MOISTURE UPTAKE IN HIGH PERFORMANCE FIBERS

A. Sheldrake (Intern), J. Deitzel (Advisor)

University of Delaware . Center for Composite Materials . Department of Materials Characterization and Development

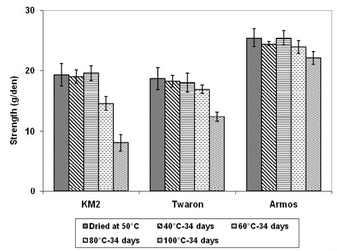
INTRODUCTION

- **Objective**: Develop a method to determine the amount of water absorbed by high performance fibers during conditioning experiments for fibers submersed in water
- High performance aramid fibers are an important component of many civilian and military applications but their degradation is not well understood
- The amount of water absorbed is an indication of the degradation of strength

BACKGROUND

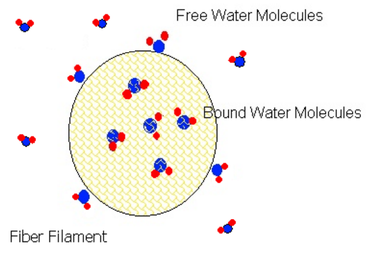
- As thermodynamically metastable materials, these fibers can be very sensitive to changes in surrounding environmental conditions
- With hygrothermal conditioning at temperatures above 80° for 34 days, the tensile properties of fibers degrade from 13-58% as compared to dried as-received fibers, depending on the type

Strength at failure (gf/den) decreases from 20 to 15 from Kevlar stored at 40° C to 100° C



CHALLENGES

- Water bound to the surface of the fiber will not affect fiber strength like moisture that has diffused into the fiber interior
- It is difficult to differentiate free water on the surface from bound water with a traditional balance

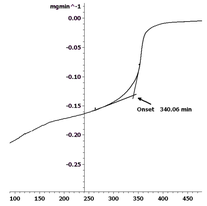


- A TGA/DSC1 provides a method to carry out precise measurements of both mass loss and heat flow as a function of time and temperature
- For a given temperature and exposed surface area, free water is expected to evaporate at a constant rate, while bound water is expected to evaporate at a slower, non-linear rate as it must diffuse out of the fiber before it can evaporate

APPROACH

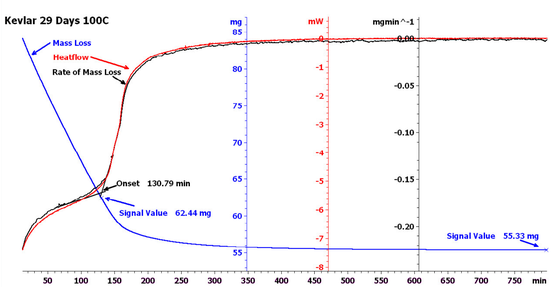
- Kevlar and Armos fibers were dried in vacuum at 50° C for 3 days
- 30 in. samples of Kevlar and 18 in. samples of Armos were wrapped around Teflon frames and placed in water maintained at 100°C for 29 days
- Samples were prepared for the TGA/DSC1 by forming as large a fiber bundle as possible for insertion in the 100 µl aluminum crucible to be closed with an aluminum mesh lid
- The TGA/DSC1 was used to measure the heat flow and rate of mass loss during evaporation over 24 hours
- The time at the onset of the derivative of the mass loss was used as the time for inflection point of the mass loss curve
- Difference between the final mass and the mass at the inflection point = amount of bound water
- Amount of Bound Water/Mass of the Fiber * 100 = % Bound Water

Onset of the derivative of the mass loss curve



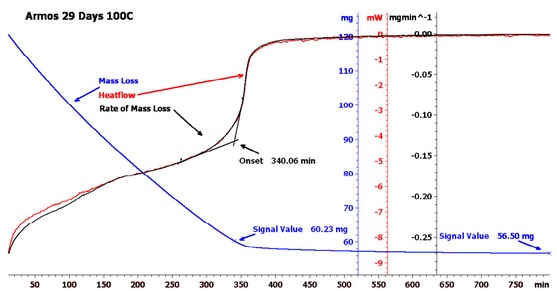
KEVLAR RESULTS

- 12.9% Bound Water



ARMOS RESULTS

- 6.60% Bound Water

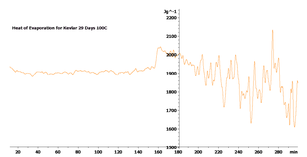


CONCLUSIONS

- It is conceivable that the differing chemical structure and microstructure of Kevlar and Armos account for the different amounts of water uptake
  - Kevlar has a larger concentration of hydrophilic amide groups than the copolymer Armos
  - Armos has a liquid crystalline microstructure that is more damage resistant
- The TGA/DSC1 has so far provided a reliable and precise method of monitoring mass loss in high performance fibers at a constant temperature but further refinement is needed
  - Analysis of the heat flow curve
  - A baseline should be established for as-received and dried fibers
- Smearing of the slope change of the mass loss curve makes it difficult to determine the boundary between free and bound water
  - Heat flow information can be used to further define the boundary

FUTURE WORK

- The heat of evaporation of water can be calculated by dividing the heat flow by the mass loss derivative (mW/(mg/sec) = J/g); bound water should have a higher heat of evaporation



The heat of evaporation of Kevlar stored in water at 100°C for 29 days

- Comparisons for fibers conditioned at different temperatures for different periods of time

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