Roles of Interfaces and nano-fillers on environmental durability and structural integrity of FRP composites

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Abstract
The interfaces of composite materials play an important role to sustain the structural integrity of the system. The health of interphase/interface determines the reliability and durability of the composite systems in the service life. It has only been during the last few decades that applications of FRPs have become so rapidly growing that tailoring the well-bonded and durable interfaces has become a curious concern. An uncontrolled and non-uniform degradation at micro- and macro-levels manifests in the interphase because of different environmental conditions during service life. These may restrain its uses in the short term and also in the long-term reliability of the material. The predicted mechanical behaviour may alter during service life because of changes in the nature of the interface. Any changes in the interface might have substantial implications on its performances. The precise mode of failure is a function of the status of environmentally conditioned interfaces and time of exposure, thus complicating the prediction of its performances and behaviour. The interface is the most highly stressed region of composite materials. The important roles of interface necessitate a critical and comprehensive understanding of environmentally conditioned interfaces in FRP composite systems. It is reasonably assumed, the molecular structure here is dynamic in nature at the interfacial area, which is different from the bulk polymer matrix. The changes occurring at the interface are highly sensitive and susceptible to degradations under different environmental conditionings. Since the interphase is a region of chemical inhomogeneity, thus it provides an easy path of the system for becoming more susceptible to thermal, chemical, thermochemical and mechano-chemical degradations. Interfacial durability is a primary factor because environments to which the FRP composite is exposed can degrade interfacial adhesion as well as properties of the materials as a whole.

Keywords: Environmental damage, FRP composite, interface/interphase, nanocomposite

1. Introduction

The interfaces of composite materials play an important role to sustain the structural integrity of the system. The health of interphase/interface determines the reliability and durability of the composite systems in the service life. This may restrain its uses in the short term and also in the long-term reliability of the material. The predicted mechanical behaviour may alter during service life because of changes in the nature of the interface [1]. The precise mode of failure is a function of the status of environmentally conditioned interfaces and time of exposure, thus complicating the prediction of its performances and behaviour. It is reasonably assumed, the molecular structure here is dynamic in nature at the interfacial area, which is different from the bulk polymer matrix. The changes occurring at the interface are highly sensitive and susceptible to degradations under different environmental conditionings. Since the interphase is a region of chemical inhomogeneity, thus it provides an easy path of the system for becoming more susceptible to thermal, chemical, thermochemical and mechano-chemical degradations. Interfacial durability is a primary factor because environments to which the FRP composite is exposed can degrade interfacial adhesion as well as properties of the materials as a whole. Performance of polymeric materials can be effectively engineered by incorporating nanofillers. Several attempts have been made to improve the thermal, mechanical and other functional properties of polymeric materials by nanofiller reinforcement. The extent of heterogeneity and types of interfaces in FRP Composite further increases with incorporation of CNT kind of nanofillers [2]. The differential response of the multiple phases in such multi-scale composite towards external mechanical and/or environmental parameters grossly governs the bulk behavior of the composite. This necessitates assessment of the nanofiller embedded FRP composites at different in-service environments.

2. Effects of environmental temperature

Several studies have indicated the influence of CNTs on the mechanical, thermal and other functional properties of the nanophased polymeric composites. However, few articles have reported the impact on in-service temperature on the structural performance of such composites. The influence on CNT reinforcement on the flexural behavior of CNT filled glass fiber/epoxy composite has been reported by Prusty et al. [3]. The results suggested that the flexural behavior of CNT filled composite has a higher degree of temperature dependence than the control sample as shown in figure 1. The thermal stress generated at the CNT/polymer interface facilitates stress transfer from the soft matrix to the hard reinforcement by increasing the interfacial shear strength of the interface.

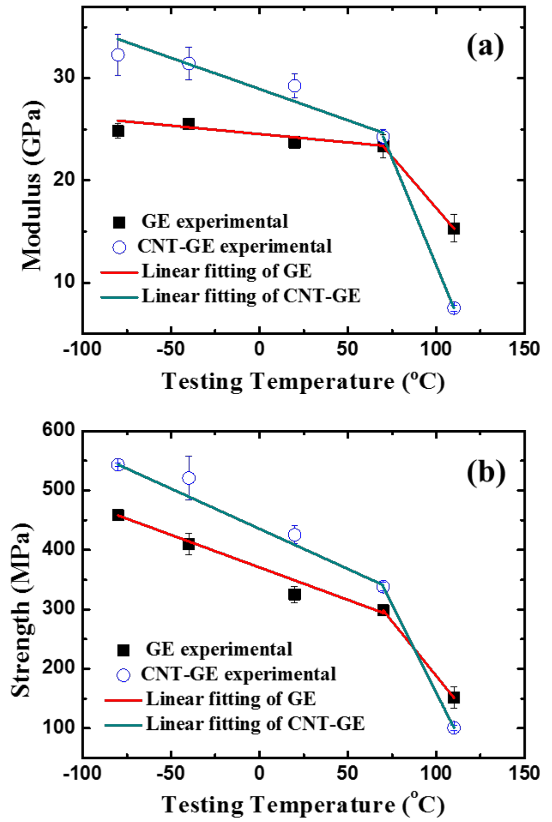

Figure 1: Temperature effects on the mechanical performance of GE composite with and without CNT.

In a similar way, the impact of CNT content on the elevated temperature mechanical response of CNT filled GE composite has been reported by Rathore et al. [4]. The results indicated that 0.1 wt.% CNT-GE composite, which shows the maximum flexural strength and modulus at room temperature, exhibits the lowest strength and modulus when tested at 110 °C, as shown in figure 2. The tensile stress generated at the CNT adhered polymer at elevated temperature promotes easy CNT slippage [5] and thus interfacial debonding at a lower applied stress. Thus the reinforcement efficiency decreases with increase in temperature.

It has been observed that CNT-GE composite has an improved water resistance over GE composite, when the ageing was carried out at relatively low temperature (25 °C). However, interfacial thermal and hygroscopic stresses accelerates the water ingression process at elevated ageing temperature (90 °C), resulting a higher uptake rate for CNT-GE composites than that of GE composite as can be observed from figure 3.

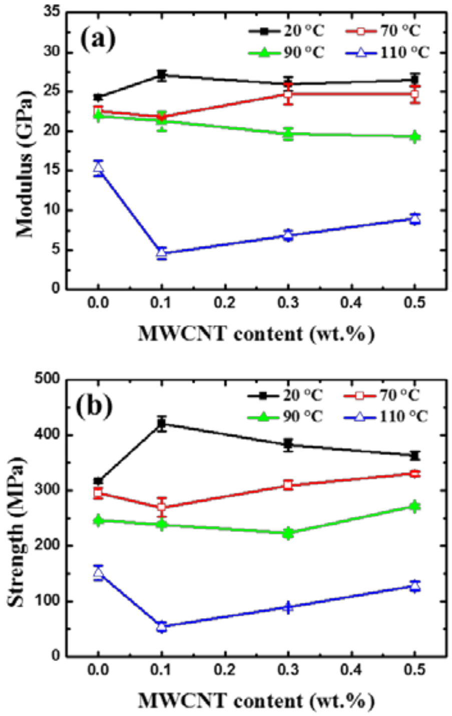

Figure 2: Effect of CNT content on elevated temperature mechanical properties.

3. Effects of water ingression

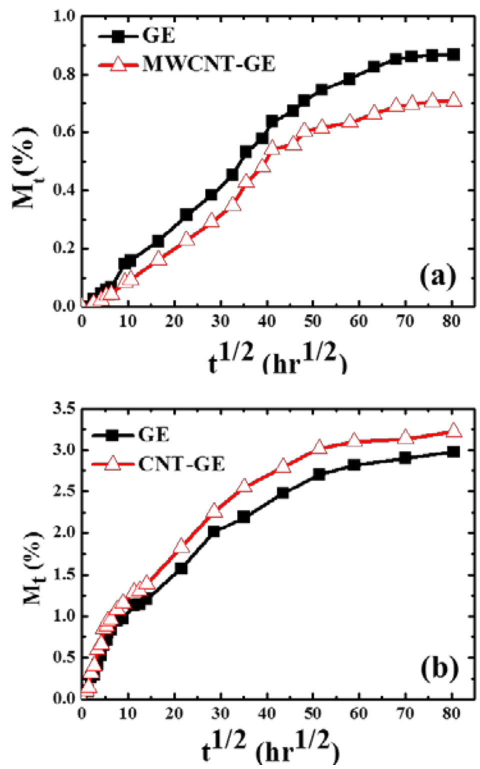

Figure 3: Water uptake kinetics of GE and CNT-GE composites at (a) 25 °C and (b) 90 °C.

4. Concluding remarks

Interface is the key parameter controlling the micro-mechanics of load transfer in polymer composites, and the extent is further huge in case of nanocomposites due to the presence of enormous high interfacial area. With increase/decrease in the service temperature, thermal stresses are generated the interface due to mis-match in the co-efficient of thermal expansion of the CNT and polymer, which eventually controls the extent of stress transfer across the interface. In a similar way, ageing temperature also affects the water uptake rate in CNT filled FRP composites.

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