Abstract

Objectives: This paper is about the mechanical characters of biaxial braided carbon fiber nanocomposites. Methods/Statistical Analysis: Hand layup technique is used for fabrication of biaxial braided fiber nanocomposites. Seven samples have been prepared with Unfilled, TiO$_2$ (1, 3 & 5wt %) and Nanoclay (1, 3 & 5 wt %). The above nanoparticles were mixed in the epoxy resin using magnetic stirrer. Mechanical properties (tensile, flexural and impact) were carried out. Findings: The experimental outcomes showed that the mechanical characterization of unfilled biaxial braided fiber nanocomposite material was lower than the TiO$_2$ (1, 3 & 5wt %) and nanoclay (1, 3 & 5 wt %) biaxial braided fiber nanocomposite materials. 3wt% TiO$_2$ and 3wt% nanoclay composite materials showed better improvement in the mechanical characters. However, 3wt% nanoclay composite material showed very excellent improvement in the mechanical characters than 3wt% TiO$_2$. This is due to nanoclay particles have higher strength and higher modulus than TiO$_2$ particles. Application/Improvements: The developed biaxial braided fiber nanocomposite materials were used in the field of aeronautics, automotive and space recreation products because of their excellent properties, light weight, corrosion resistance, high energy absorption and excellent strength characteristics.

Keywords: Biaxial, Braided Fibre, Mechanical Properties, Nanoclay, TiO$_2$

1. Introduction

More than thirty decades reinforced composite material, plastics, textile composites and ceramics are considered as the main talented materials. Carbon fiber braided composite material have good mechanical properties, light weight, improved delaminating resistance, strength and modulus, compared to conventional type composites. Studying the mechanical characters of carbon braided fiber composites became very important in aerospace, automobiles and many industrial applications. Considering this in mind, several research pupils have studied the different characters of braided composites. The essential textures of the braided textile fabric are the stability of every fiber bundles diagonally leaned. Thus the braided textile fabric reinforced composite have shown better mechanical characters. The current improvements in the fabrication techniques and sympathetic of their mechanical behaviors contribute to the increasing popularity of braided materials.

In present, researches have been concentrated on the practice of nanoparticle to reinforce polymer textile composite materials. The accumulation of firm micro-scale fillers to resin frequently improves its strength, but reduces the toughness because the nanoparticles may stimulate stress concentration, which creates cracks and make larger than the serious crack size that may cause failures. Consequently, this is an excellent method to reinforce the textile polymers with nanoparticles in order to boost the crack toughness without sacrificing the strength of the textile polymers since well-dispersed nanoparticles are much lesser than the serious crack size to begin crash. Therefore, they offer a path for concurrently strengthening and toughening the polymers. If the nanoparticle reinforced resin is used for composite laminated panels, inter laminar crack toughness and the

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impact characters can be enhanced at room temperature\(^4\). Currently, the majority of the research outcomes of composites on energy absorption have relied on practical and by unstable design parameters. The design parameters are fillers, shapes, sizes or volume fraction\(^2\). Fracture toughness mode I of carbon fiber laminate with nanoparticles adapted epoxy resin matrix has studied with the help of DCB test. Laminates with 10 wt% rubber nanoparticles given the maximum development in toughness which is 2.5 times that of the managed, at the same time silica tailored laminates have shown only reasonable raise of 20–30\(^%\)\(^5\). Along with many nanocomposites precursors, TiO\(_2\) nanopowder is investigated as they are non toxic, less cost, rust resistant and also has high refractive index, UV filtration capability and elevated hardness. Literatures have also exposed that nanoscale TiO\(_2\) support brings new properties such as electrical, optical and physiochemical attained at very little TiO\(_2\) content, which brings polymer TiO\(_2\) nanocomposite a talented new group of materials\(^6\). Mechanical characters of biaxial braided carbon composite with TiO\(_2\) might be efficiently attuned by accumulating nanoparticle of TiO\(_2\) in different weight percentage. It was experimental that the biaxial carbon braided composite up to 3wt% of TiO\(_2\) have shown an excellent enhancement in tensile and flexural strength\(^8\). The grafted particles showed better compatibility with an epoxy resin and enabled translucent high refractive index TiO\(_2\) epoxy nanocomposites\(^2\). Cordierite– TiO\(_2\)’s flexural strength (CTi10) is noted as 158.47MPa; which is superior to CTi20. The composite materials exhibited a extremely little coefficient of thermal expansion 3.61×10\(^{-6}\) per degree Celsius. The 10 wt% cordierite– TiO\(_2\) exhibited enhanced mechanical characters; these enhanced properties despoiled with superior weight percentage accumulation of TiO\(_2\)\(^1\). As a matter of fact, one of the most attractive aspects of nanoparticle research is that well-known materials like Titania, carbon or gold (to mention only a few) revealed completely different properties on the nanoscale\(^1\). TiO\(_2\) -nanoparticle-loaded encapsulate for LEDs are fabricated. As-received TiO\(_2\) nanoparticles with average diameter of 40 nm are dried, mixed with a solvent, refluxed, centrifuged, and mixed with epoxy to create surfactant coated nanoparticles. An extreme reduction of TiO\(_2\) agglomeration in epoxy resin is observed for surfactant-coated TiO\(_2\) nanoparticles\(^1\). Polymeric matrix composites with nanoclay reinforcement have become very admired in structural applications because of its excellent mechanical properties. The benefits of nanoparticles reinforcement in polymer matrix composites are apparent in the form of increased modulus, strength and so on. Epoxy/clay Nanocomposites were fabricated by means of OM clays, in order to assess their possible use as matrices for long-fiber structural composites with better properties\(^1\). In mentioned that polymer clay nanocomposites enhanced stiffness, toughness, strength and thermal properties as well as thermal expansion coefficient and condensed gas permeability\(^1\). The interlaminar shear characters and hardness of nanoclay epoxy composite materials with different quantity of nanoclay substance were studied, which produced various sizes of nanoclay epoxy clusters after incorporation in an extruder\(^1\). Improved fracture toughness of the epoxy system with the accumulation of nanoclay\(^1\).

However, there are few literatures on the properties of biaxial carbon braided fiber/ epoxy laminates. The main purpose of this work is to studied the addition of nanoparticles such as TiO\(_2\) with unfilled, 1 wt%, 3wt% and 5wt% and nanoclay with unfilled, 1wt%, 3wt% and 5wt% individually in the epoxy resin to advance the mechanical properties of biaxial braided nanocomposite. Then the results of TiO\(_2\) and nanoclay particles are compared. Nanoclay showed greater mechanical properties than TiO\(_2\). It also showed that nanoclay particle with 3wt% has very high tensile strength, flexural strength and shear strength.

2. Experimental Methods

2.1 Materials and Fabrications

Carbon biaxial braided sleeves with 4” dia of specifically oriented fibers of greatest stiffness, torsion properties and compressive strength had been used to manufacture composite materials. The textile braid has a 45° orientation and could be enlarged from its diameter to 30% and reduced to 70%. When DGEBA is combined with Hardener HY951 and nanoparticles, it gives a solvent free curing system. Stripped platelets- Carbon nanofiber, above 98% carbon basis, Diameter-100nm, length-20 to 200 μm were obtained from Sigma Aldrich. An epoxy resin of LY556 and hardener HY951 are mixed in the weight ratio of 10:1 and used as the matrix material with unfilled, 1wt%, 3wt% and 5wt% nanoparticles (TiO\(_2\) and Nanoclay individually). Mixing was conducted in the magnetic hot plate stirrer for 4h at 75° C. The mixture was subjected to sonication by means of an ultrasonicator at
an ultrahigh frequency for 3h to further disperse the nano particles while maintaining the resin temperature at 75°C using a hot water bath. The mixture was followed by accumulation of HY951 and the mixture was stimulated well to avoid the formation of bubbles. The composite materials were manufacture using hand layup technique. It is followed by a press machine for 24 hours at room temperature. Then, the composites were put in an oven with a treatment for 1h at 100°C. Fiber volume fraction of the laminates was 45±0.6%. 8 layers of biaxial fiber were used to get 3mm thickness of composite material.

2.2 Tensile Test
Tensile test was performed to determine the tensile modulus and tensile strength of braided carbon fiber composites with an amount of unfilled, 1wt%, 3 wt% and 5 wt% of TiO₂ and nanoclay individually. A UTM (Universal Testing Machine) gear ratio speed of 0.25cm/minute was used to load the specimen, consistent with ASTM D638. The specimens were cut in the dog bone shape with the dimension of 165mm x 12.7mm x 3mm and gauge length 57mm with radius of 25mm.

2.3 Flexural Test
The flexural properties of the biaxial carbon braided fiber composites was calculated using 3point bending test with the ASTM D790 for the samples 127mm x 12.7mm x 3 mm.

2.4 Double Shear Test
Shear strength is the utmost load applied normal to a fastener’s axis that can be supported previous to break. Double shear is the instantaneous shear across two usually parallel planes and cut into three pieces. The shear strength is measures with the help of MTS Universal testing machine (UTM) with hydraulic hold, model 744 and extensometer, at the rate of 0.5 cm/minute, at room temperature of 23°C. ASTM D5379 for fiber resin composites was used to find the shear strength. The composite specimens with dimensions of 45x 10 mm were used to do the double shear test.

3. Results and Discussions

3.1 Tensile Properties of Biaxial Nanocomposite
The experimental test results are presented in Figure 1(a) and (b). The tensile properties of the composite were enhanced by adding the nanoparticles up to 3 wt%. But the modulus and strength were shown greater improvement in the addition of nanoclay when compared to TiO₂. Nanoclay has high modulus and strength than TiO₂. However, the stiffness and the composite's tensile strength were decreased by accumulating the nanoparticles in 5wt%. The reason seems that 5wt% of nanoparticles were not mixed enough with epoxy resin and forms agglomeration. Due to the above reason, loads were not successfully transferred to the composite material during loading and each ply was fractured individually. The fracture surface of the tensile specimen indicates brittle fracture mechanism of neat epoxy resin and other composite specimen except 5wt% ductile fracture mechanism and improved tensile properties. The reduction in strength and modulus is linked with a poor dispersion and void formation of the high content level of nanoparticles in the resin.

3.2 Flexural Properties of Biaxial Nanocomposite
Flexural properties of biaxial braided nanocomposite are presented in Figure 2(a) and (b). It was well-known that 3wt% of nanoclay's flexural modulus showed the utmost value. Other biaxial braided composite materials showed a gradual weight rise and elevated yield displacement. It was proved that flexural stress and flexural modulus of 3wt% nanoclay biaxial braided composite was greater than that of other samples. TiO₂ showed very good improvements when compared to nanoclay particles; it shows less improvement in their flexural modulus and flexural strength.
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5. References

1. Lomov SV, Nakai A, Parnas R, Verpoest I, Ghosh SB. Experimental and theoretical characterization of the geometry of flat two- and three-axial braids. Textile Research Journal. 2002 Aug; 72(8):706–12. doi:10.1177/004051750207200810.
2. Parimala R, Jabaraj DB. A study on E-glass fibre reinforced composites. Journal of Harmonized Research in Engineering. 2014; 2(2):274–80.
3. Ajayan PM, Schadler LS, Braun PV. Nanocomposite science and technology. Weinheim: WILEY-VCH GmbH & Co. KGaA; 2003.
4. Kim BC, Park SW, Lee DG. Fracture toughness of the nanoparticle reinforced epoxy composite. Composite Structures. 2008 Oct; 86(1–3):69–77. doi:10.1016/j.compstruct.2008.03.005.
5. Tang W, Santar MH, Advani SG. Melt processing and mechanical property characterization of multi-walled carbon nanotube/high density polyethylene (MWNT/HDPE) composite films. Carbon. 2003 Jan; 41(14):2779–85. doi:10.1016/S0008-6223(03)00387-7.
6. Zeng Y, Liu HY, Mai YW, Du XS. Improving interlaminar fracture toughness of carbon fibre/epoxy laminates by incorporation of nano-particles. Composites: Part B Engineering. 2012 Jan; 43(1):90–4. doi:10.1016/j.compositesb.2011.04.036.
7. Sun L, Ronald F, Gordaninejad GF, Suhr J. Energy absorption capability of nanocomposites: A review. Composites Science and Technology. 2009 Nov; 69(14):2392–409. doi:10.1016/j.compscitech.2009.06.020.
8. Parimala R, Jabaraj DB. Carbon braided biaxial fiber with TiO2: Mechanical properties. International Conference on Science Engineering and Management Research (ICSEMR); 2014 Nov. p. 1–4.

3.3 Shear Properties of Biaxial Nanocomposite

Figure 3(a) and (b) represent the shear modulus and shear strength of the biaxial carbon braided fibre composite materials on the different weight percentage of TiO_2 and nanoclay. The shear strength is increased initially up to 3wt% of TiO_2 and then showed a fall. Similarly, the shear strength is increased up to 3wt% of nanoclay which shows greater improvement than TiO_2. The sample with 3wt% of nanoclay is showing the highest shear modulus among the other samples.

4. Conclusion

In this paper, the effective mechanical properties are deduced experimentally. The effects of TiO_2 and nanoclay loading on the biaxial braided fibre are investigated. TiO_2 and nanoclay composites results are compared to experimental method. The different percentage of TiO_2 and nanoclay loading has significant influences on the modulus and strength of biaxial braided fibre composites. The modulus and strength properties in 5wt% were lower than that neat, 1wt% and 3wt%. This shows that uniform TiO_2 and nanoclay distribution was not easy at high nanoparticles loading. The inclusion of higher nanoparticles (5wt %) content declined the mechanical properties and difficult to disperse. Moreover, nanoparticles inclusion with braided biaxial composite improved the mechanical properties up to 3wt% of the braided biaxial fiber composite.
9. Tao P, Li Y, Rungta A, Viswanath A, Gao J, Benicewicz BC, Siegel RW, Schadler L. TiO2 nanocomposites with high refractive index and transparency. Journal of Material Chemistry. 2011 Oct; 21(46):18623–9. doi:10.1039/c1jm13093e.

10. Marikkannan SK, Ayyasamy EP. Synthesis, characterisation and sintering behaviour influencing the mechanical, thermal and physical properties of cordierite-doped TiO2. Journal of Materials Research and Technology. 2013 Jul-Sep; 2(3):269–75. doi:10.1016/j.jmrt.2013.03.016.

11. Heiligtag FJ, Niederberger M. The fascinating world of nanoparticle research. Materials Today. 2013 Jul–Aug; 16(7–8):262–72. doi:10.1016/j.mattod.2013.07.004.

12. Mont FW, Kim JK, Schubert MF, Schubert EF, Siegel RW. High-refractive-index TiO2 –nanoparticle-loaded encapsulants for light-emitting diodes. Journal of Applied Physics. 2008 Apr; 103(8):1–6. doi:10.1063/1.2903484.

13. Dorigato A, Morandi S, Pegoretti A. Effect of nanoclay addition on the fiber/matrix adhesion in epoxy/glass composites. Journal of Composite Materials. 2012 Jun; 46(12):1439–51. doi:10.1177/0021998311420311.

14. Quaresimin M. Private communication. Journal of Hormonized Research in Engineering. 2009; 2(2):274–80.

15. Lama CK, Cheunga HY, TakLaua K, Zhoua LM, Hob MW, Huib D. Cluster size effect in hardness of nanoclay/epoxy composites. Composites: Part B Engineering. 2005 Apr; 36(3):263–9. doi:10.1016/j.compositesb.2004.09.006.

16. Liu W, Hoa SV, Pugh M. Fracture toughness and water uptake of high-Performance epoxy/nanoclaynanocomposites. Composites Science and Technology. 2005 Dec; 65(15–16):2364–73. doi:10.1016/j.compscitech.2005.06.007.