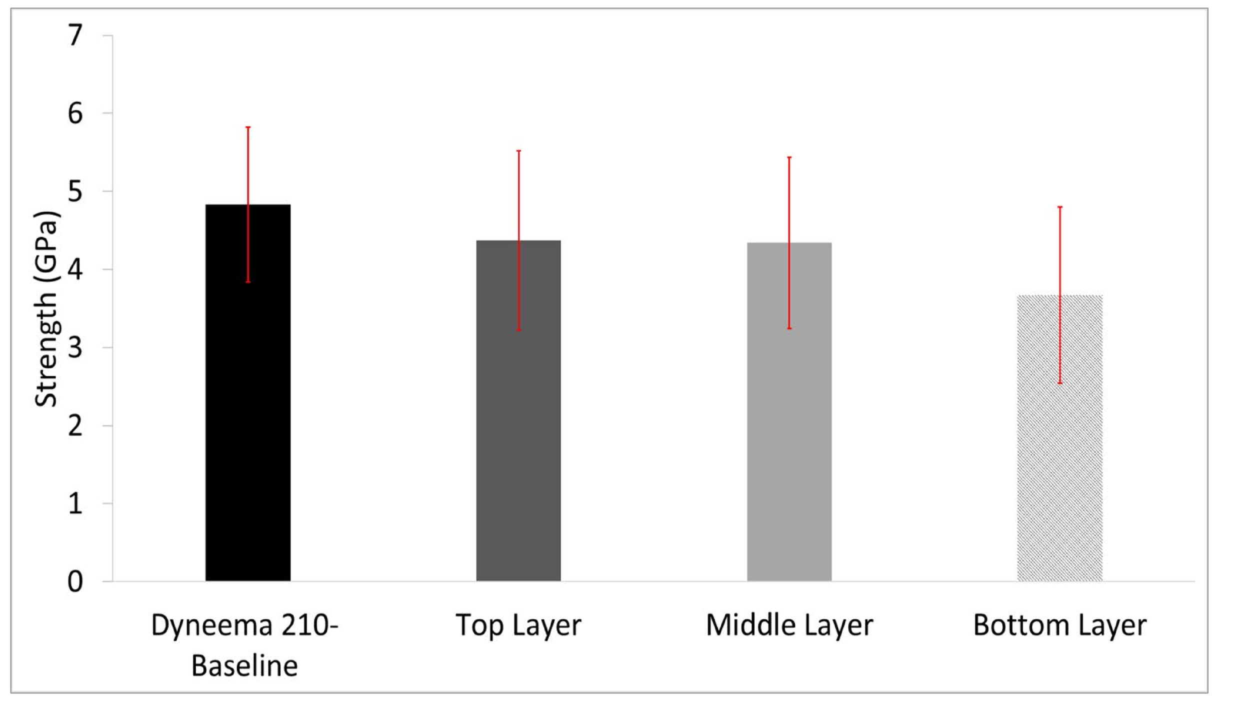


Representative SEM Images for Fibers



- Surface of fiber from bottom layer exhibits splitting.

Averages Strength of Extracted Fibers



- The bottom layer fibers exhibit a noticeably reduction in tensile strength compared to the top and middle layers.
- The strength reduction is due to temperature and pressure experienced by the fiber during processing.
- Temperature/pressure gradient can be developed through thickness resulting in variation in strength of fibers.

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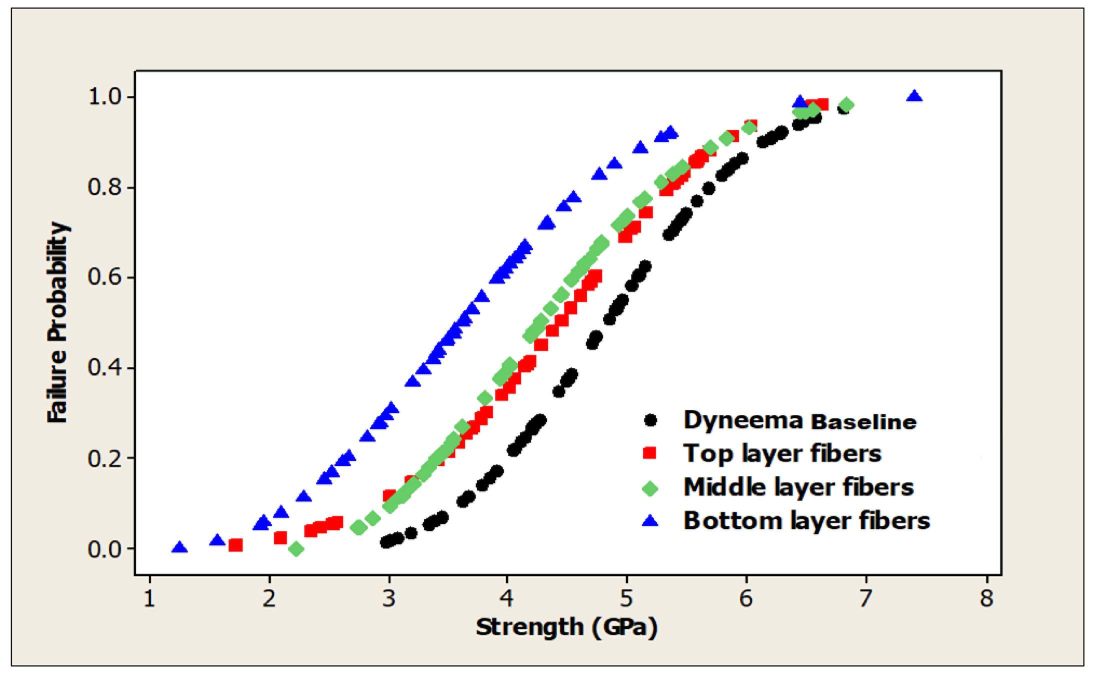
Failure Probability Distributions



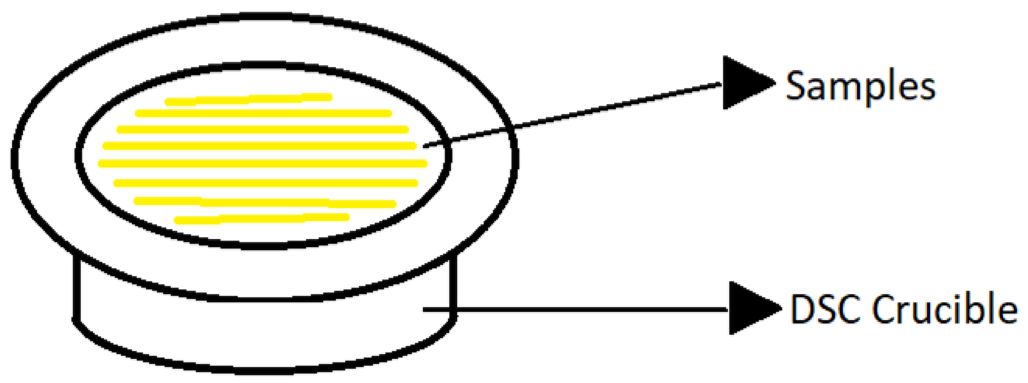
- Fibers from processed panel show clear shifts to lower strength levels.
- Shift to lower strength level from bottom layer fibers is larger than that for fibers from the top and middle layers
- Results confirm that the processing impacted the mechanical properties of the fibers through thickness of the processed panel
- Strength degradation was quantified based on strength values at 50% probability.

Fiber	Strength (GPa) at 50% probability	Reduction in strength
Dyneema Baseline	4.81	
Top Layer	4.42	8%
Middle Layer	4.27	11%
Bottom Layer	3.56	26%

- Strength degradation is the lowest for top layer fibers and the highest for bottom layer fibers
- Results confirm that the processing parameters applied impacted the mechanical properties of the fibers through thickness of the processed panel

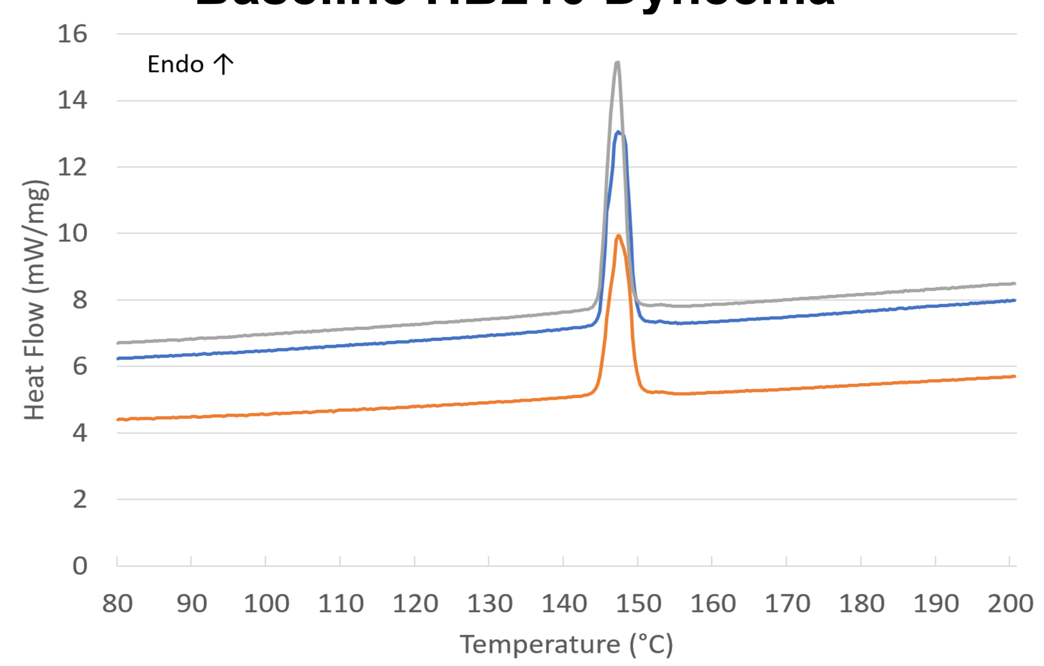
Differential Scanning Calorimetry (DSC)

- DSC measurements were performed on baseline and extracted fibers
  - 5℃/min scanning rate and a temperature range of -20 to 200℃ were applied.
- The fibers were cut and put into the DSC sample crucibles
- When heated, the PE fibers shrink and compress
  - All fibers in the DSC sample crucibles are laid in the same direction to prevent constriction

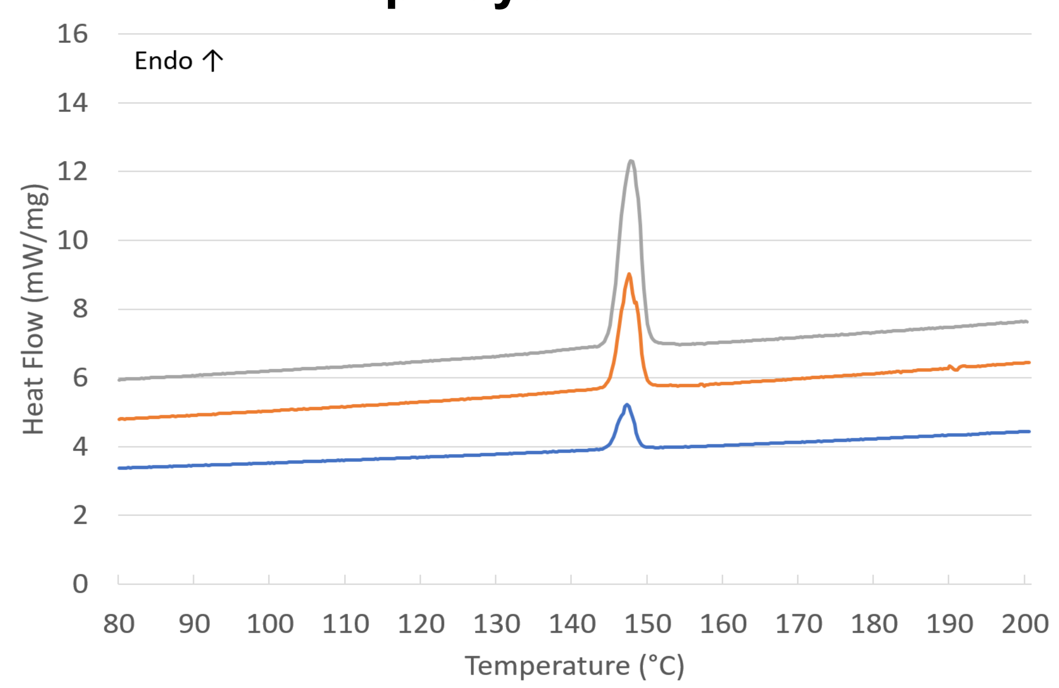


DSC Results and Discussion

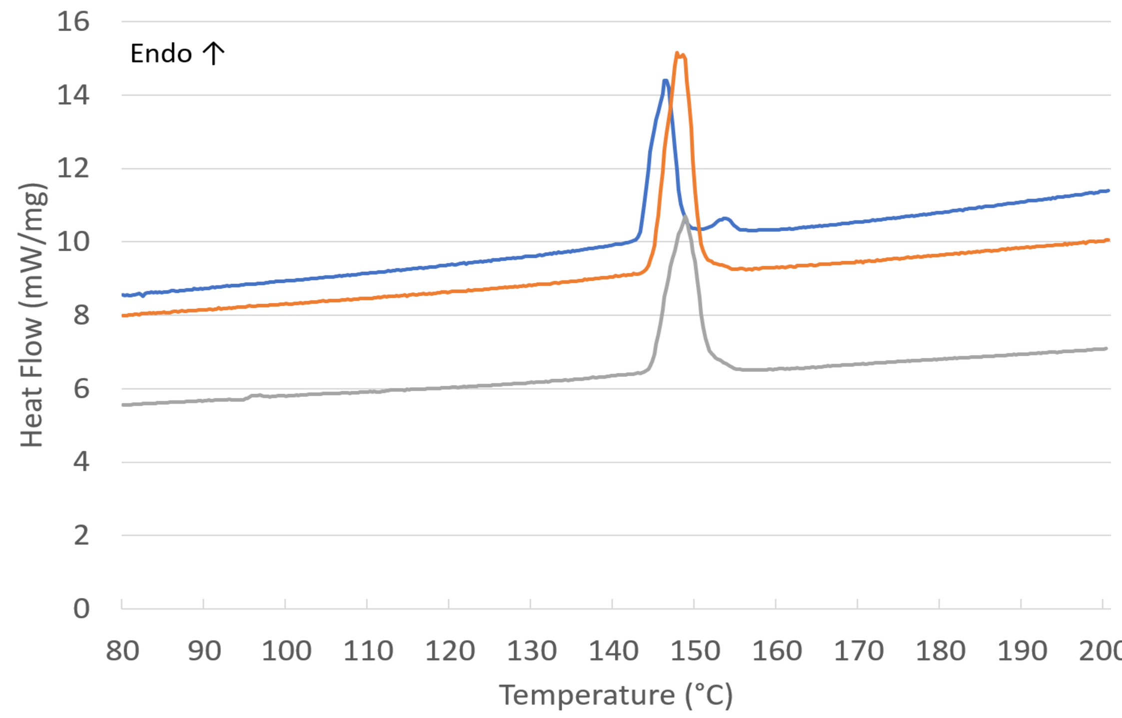
Baseline HB210 Dyneema



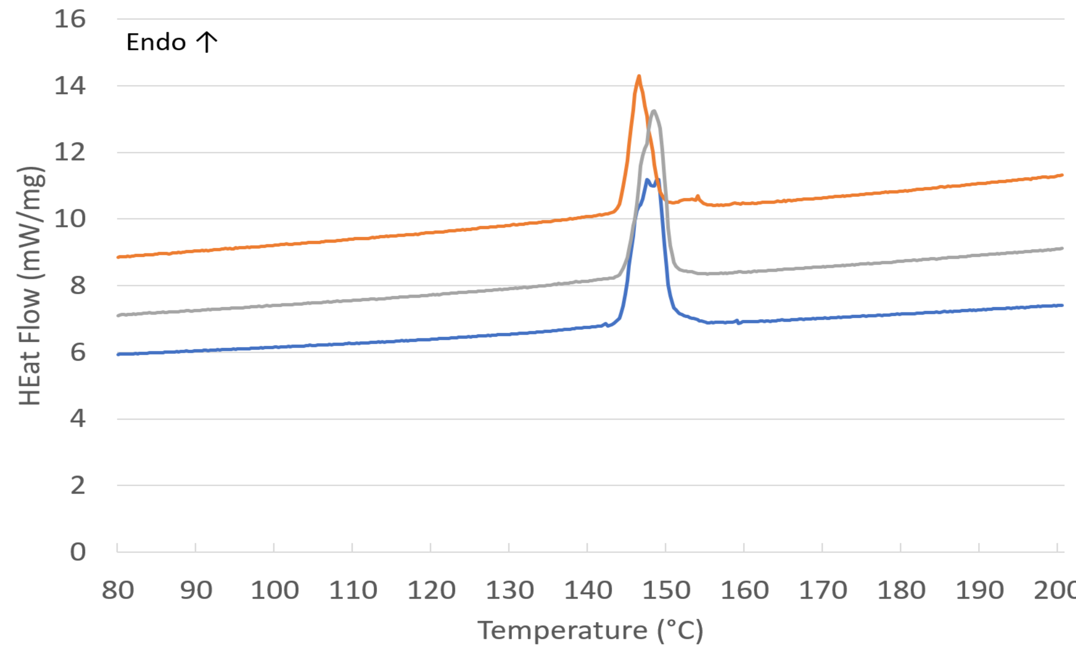
Top Layer Fibers



Middle Layer Fibers



Bottom layer Fibers



	Average Peak Temp (°C)	Average Start of Peak (°C)	Average Area of Peak (J/g)
Baseline Dyneema	146.7	143.5	224.1
Top	147.0	143.3	119.5
Middle	146.8	142.8	239.9
Bottom	147.5	142.9	202.8

- The start of all the peaks are 143 °C
- Average peak temperatures for baseline and fibers from top, bottom, and middle layer exhibit insignificant differences
- Bottom and Top layers exhibit lower energies required for melting (average area under the peak)
- Results reveal that temperature reduced the crystalline regions in fibers from top and bottom layers. Therefor, a reduction in strength of theses fibers were observed.

Conclusions and Future Work

Conclusions

- Temperature/pressure gradient developed through processing can induced variations in thermo-mechanical properties of fibers
- Fibers from bottom layer showed the highest strength degradation compared to other fibers
- Average melting temperature of the baseline and processed fibers are essentially identical
- Average initial melting temperature of all fibers are around 143°C indicating plausible melting in the fibers

Future Work

- Test crystallity of fibers
  - Determine if crystallinity deteriorated due to processing
- Grow and test single UHMWPE
  - Understand fiber properties on micro scale
- Test composite panels made with more precise procedure and notice any differences

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