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Mechanical Properties of Hybrid Glass Fibre/ Epoxy Reinforced TiO_2 Nanocomposites

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Abstract— This paper presents the influence of TiO_2 nano particles on the epoxy/hybrid glass fibre, in combination with woven roving and chopped strand mat reinforced composite. Hand lay-up technique was employed to prepare the hybrid fiber laminates with varied (0, 1, 2, 3, 4 and 5) weight percentage of TiO_2 nano particles. The interlayer separation of TiO_2 nanoparticles in the epoxy resin was studied using X-ray diffraction. Mechanical property of the prepared nanocomposites was investigated taking Tensile Test and the fractured part was analyzed using scanning electron microscope.

Keywords—Hybrid glass fiber; TiO_2 nanoparticles; X-ray Diffraction; Mechanical properties; scanning electron microscopy.

1 INTRODUCTION

GLASS fibre reinforced polymer based composites have been drastically improving owing to their reduced weight, improved mechanical properties making them equivalent to those of metallic materials. The dispersion of nanoparticles in the polymer matrix influences its physical properties. Moreover hybridization of glass fibres induces the binding strength of fibres of both woven roving and chopped strand types. Mechanical properties play a vital role in studying the behavior of the materials under application of pressure or load. Their design flexibility provide an opportunity for tailoring a structure in the direction of major stresses, increase its stiffness in a preferred direction, fabricate curved panels without any secondary forming operation and with poor coefficients of thermal expansion. For these reasons, fiber reinforced polymers are either used or being considered for the substitution of metals in many weight-critical components in aerospace, automotive, and other industries.

Júlio C. Santos et al. [1] studied the characteristics of Hybrid glass fibre reinforced composites with micro and poly-diallyl-di-methyl-ammonium chloride (PDDA) functionalized nano silica inclusions made an inevitable conclusion that inclusion of nanoparticles maximizes tensile strength of the hybrid glass fibre materials. M. Sudheer et al. [2] investigated the Enhanced Mechanical and Wear Performance of Epoxy/glass Composites with PTW/Graphite Hybrid Fillers and concluded that solid hybrid filler materials could improve the tribological properties of glass fibre composites. Feng-Hua Su et al. [3] studied the Tribological behavior of hybrid glass/PTFE fabric composites with phenolic resin binder and nano-TiO_2 filler and found that The improved tribological performance of 4% nano-TiO_2 filled hybrid glass/PTFE fabric composites can be attributed to the improved structural integrity of the composites, the character of transfer film and the special anti-wear action of nano-TiO_2 during friction process. Yuan Xu et al. [4] studied the Mechanical properties of carbon fiber reinforced epoxy/clay nanocomposites. Emrah Bozkurt et al. [5] studied the Mechanical and thermal behavior of non-crimp glass fiber reinforced layered clay/epoxy nanocomposites.

2 EXPERIMENTAL

2.1 Materials used

The Epoxy resin with chemical name diglycidyl ether of bisphenyl-A (DGEBA) and trade name LY 556 was employed as the preferable matrix material. Araldite with the trade name HY 951 was used as a curing agent for epoxy resin. TiO_2 nanoparticles were taken as filler materials. Chopped Strand Mat (CSM) and Woven roving mat (WRM) were taken as reinforcement. Poly-vinyl Alcohol (PVA) was used as a releasing agent.

2.2 Preparation of polymer matrix solution

The polymer matrix solution was prepared by uniform mixing of TiO_2 nanoparticles with the epoxy resin by controlled dispersion process using high speed mechanical stirrer at a uniform speed of 800 rpm for about 2 hours. Hardener was added and the stirring process was continued for another 10 minutes in order to get the homogeneity in the mixed solution.

2.3 Preparation of the nanocomposite laminates

Poly-vinyl Alcohol was applied initially on the moulding board. Polymer matrix solution was applied over each layer using brush. Hand lay-up process was used to prepare the laminates. 3 layers from each type glass fibre mats (WRM and CSM) with were laid alternately to get the hybrid glass fibre laminates. Mechanical roller was used to uniformly firm the layers of laminate from each other. 6 layers of fibre mats were laid as a whole to get single laminate. The laminates were let to cure at room temperature for 48 hours and removed from moulding board.

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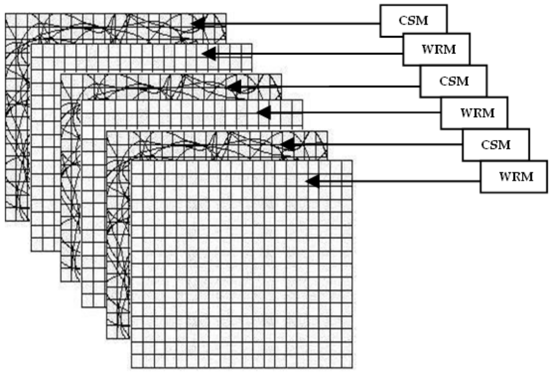


Fig. 1. Arrangement of fibre mats

Fig. 2. Hand lay-up process

3 Material Characterization

3.1 X-ray Diffraction

X-ray diffraction (XRD) test was performed on X-ray diffractometer. The prepared composite sample was subjected to 2θ° scanning from 2° to 10° at 0.02° step size for 0.5 s per step with CuKα radiation source (1.541A°) operating under a current of 30 mA, and a voltage of 40 kV. The structural characteristics of nanocomposites were determined and the dispersion of TiO_2 nanoparticles in the epoxy resin was evaluated. The intercalated and exfoliated structural morphologies obtained on the dispersion of TiO_2 nanoparticles in the epoxy resin, were considered for the study of improvement of laminate properties. The results obtained were analyzed using Bragg's law to calculate the d-spacing (interlayer separation).

3.2 Scanning Electron Microscopy

The microscopic images of epoxy/TiO_2 nanoparticles dispersion and interlaminar bonding of hybrid glass fibres and the polymer matrix solution were analyzed using scanning electron microscope for obtaining magnification range from 20X to 30,000X. Various structural characteristics of nanocomposites obtained after conducting the mechanical tests, such as modes of fracture, interfacial bonding nature and dispersion nature of TiO_2 nanoparticles in epoxy resins were studied using the micrographs.

4 Results and Discussions

4.1 X-ray diffraction

The graph obtained from XRD on TiO_2 nanoparticles show the sharp peaks at 19.8° of 2Θ values and corresponding d – spacing value was 12 Å. The neat epoxy and epoxy nanoparticles samples (0% and 3%) did not show any significant diffraction peaks in the XRD pattern. Hence the absence of peak reflection in the nanocomposites suggests good exfoliation of the TiO2 particles in the epoxy matrix.

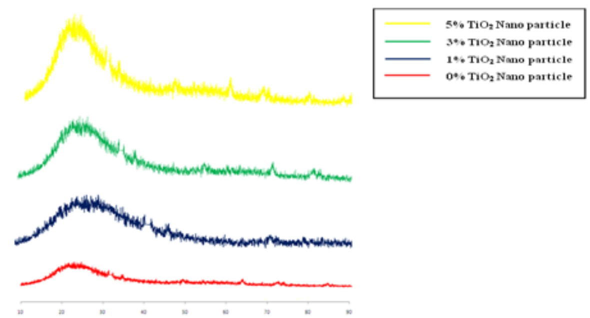


Fig. 3. XRD pattern of epoxy-TiO_2 nanocomposites

The XRD graph for 5% nanoparticles sample shows broad peaks which indicate a large intercalation structure. When adding higher percentage of nanoparticles, the particles are difficult to disperse and cannot obtain exfoliated structure. This is due to the strong tendency of nanoparticles to agglomerate and increased viscosity of resin when mixed with nanoparticles.

4.2 Mechanical Test

The laminates were cut to the dimension as per ASTM standards. A pair of specimens was taken from each of six laminates for conducting the tensile test and an average value was evaluated from each tests.

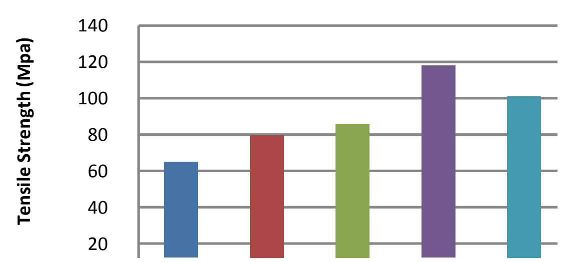
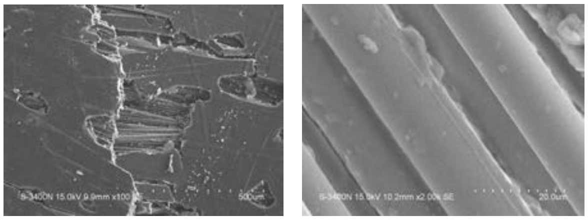


Fig. 4. Tensile strength of nanocomposite

The maximum tensile strength was obtained with the inclusion of 3% nanoparticles loading. An increase of 22% was achieved over the neat epoxy/hybrid glass fibre composites. A good interfacial bonding between fibre and matrix is the reason for improving the tensile properties.

4.3 Scanning electron microscope



(a) (b)

Fig. 5. SEM micrographs of nanocomposites (a) Fracture propogation during Flexural test (b) Proper interfacial bonding of fiber and matrix solution

The SEM micrographs taken from the nanocomposites intimated several characteristic properties underwent by the laminate specimens during the mechanical test. The micrograph of fracture propagation of nanocomposite with 3 wt.% TiO_2 nanoparticles during the tensile test is shown in the Fig. 5. (a). The micrograph of proper interfacial bonding of fibre and neat epoxy matrix is shown in Fig. 5. (b).

5. Conclusion

From the experimental results, the following conclusions are highlighted:

(i). The XRD pattern of nanocomposites exhibited fully intercalation or orderly exfoliation structure, which ensures that the nanoparticles particles are uniformly dispersed into epoxy resin.

(ii). Incorporation of nanoparticles up to 3% in the epoxy/ hybrid glass fibre results in enhancement of tensile strength compared to conventional composites laminates.

(iii). Addition of 3% nanoparticle resulted in an increase of the tensile strength of the composite by 22%.

(iv). The improvement in mechanical properties of glass fiber/epoxy composite is attributed to the presence of nanoparticles which acts as an interface material between fibre and matrix.

(v). Scanning micrographs also revealed improved adhesion of fibers to the matrix material with increasing nanoparticles content as shown in Fig.5 (a) and (b).

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