SURFACE MODIFICATION FOR IMPROVING COMPOSITE IMPACT PERFORMANCE

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OBJECTIVES

Increase the energy absorption by texturizing the fiber surface for better mechanical interlocking

1. Tailor the interphase adhesion by varying the functional group on the fiber sizing
2. Develop various textures on the fiber surface to improve mechanical interlocking between fiber and matrix
3. Characterize the influence of texture on the energy absorption and optimize it
4. Identify the failure location and the mechanism of failure

ACKNOWLEDGEMENTS

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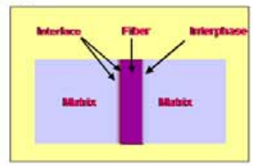
BACKGROUND

Interphase: the region that forms in the vicinity of the fiber surface and possesses distinct properties compared to those of the bulk resin.



Interphase Formation → Preferential adsorption of curing agent onto fiber coating(silane networks)

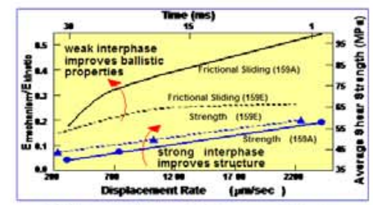
Tailoring Interphase → Strength, Durability, Impact Resistance

PREVIOUS WORK

Strength ⟷ Adhesion ⟷ $(R\text{-})_n\text{-Si-}(O\text{-}R')_{4-n}$

Energy Absorption Mechanisms:

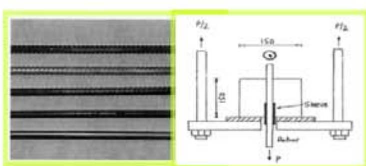
- Fiber-matrix debonding
- Fictional Sliding

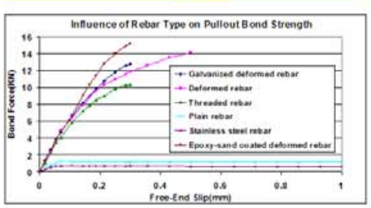


159A - unsized   159E – compatible size

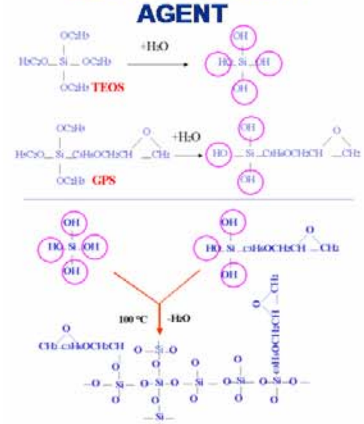
* M. Tanoglu, S. H. McKnight, G. R. Palmese and J. W. Gillespie Jr., "Composites Science and Technology", V. 61(2), 2001, Pages 205-220

REBAR ANALOGY - BENEFITS OF TEXTURING



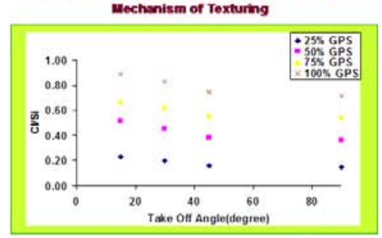


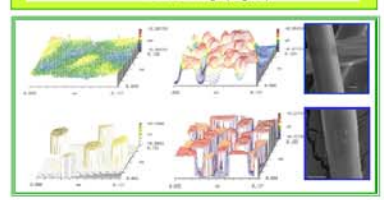
SILANE COUPLING AGENT



SURFACE MODIFICATION

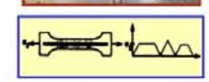
Mechanism of Texturing





EXPERIMENTAL TECHNIQUES



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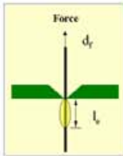
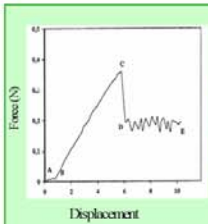
MICRODROPLET TEST

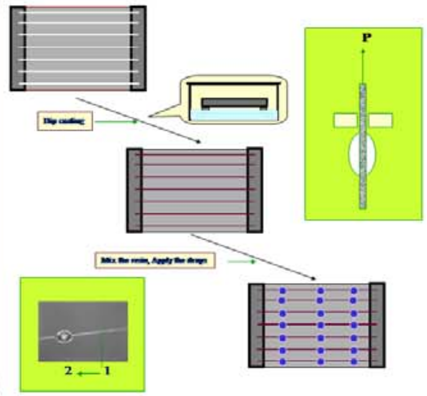




$$\tau = \frac{F}{\pi d_f l_e}$$

$$E_{s\text{-}frictional} = \frac{\int_{\delta_0}^{\delta} F d\delta}{\pi d l_e}$$

MICRODROPLET SAMPLE PREPARATION



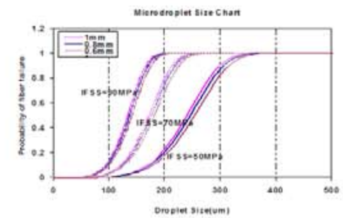
MICRODROPLET SIZE CALCULATION

The major problem: Fiber breakage before droplet sliding

$$\sigma_{IFSS} \times \pi \times d_f \times l_e < \sigma_{fiber} \times \frac{1}{4} \times \pi \times d_f^2$$

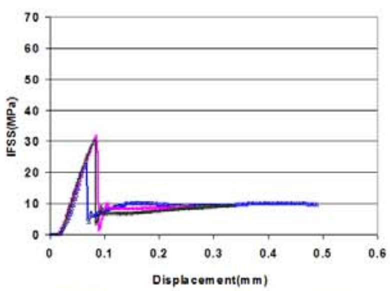
$$l_e < \frac{1}{4} \times d_f \times \frac{\sigma_{fiber}}{\sigma_{IFSS}}$$

$$P(\sigma_{fiber}) = 1 - \exp\{-(\frac{l_f}{l_0})^{0.58}(\frac{\sigma_{fiber}}{3030})^{5.43} \quad \cdots\cdots\cdots\cdots (1)$$



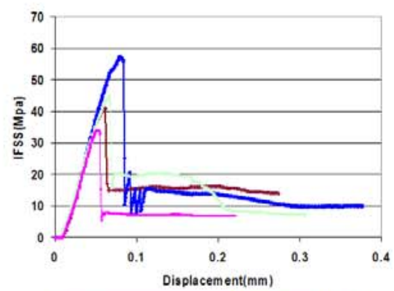
[1] J. Andersons; R. Joffe; etc. "Glass fiber strength distribution determined by common experimental methods", Composite Sci. and Tech. 62 (2002) 131-145

UNSIZED GLASS FIBER/DER 3353



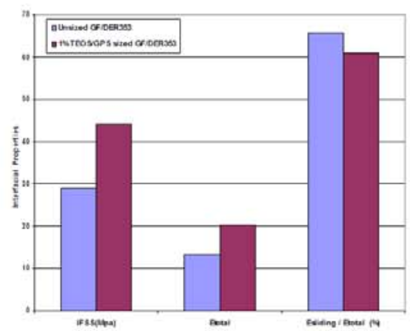
USGF	Average	Std.
Drop Size(um)	238	26.6
Fiber free length(mm)	0.97	0.09
IFSS(Mpa)	28.9	3.8

SIZED GLASS FIBER/DER 353



G Series	Average	Std.
Drop Size(um)	149	27.3
Fiber free length(mm)	0.7	0.05
IFSS(Mpa)	44	9.5

COMPARISON BETWEEN SIZE AND UNSIZED SYSTEMS



CONCLUSIONS

- The XPS spectrum proves phase separation existing between GPS and TEOS, which disclose the mechanism of texture formation and provide the information of the functional group distribution inside the coating.
- Various textures have been created using these novel silane blends on the model surface with the roughness value ranging from several nanometer to hundreds nanometer.
- The novel sizing system improves the IFSS by 52%, and the total energy absorption was increased by 53%. Sliding is proved to be the major mechanism for energy absorption, which absorbs more than 60% of the total energy during impact.
- This research has established a new method for improving the composite impact properties and will continue to optimize texture and tailor adhesion for better properties.

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