Tension-tension Fatigue Behavior of Nanosilica Modified Epoxy/Glass Nanocomposites for Wind Turbine Blades

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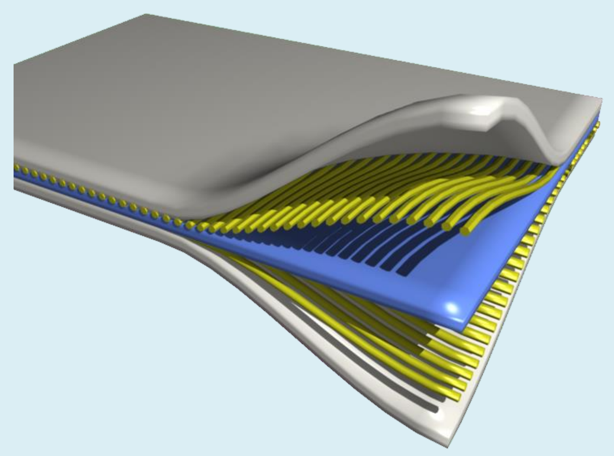
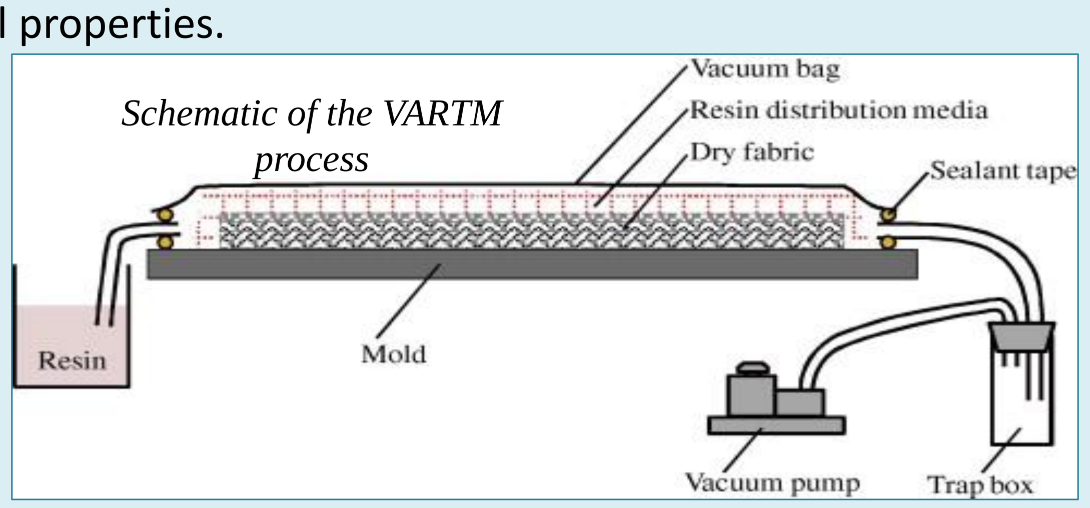
Abstract

A comprehensive study of tension-tension fatigue performance of nanosilica modified epoxy/glass composites. Three different concentrations of nanosilica (6, 7, and 8 wt%) were tested in static tests and compared with control (0 wt% nanosilica). 6wt% nanosilica composites showed the greatest improvement in tensile strength, percentage elongation, and inter-laminar shear strength (ILSS). Extensive tension-tension fatigue tests (R-ratio of 0.1 and frequency 2 Hz) were conducted on control and 6wt% nanosilica composites. The stress applied was from 80% of UTS, and reduced in steps of 10% until specimens survived 1 million cycles. 6 wt% nanosilica composites showed 10 and 3 times improvement in fatigue life in high-cycle and low-cycle fatigue, respectively, when compared to control composites.

Polymer Matrix Composites (PMC)

Polymer matrix composites, especially E-glass reinforced, dominate the wind turbine blade market because of their superior fatigue characteristics. Modified epoxies using nanosilica particles can help improve the fatigue performance and have shown 10-15 times improvement in fracture energy without knocking off desire able mechanical properties.





Materials System- Popular in Wind Turbine Blades: ±45^{0} E-glass non crimp and stitch bonded fabrics (Saeretex); and EPIKOTE MGS™ RIM 135 epoxy resin system. Predispersed Nanopox™ F400 (nanosilica) in epoxy.

Manufacturing: Four different E-glass reinforced nanosilica composite panels were manufactured by low cost vacuum assisted resin transfer molding process (VARTM) technique.

Control 0 wt% nano silica | 6 wt% nano silica | 7 wt% nano silica | 8 wt% nano silica

Results and Discussion

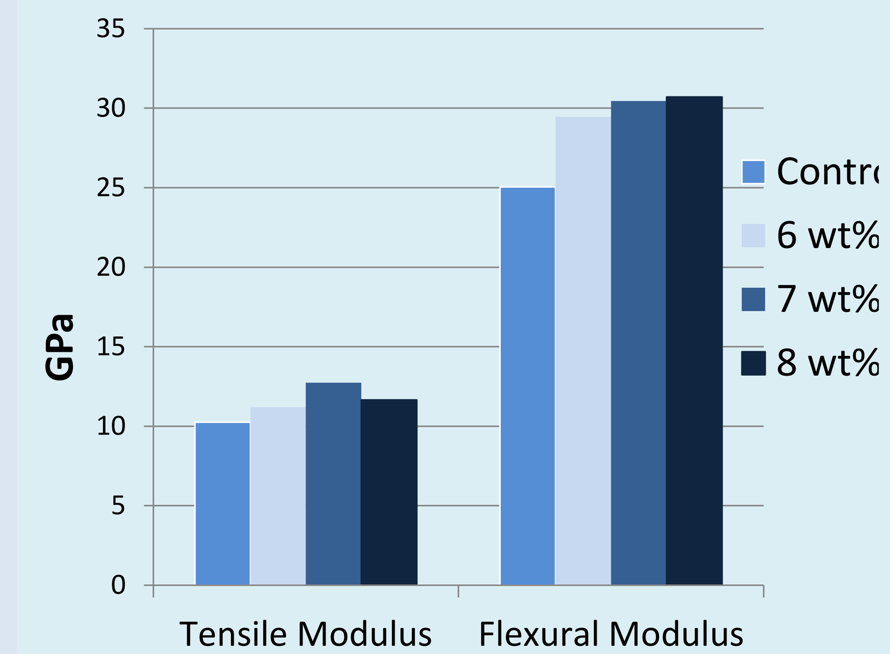


Figure. 1

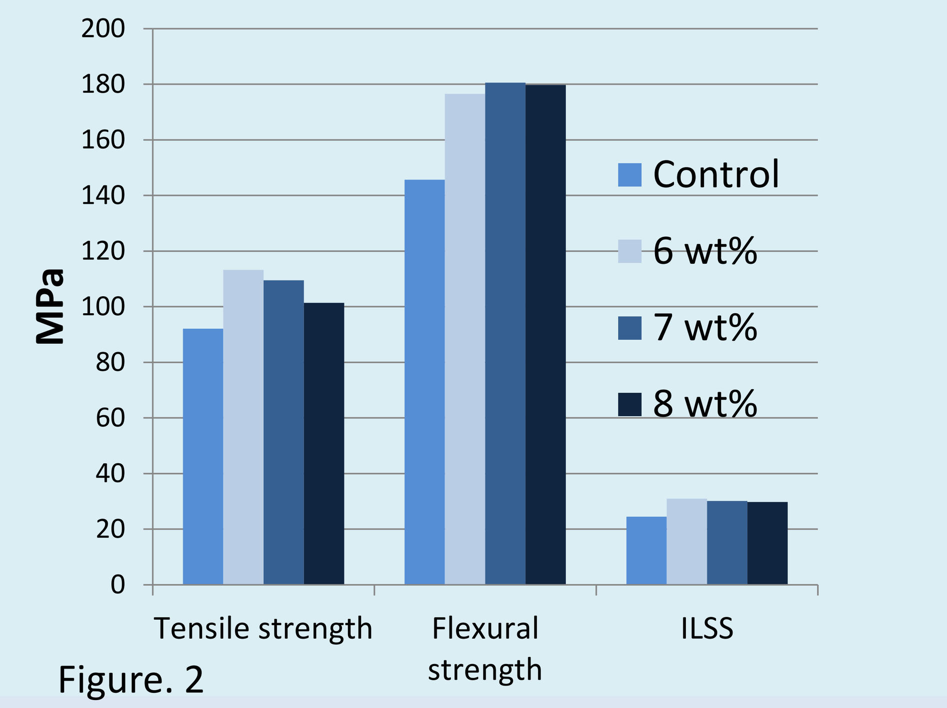


Figure. 2

Table 1. Number of cycles to failure (control)	
Maximum stress, MPA	2HZ
46.6	1000000*
55.9	17580
65.3	2041
74.5	549

Table 2. Number of cycles to failure (6 wt% nanosilica)	
Maximum stress, MPA	2HZ
46.6	1000000*
55.9	166675
65.3	6306
74.5	1396

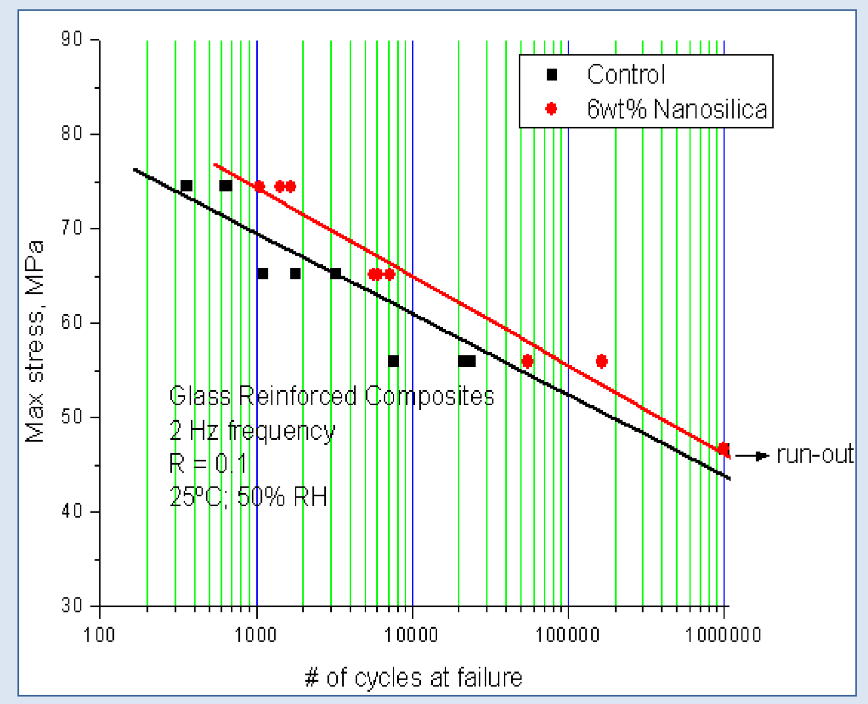


Figure 4. Stress versus number of cycles at failure (S-N) curves.

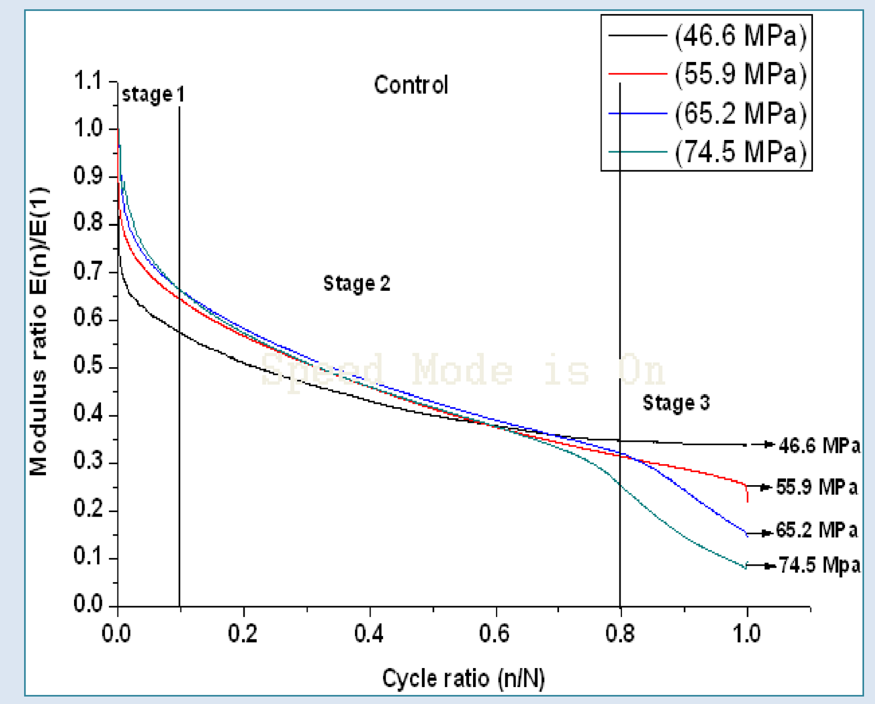


Figure 4. Stiffness degradation curve of control.

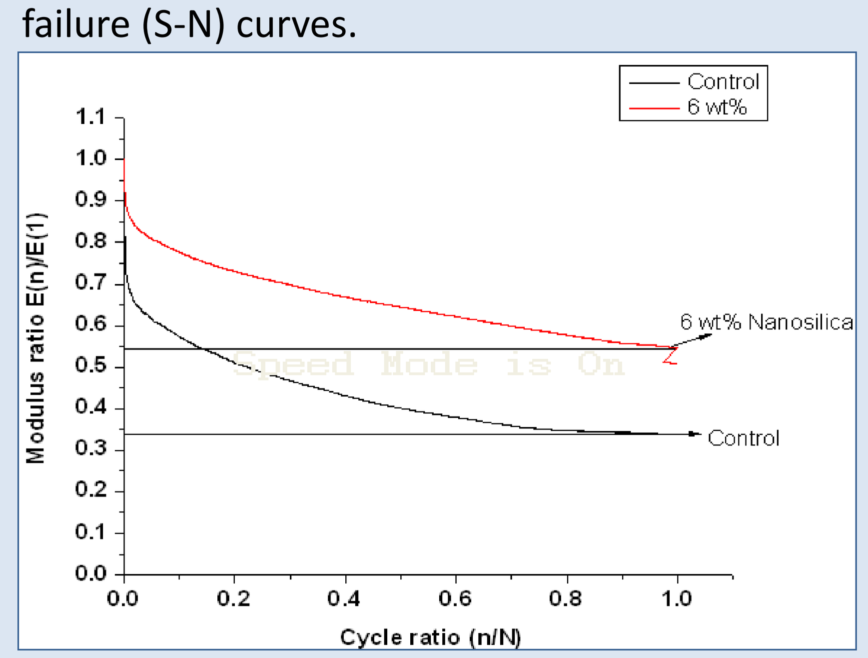


Figure 5. Superimposed stiffness degradation curves at maximum stress 46.6 MPa

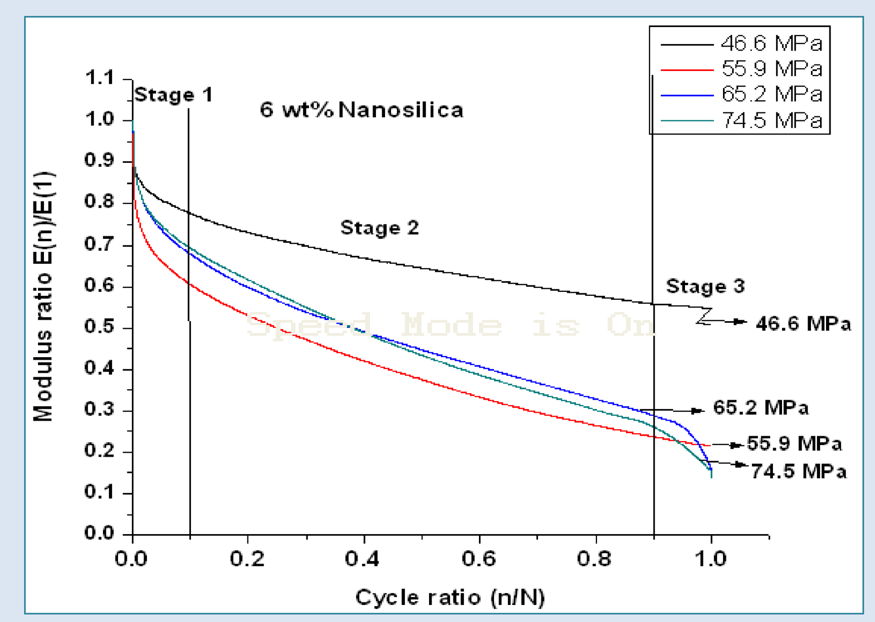


Figure 6. Stiffness degradation curve of 6 wt%.

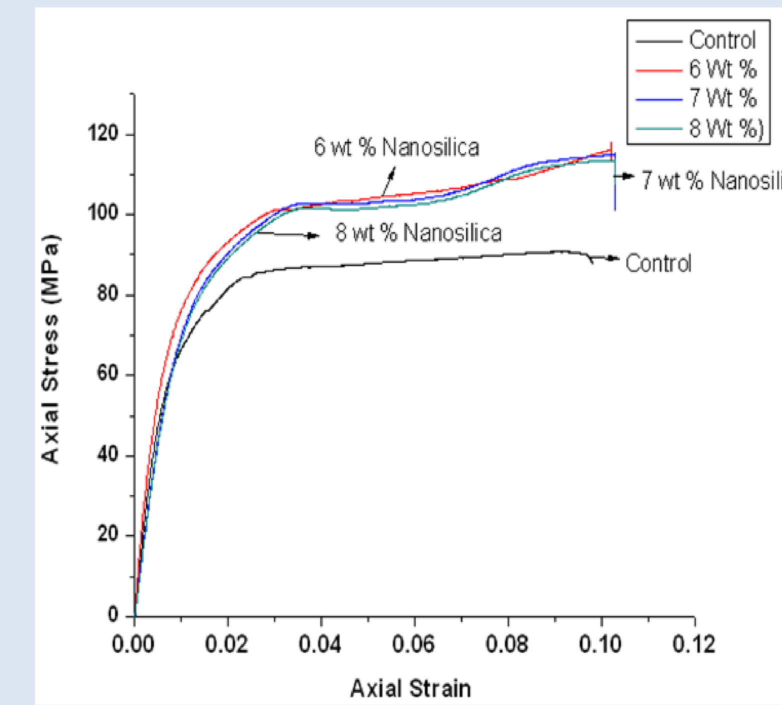


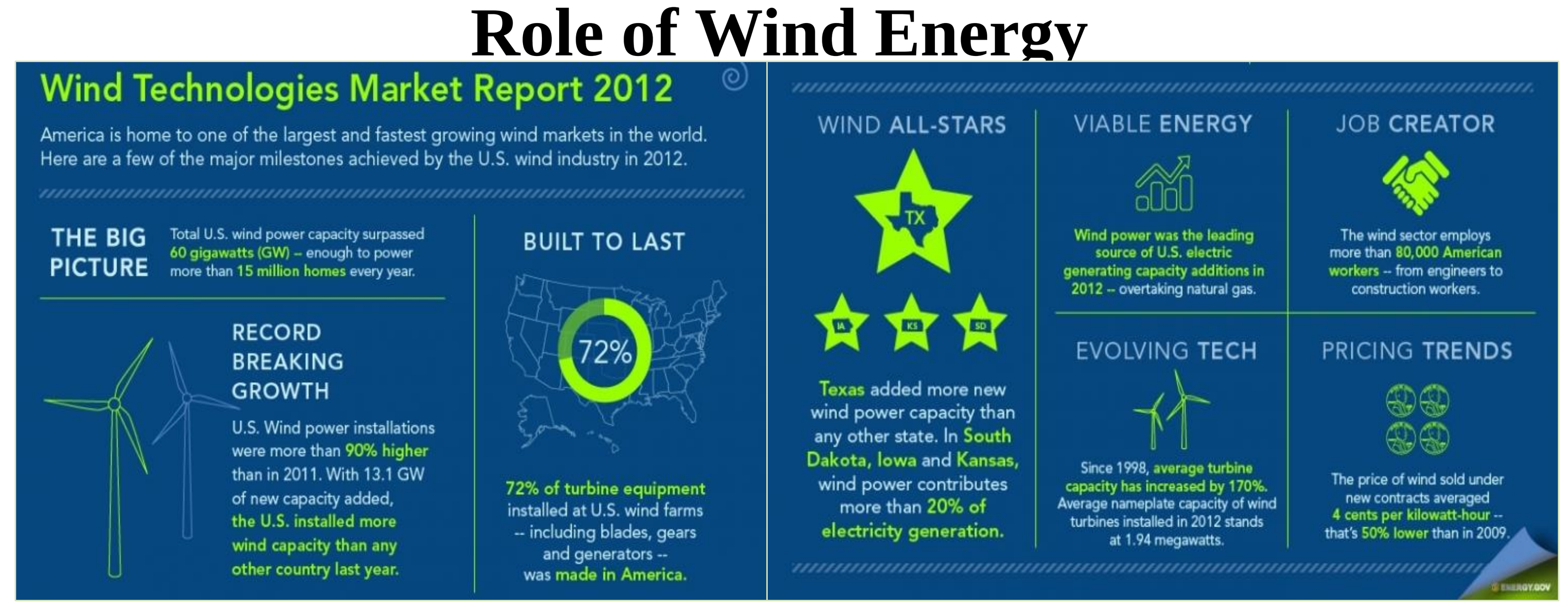
Figure 7. Tensile stress-strain curves for control and nanosilica modified composites.

- •6 wt% nanosilica comosites are toughest amongst all.
- •22% improvement in tensile strength for 6wt% nanosilica composites compared to control (110MPa vs 92 Mpa).
- •The addition of 6 wt% nanosilica resulted in a 3-time improvement in fatigure life at low cycle fatigue, when compared to the control specimen.
- •Stiffness degradation curves exhibit typical a three stage pattern.
- •Stage I: 10% fatigue life was lost for control and 6 wt % nanosilica concentrations.
- •Stage II: 60-70% fatigue life and 70% of modulus is lost for control. For 6 wt% nanosilica, this stage contributed to about 75% fatigue life and 45-70% modulus lost.
- •Stage III: Final failure occurs with the breakage of fibers at stage III.

Objective of Research

The major objective of this research is to develop a material system that has enhanced fatigue performance for wind turbine blades. This solution not only would reduce blade failures, but also would help build longer but lighter blades. Furthermore, this solution could be implemented for other applications, such as helicopter rotor blades, which have similar mechanical loading as wind turbine blades.

Role of Wind Energy



Installation of New wind turbines in 2008 exceeded 28,000 megawatts of rated capacity. Wind power has steadily increased by increasing blade length, some measuring from 37 meters to more than 60 meters and weigh more than 5,440kg each.

Conclusion

- •At 46.4 MPa stress level, control composites survived 1 million cycles at 2 Hz frequency as opposed to only 15820 cycles at 5 Hz frequency.
- • The addition of 6 wt% nanosilica modification show an improvement of 10 and 3 times in tensile fatigue, for high-cycle, and low-cycle fatigue, respectively, when compared to control (0 wt%) composites.
- •Both control and 6 wt% nanosilica composites survived 1 million cycles, at maximum stress of 46.6 MPa, but at the end of 1 million cycles, control composites lost about 65% modulus compared to only 45% modulus lost by 6 wt% nanosilica composites.