An Investigation on Failure and Fracture Behavior of Environmentally Conditioned Fibre Reinforced Polymeric Composites
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Abstract
At the present time, the use of composite materials for engineering applications has widely spread, replacing other more common and conventional materials (i.e. steel), thanks to their interesting weight ratios. Different composite materials have been developed; considering fibre reinforced polymer (FRP) composites. In light of their use as structural components, it is certainly very important to study their static and fatigue behavior. The components made up of FRP composites are exposed to temperature variations (thermal shock, thermal spike, low temperature environment, high and low temperature environment, humidity variations, UV radiation and often the combined exposure of these environments leads to more detrimental effect on the performance of the composites during fabrication, in-service time and storage. Further, the rate of loading has significant effects on the mechanical performance of FRP’s. Another important aspect is to study the effect of addition of different nano fillers that alters the thermodynamic properties of the interface/interphase. The investigations in the study deals with mechanical behavior of the FRP composites exposed to aforesaid environments and loading rates. Also, different nano-fillers are used in the composites to enhance the strength and stiffness of the materials to better withstand in different harsh and hostile environments. Scanning electron microscope (SEM) was carried out to know the main cause of fractures that induces different morphologies. The in-service temperature of the FRP composite was measured using TMDSC (temperature modulated differential scanning calorimetry). Furthermore, dynamic mechanical thermal analyser (DMTA) was used to correlate the mechanical and thermo-mechanical response of the FRP composites. Furthermore, research is needed to characterize the interfaces in micro-scale and also by suitable modelling and simulation to explore the tailorability of the interfaces for making these composite materials sustainable and reliable at different service environments.

Keywords: Fibre reinforced polymeric (FRP) composite, Mechanical properties, Loading rate, Nano-fillers, Dynamic mechanical thermal analysis (DMTA)
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Objectives

- Fabrication of different glass fibres reinforced polymer composite with different volume fractions.
- Different environmental conditioning such as high and thermal shock.
- Assessment of mechanical behavior with different loading rates at room temperature, high temperature and also at thermal conditioning environment.
- To evaluate the effect of loading rates on the strengthening mechanisms and eventually the mechanical performance of glass-epoxy composite with modified carbon nanotube (MWCNT) and nano-Al2O3.

Introduction

Fig. SEM images fractured GFRP composites tested at 1000 mm/min loading rates respectively (a) 0.1 wt.

Experimental

Fig. Stress vs strain plot at (a) 25°C, (b) 70°C, (c) 90°C

Fig. Stress vs strain plot at (a) 25°C, (b) 70°C, (c) 90°C, (d) 110°C at 1, 10, 100, 500, 1000 mm/min loading rate with fibre volume fraction (Vf) ≥70%.

a) High Temperature

Fig. Glass transition temperatures (Tg) plot of GFRP composites at 25°C, 70°C, 90°C and 110°C with 70% and 50% volume fractions of fibres respectively.

The detailed marks in Figs. 3 and 4 represent the Tg of conditioned samples which is near to 125°C in all conditioning temperatures. This may be attributed to the presence of the transitional temperature of the polymeric phase in the GFRP composites and due to no further crosslink between the polymeric chains in the PMCs.

Conclusions

- The values of tensile strength of the investigated GFRP composites increase with the increase in crosshead speed at all test temperatures. At higher crosshead speed the response of the composite is primarily governed from the fibre phase and increase in load carrying capacity can be attributed to fibre dominated mechanical response.
- The tensile fractures surfaces indicated various dominating failure modes for the investigated GFRP composite specimens. Matrix fracture was predominant at lower crosshead speeds while in case of higher crosshead speeds fractures were of complex nature due to intrinsic mechanical debonding, fibre pullout, both fibre and matrix cracking.
- Increase in the CNT content up to 0.3% the tensile strength increasing for all the crosshead speeds as compared to the control GFRP composites.
- The steam induced fracture of the control GE and nano-Al2O3/GE enhanced composites was evaluated. With increase in the nano-Al2O3 content the steam modulus also increases. While, the glass transition temperatures (Tg) of 8.5 wt. % nano-Al2O3 enhanced composite is found to be decreasing from 122.1°C to 104.4°C as compared control GE.

Results and Discussion

Fig. SEM images fractured GFRP composites tested at 1 mm/min at different temperatures and different volume fractions of fibres (a) 25°C, Vf ≥70% (b) 70°C, Vf ≥70% (c) 90°C, Vf ≥70% (d) 110°C, Vf ≥70%.

Fig. SEM images fractured GFRP composites tested at 1000 mm/min at different temperatures and different volume fractions of fibres (e) 25°C, Vf ≥70% (f) 70°C, Vf ≥70% (g) 90°C, Vf ≥70% (h) 110°C, Vf ≥70%.

Fig. The graph of Tg vs percentage of volume fraction of fibres.

References


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