Effects of Hygrothermal Conditioning /Weaving Parameters on Performance of KM2 Fibers

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INTRODUCTION

- 2D and 3D weaving process can degrade the performance of the fibers. Degradation in performance of fibers during weaving can be dominated by several factors, such as curvature (fiber bending), abrasion, tension and velocity level.
- Damages and defects in fibers due to weaving can accelerate the degradation of the mechanical performance of fibers, especially, when the fabric is exposed to heat / moisture environment.
- Objective: To identify the performance degradation mechanism of aramid fibers (Kevlar KM2 600) after hygrothermal conditioning, wrapping procedure, hygrothermal conditioning / wrapping procedure combined treatments, abrasion and hygrothermal conditioning /abrasion combined treatments

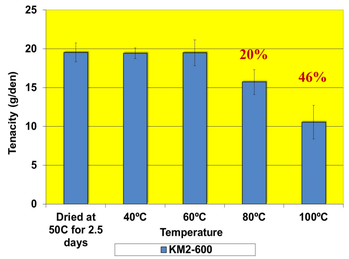
EXPERIMENTAL METHODS

- Specimen Preparation for Tensile Testing
  - Tows were cut in 15” long samples
  - Specimens were end-tabbed using cardboard and RT adhesive
- Tensile Testing
  - Applying ASTM standard D 2256-02
  - Testing was carried out for all specimens applying a crosshead speed of 12 in/min and gage length of 10 inch
  - 100 lb load-cell was used
  - Tests were conducted on control samples , after abrasion, hygrothermal treatments and wrapping procedures
  - Tenacity (g/den) and elastic modulus (in strain range of 0.05%-0.1%) were quantified

HYGROTHERMAL CONDITIONING

- Specimen Preparation
  - Control tows were dried under vacuum at 50C for 2.5 days (baseline samples)
  - Then, samples were treated in water for 30 days at 40C, 60C, 80C and 100C
  - Samples were then again dried under vacuum at 50C for 2.5 days
  - Samples were then tested in tension

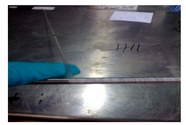
TENACITY FOR CONDITIONED FIBERS IN WATER



- **Little or no tenacity degradation is observed for temperatures below 80°C. Tenacity degradation is significant at 100°C**
- **Diffusion of water into and then removal of water from the crystalline regions results in disruption of the crystal structure and formation of micro-cracks, causing the tensile tenacity to degrade.**

WRAPPING PROCEDURE EFFECTS

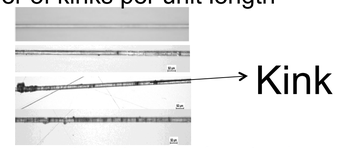
- Specimen Preparation
  - Fiber tows were wrapped around steel rods having different diameters ranging from 0.5 mm to 10 mm
  - Samples were then tested in tension and tenacity degradation was measured



- **Wrapping procedure around steel rods**

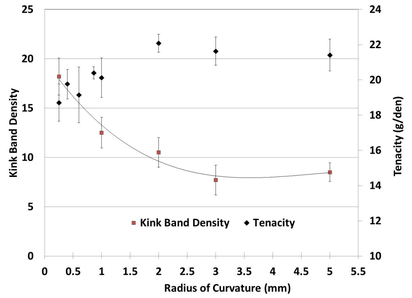
WRAPPING PROCEDURE EFFECTS

- Kink band density measurements
  - Monofilaments of KM2 fibers were around steel rods having different diameters ranging from 0.5 mm to 10 mm. Then kink bands were imaged using a light microscope.
  - Kink band density was defined as number of kinks per unit length



- **Evolution of kink bands formation as the radius of curvature decrease (top to bottom)**

KINK BAND DENSITY AND TENACITY AFTER WRAPPING PROCEDURE



- **A decrease in the radius of curvature causes the kink bands density to increase and consequently the tenacity decreases**

Effects of Hygrothermal Conditioning /Weaving Parameters on Performance of KM2 Fibers

Continued

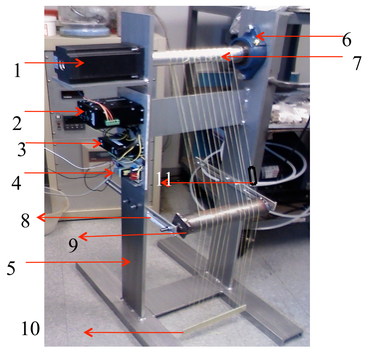
ABRASION EFFECTS: TEST MACHINE

- Abrasion test machine was specially developed at CCM to conduct abrasion test on synthetic fibers at different parameters: tension, velocity and contact angles.

Capabilities:

- Initial acceleration, speed and number of cycles can be controlled
- Real time load can be captured

Abrasion Test Machine



1: Stepper Motor, 2: MLA1064 Driver,3: Controller, 4: DC Power Supply, 5: Frame, 6: Ball Bearing Support, 7: Motor Spindle, 8: Abrasion Bar Rail, 9: Abrasion Bar,10: Weight (variable) and 11: load cell location

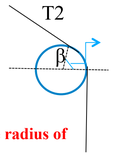
ABRASION TEST

- Specimen Preparation
  - Tows were carefully cut (each sample was 20" long) Then, samples were end-tabbed using cardboard and RT adhesive.
  - Sample was aligned and gripped in the fixtures
- Test Parameters
  - Abrasion cycles range from 1 to 50cycles (One cycle corresponds to 10 inches of fiber that experience abrasion.
  - Tension level was 8% of the tenacity and 24 in/min was the speed. Contact angels were (ß= 6.9º, 11.6º,17.5º)

The total contact length (L) is defined as::

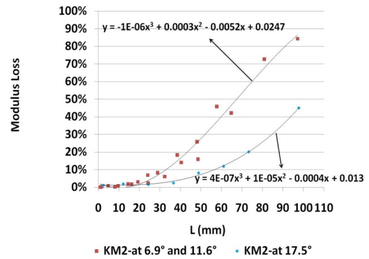
$$L = N^* r\pi^* \beta / 180$$

N is the number of cycles, β is the contact angle, r is the radius of the roller

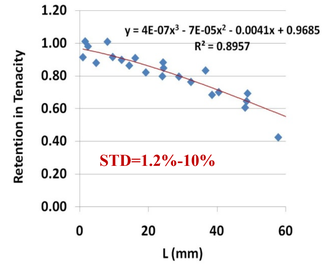


ABRASION TEST RESULTS

Modulus Loss



Retention in Tenacity



- **With increased contact length (L), the degradation in modulus and in tenacity exhibit increasing trends**
- **Majors sources for tenacity and modulus degradation can be fiber breakages and micro-structures damages**

TENACITY DEGRADATION MECHANISM

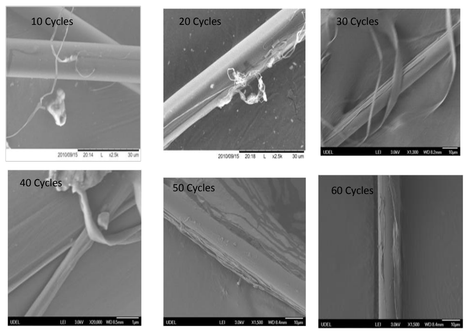
- Calculated losses at frictional contact length of L=25 mm

Fiber	Tenacity Degradation	Mass Loss	Micro-Structure Damages	Broken fibers
KM2-600	17%	~0.17%	~12.5%	~4.5%

- **Fiber breakage was quantified from modulus loss data**
- **Mass loss is negligible**
- **Micro-structure damages are the highest percentage**
- **Major factor for tenacity degradation during abrasion is the micro-structure damages**

SURFACE MORPHOLOGY OF FIBERS

KM2 Fiber Surfaces After Abrasion Test at β=17.5°



- **Degree of damages in fibril structure increases as the number of cycles increase**

CONCLUSIONS

1) Fibers conditioned in water for 30 days did not show significant changes in tenacity till 80C
2) Reduction in tenacity due to wrapping procedure at 1 mm radius of curvature and below is mainly due to the increase in the kink bands density.
3) Abrasion resistance for KM2 was investigated. Master curves of tenacity-contact length was established.
4) Major factor for degradation in tenacity is micro-structure damages occurred during abrasion

WORK IN PROGRESS

- Evaluation of mechanical performance of fibers after
  - Hygrothermal conditioning / wrapping procedure combined treatments
  - Hygrothermal conditioning / abrasion combined treatments

ACKNOWLEDGEMENTS

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