Effect of bath concentration during electrophoretic deposition on the interfacial behaviour of hybrid FRP composites

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Abstract

Carbon fibre reinforced polymer (CFRP) composites have been attracting increasing attention as an ideal structural material due to their excellent tensile strength, high stiffness, light weight and great thermal resistance. But their inferior out-of-plane properties which are controlled by the matrix–fibre interface restrict the use of CFRP composites in critical applications. Incorporation of nano-filler in the CFRP composites has found to improve the fibre- matrix interface and there by the out-of-plane response. Though matrix modification has contributed to the improvement of interface, fibre modification has a scope for higher levels of nano-filler incorporation and proper fibre nano-filler adhesion. Out of several methods available for fibre modification electrophoretic deposition (EPD) is an attractive technique for manipulation and deposition of nanomaterials. Graphene, a monolayer of sp^2-hybridized carbon atoms arranged in a two-dimensional lattice, has attracted tremendous attention in recent years. Among the graphene based functionalised nanofillers Carboxyl functionalized Graphene (G-COOH) modified CFRP composites have shown better inter laminar shear strength (ILSS) properties. This research primarily aims to fabricate a CFRP composite using G-COOH modified carbon fibres with varying nano-filler concentrations of 0.5g/ltr, 1g/ltr and 1.5g/ltr in the EPD bath and its impact on the mechanical properties of the FRP composites was studied. The laminates thus obtained were subjected to short beam shear test for the determination of ILSS. Fractography of the tested samples to observe various failure modes has been carried out by using Field emission scanning electron microscope (FESEM).

Introduction

Carbon fibre (CF) is one of the significant reinforcing materials used in the fabrication of the high performance composites for structural applications. The properties of carbon fibre reinforced polymer (CFRP) composites are mainly dependent on the interfacial bond strength between the matrix and reinforcement. Carbon fibres have superior in-plane properties, however the out-of-plane properties limit their capability to replace conventional materials in critical structural applications. Deposition of nano-fillers on CF surfaces affects the surface morphologies of carbon fibres, and enhances the surface wettability of carbon fibres by increasing the surface free energy of the fibres. This decoration of carbon fibre can be attained by the Electrophoretic deposition (EPD) which has been a successful technique for the incorporation of the nano-filler. A colloidal process in which the suspended particles are deposited on the substrate by means of an electric field is called electrophoretic deposition (EPD). EPD is known to be one of the most favourable deposition techniques to create extensive reinforcement of nanoparticles in composite applications, which offers several advantages over other surface coating methodologies, such as process simplicity, uniformity of the deposited films and good control of the deposited thickness. Here in this work G-COOH is chosen as the nano-filler to be deposited because of its high polarity and presence of oxide functional groups which help in proper bonding. Cathodic EPD is used to deposit various concentrations of G-COOH nano-fillers i.e. 0.5g/ltr,1g/ltr and 1.5g/ltr on the carbon fibres and the best concentration was chosen based on the mechanical properties of the CFRP composites fabricated with these modified carbon fibres.

Results and Discussions

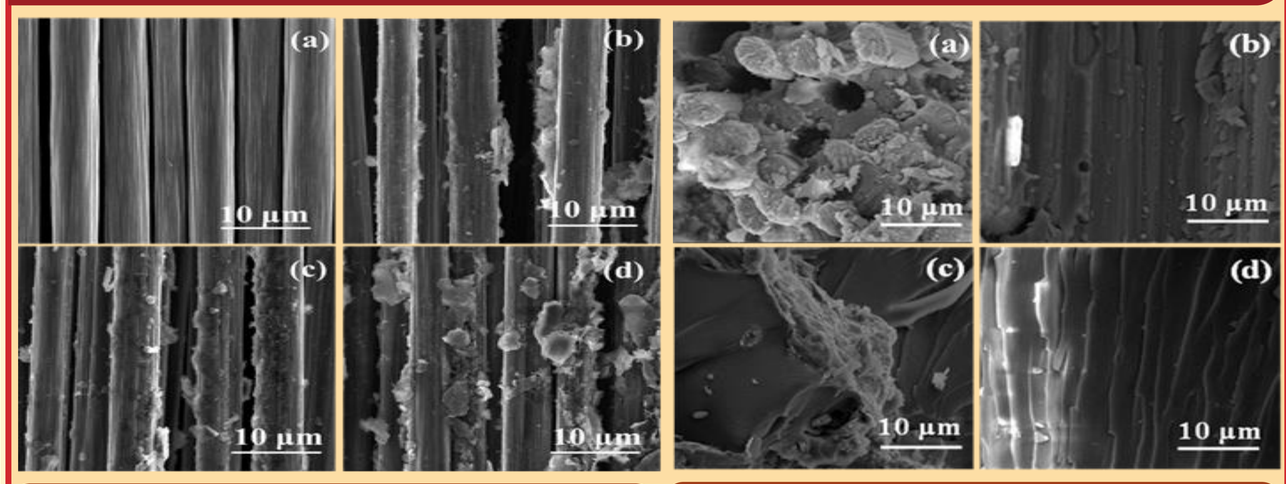

Fig.1. SEM images showing fibre morphology (a) Neat (b) 0.5 g/ltr (c) 1 g/ltr (d) 1.5 g/ltr

Fig.2. Modes of failure (a) fibre pull-out in 1 g/ltr (b) delamination in 1.5 g/ltr (c) matrix fracture in neat (d) deformed matrix in 1 g/ltr

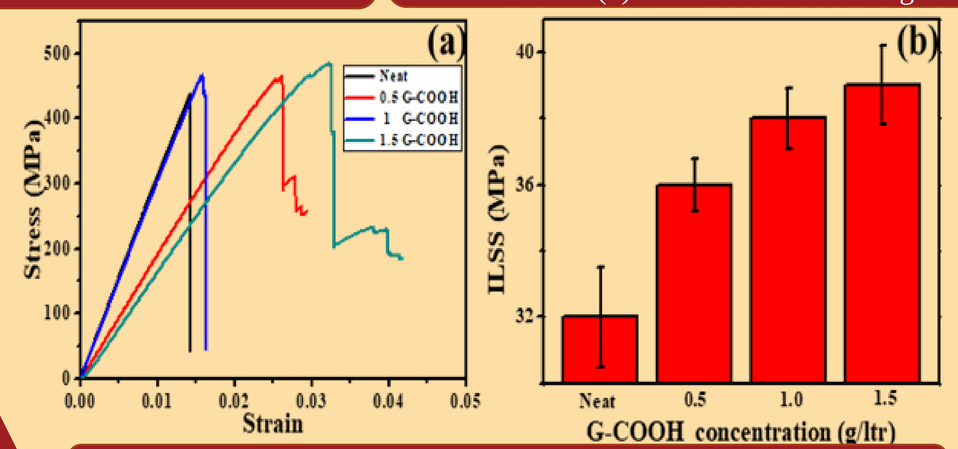

Fig.3. Short beam shear test of the Composite (a) Stress-Strain Curve (b) ILSS of Composite

Experimentation

(Nano filler (1g/Litre) + Distilled water) Sonication for 1 hour

→ (Methyl Violet(0.5g/Litre) is added in the suspension) Sonication for 1 hour

↓

EPD Process had been carried out for 30 minutes at a current of 5 Amperes on de-sized CF

← Soaking of the deposited CFs for 1 hour in the tray of acetone solution to remove extra additives.

↓

Thermal annealing at 140°C for 2 hours of the G-deposited CFs for making the covalent bonding between the G and CFs.

→ The fibers had been used for fabrication of the FRP composite using hand layup method.

↓

The laminate obtained is cut to dimensions according to ASTM D7264

← The samples are tested in UTM Instron5967fab

Conclusions

Carbon fibres were decorated with G-COOH using electrophoretic deposition technique. Laminates were fabricated using hand lay-up method. The effect of nanofiller concentration on ILSS was explained. From the obtained results, the following remarks can be concluded:

1. Present work proposes EPD as a promising technique for improving the interlaminar properties of CFRP composites.
2. ILSS increases with increase in the nano-filler concentration in the suspension i.e. 0.5 g/ltr has shown an improvement of 15.7 % compared to neat, 1 g/ltr has shown an improvement of 22.8 % compared to neat and 1.5 g/ltr has shown 25.4 % improvement compared to control sample.
3. The strain to failure increases with increasing nano-filler concentration because of the induced stiffening at the interface.
4. FESEM analysis confirmed the deposition of the nanofiller and uniform deposition was observed in 1 g/ltr.
5. Fractography revealed various modes of failure i.e. matrix cracking, fibre pull out, delamination and deformed matrix in the modified CFRP composites.

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