EVALUATION OF THE INTERFACIAL SHEAR STRENGTH AND ENERGY ABSORPTION OF POLYMER-CONTAINING POLYSILOXANE SIZINGS FOR E-GLASS FIBERS

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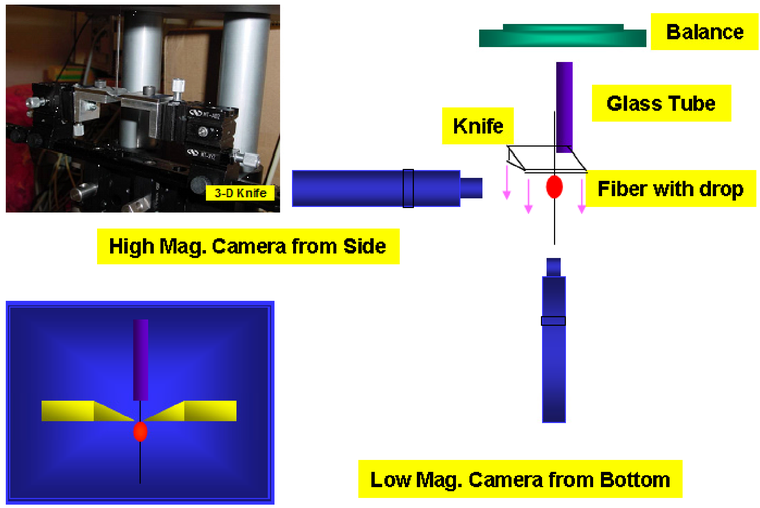
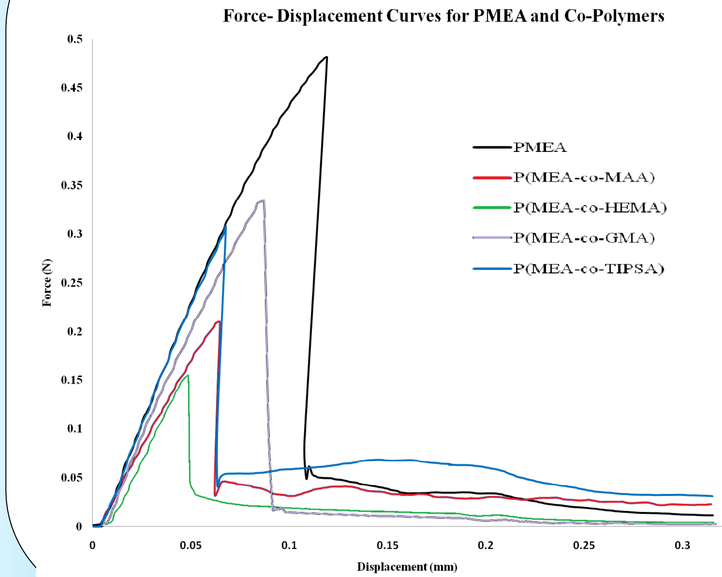
MOTIVATIONS AND OBJECTIVES

- **Motivation**: Increase the energy absorption of the composite material while maintaining strength through use of tailored chemical bonding between the fiber surface and matrix.
- **Objective**: Evaluate the effect of different polymer-containing polysiloxane sizings on the energy absorption and strength of an E-glass/epoxy composite.
  - E-glass fibers were sized with polysiloxane siznges synthesized using five different polymers from Arkema, Inc.
  - The interfacial strength and energy absorption in sized E-glass fibers/epoxy resin composites were evaluated using microdroplet test techniques.
  - The sizings were further evaluated on a macroscale using the punch shear test techniques.

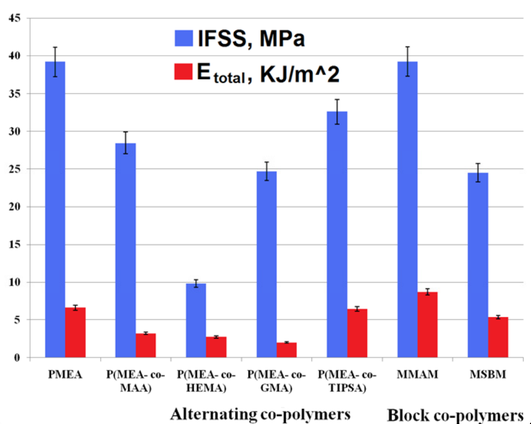
MICRODROPLET TESETS



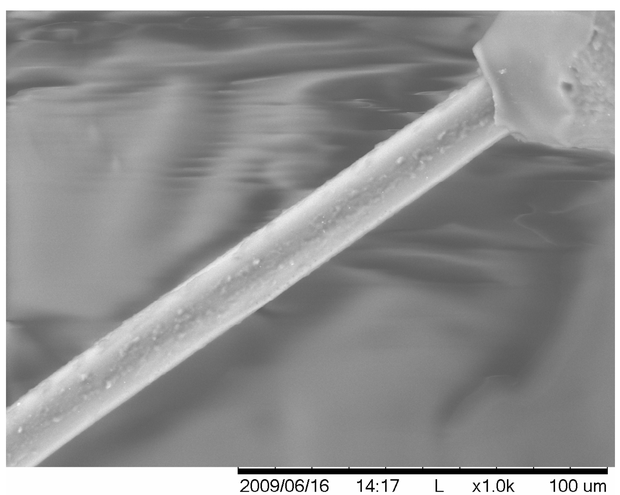
FORCE-DISPLACEMENT CURVES



MICRODROPLET TEST RESULTS

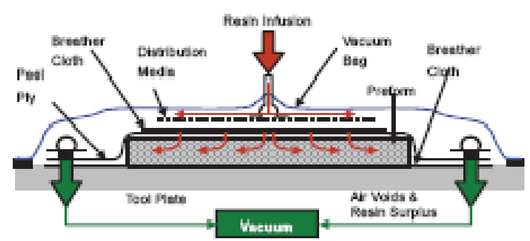


FAILURES MODES BY SEM



Representative SEM image of mircodroplet after debonding. Mixed adhesive/cohesive interface failure mode was observed for all samples

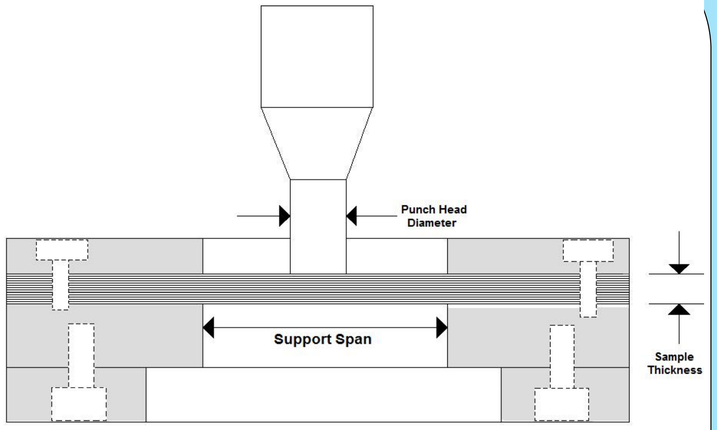
VARTM INFUSION OF A COMPOSITE PANEL



VARTM was used to create a composite panel of E-glass fibers sized with PMEA and the CCMFCS2 Epoxy resin.

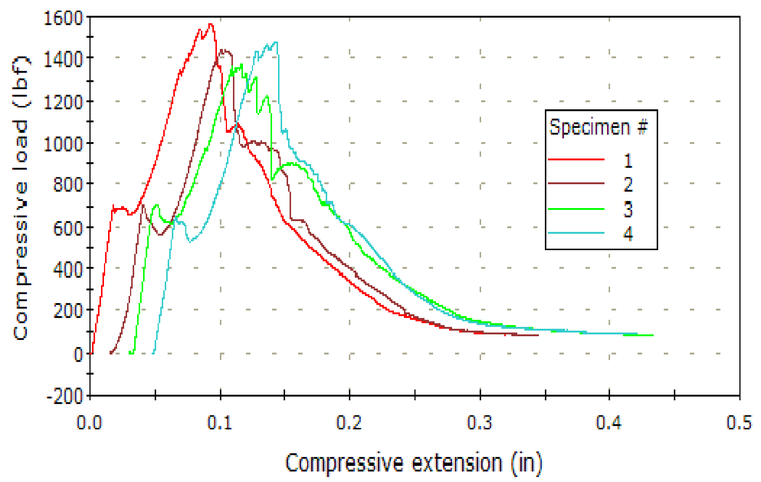
EVALUATION OF THE INTERFACIAL SHEAR STRENGTH AND ENERGY ABSORPTION OF POLYMER-CONTAINING POLYSILOXANE SIZINGS FOR E-GLASS FIBERS (Continued)

PUNCH SHEAR TEST



Four samples were tested using a punch head diameter of 0.3 inches, a span-to-punch ratio of 2 and a crosshead speed of 0.05 inches per minute. Two additional samples were tested using a 1 inch diameter punch head and the same span-to-punch ratio and cross head speed.

PUNCH SHEAR TEST RESULTS



PUNCH SHEAR TEST RESULTS CONT.

Sizing for E-glass/epoxy panel	Normal Strength (MPa)
PMEA/TES/GPS/SiO_2 nanoparticles 1:1:1:1 wt%	109.75±0.35
MMAM/TES/GPS/SiO_2 nanoparticles 1:1:1:1 wt%	70.38±2.14
MSBM/TES/GPS/SiO_2 nanoparticles 1:1:1:1 wt%	56.76±2.16
Unsized E-glass fiber	40.37±1.56

ABBREVIATIONS USED

TES – tetraethoxysilane
GPS – 3-glycidoxypropyl trimethoxysilane
PMEA - polymethoxyethylacrylate
P(MEA-co-MAA) - random co-polymer with methacrylic acid
P(MEA-co-HEMA) - random co-polymer with hydroxyethylmethacrylate
P(MEA-co-GMA) random co-polymer with glycidyl methacrylate
P(MEA-co-TIPSA) random co-polymer with triisopropyl silyl acrylate
MMAM – ethanonlamine-modified modified poly(methylmethacrylate-butylacrylate-methylmethacrylate) block co-polymer
MSBM – ethanonlamine-modified modified poly(styrene-butadiene-methylmethacrylate) block co-polymer

VOID AND FIBER CONTENT

$$\phi_{void} = 100 - D_C\left(\frac{X_m}{D_m} + \frac{X_f}{D_f}\right)$$

$$\phi_{fiber} = 100 - D_C\left(\frac{X_m}{D_m}\right) - \phi_{void} = D_C \times \frac{X_f}{D_f}$$

$$\text{where: } X_f = \text{fiber mass \%} = 100 * \frac{\text{fiber mass}}{\text{sample mass}}$$

$$X_m = \text{matrix mass \%} = 100 - X_f$$

$$D_C = \text{specific gravity(T)} * \text{water density(T)}$$

$$\text{specific gravity(T)} = \frac{\text{mass of sample in air}}{\text{mass of sample in air - mass of sample in water}}$$

D_f = fiber density

D_m = matrix density

Fiber Volume Fraction = ϕ_{fiber} = 52.06%

Void Content = ϕ_{void} = 6.79%

CONCLUSIONS

- Random co-polymers do not show any improvement in strength or energy absorption over block co-polymers.
- The PMEA homopolymer demonstrates nearly equal energy absorption and interfacial shear strength as the MMAM block co-polymer, yet the other random co-polymers were inferior to the MMAM polymer as components of polysiloxane sizings in E-glass/epoxy composites.

FUTURE WORK

- Analyze the composition of the sizing on glass surface using NMR to understand why the random co-polymers are not as effective sizing components as block co-polymers.
- Perform Atomic Force Microscopy on glass surface to see how the sizing aggregates.

ACKNOWLEDGEMENTS

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