International Journal of ChemTech Research
CODEN (USA): IJCRGG ISSN: 0974-4290
Vol.7, No.2, pp 617-621, 2014-2015

ICONN 2015 [4th -6th Feb 2015]
International Conference on Nanoscience and Nanotechnology-2015
SRM University, Chennai, India

Studies on Effect of Nano TiO_2 Ceramic Fillers of Polymer Matrix Composites

T. Sornakumar[1]*, D.Ravindran[2] And G.Seshanandan[3]

[1,3]Department of Mechanical Engineering, Thiagarajar College of Engineering, Madurai-625015, India
[2]Department of Physics, Thiagarajar College of Engineering, Madurai-625015, India

Abstract : Fiber reinforced composites are materials made of polymer matrix reinforced with fibers and is very widely used in automotive, marine, aerospace and construction industries because of their high specific tensile and compressive strength, low coefficient of thermal expansion, good fatigue resistance and suitability for the production of complex shape materials. The objective of the present work is to study the effect of nano titanium dioxide fillers on the properties of glass fiber reinforced plastics. The glass fiber reinforced plastic specimens were manufactured with glass fiber chopped strand mat, polyester resin and nano titanium dioxide fillers by the hand layup technique. The nano titanium dioxide fillers are incorporated in different weight ratios in the fiber reinforced plastics and the mechanical properties are evaluated. The mechanical properties of the glass fiber reinforced plastics improved with addition of nano TiO_2 filler particles.
Keywords: Glass fiber reinforced plastic, Composite, Filler, Titanium dioxide, Strength.

Introduction

The composite materials based on the strong and stiff fibers are generally used in the aerospace industry for a part of aircraft or space shuttle [1]. The lightweight composite materials can offer the impressive mechanical properties such as a high specific strength, stiffness and the relatively good energy absorbing characteristics [2]. High performance composites are commercially used in the fabrication of aircraft, automotive and marine structures [3]. The composite materials usually involve a matrix, such as polymers, and fillers such as fibres. Glass is the most common form of the reinforcing fibres because it is cheap and has good mechanical properties. The resultant composites are used in a range of industries including aerospace, leisure, sporting, automotive, and construction [4]. The most common synthetic fibres are aramid, glass, polyethylene, and carbon. The lower stiffness and strength of polymer can be improved through the addition of stiffer and stronger fibres in polymer matrix composites [5].

The search from time immemorial for stronger, lighter and more durable materials used in construction and tools continues to this day. This urge to discover, invent and synthesize new materials has resulted in innumerable kinds of alloys, plastics and composites owing to the very exacting demands from different industries like aerospace, automobile, chemical, marine and so on. Glass fibers reinforced in polymers have received considerable attention during the last century. Studies conducted during the last decade reveal that adding small amounts of foreign particles (like clay or silica) of nanosize significantly improves the engineering properties of the polymers [6]. Glass fiber reinforced plastic (GFRP) composite material was developed to meet the requirements of the industry for high strength materials with low weight. The advantages of GFRP material include savings in weight, improvement in strength and decreased cost of material and fabrication. Glass fibre reinforced composites have been used for engineering applications, and various types of glass fibres are used as reinforcements. E-glass fibres are widely used as they have special characteristics such as high strength to weight ratio, good dimensional stability, good resistance to heat, cold, moisture, and corrosion, and good electrical insulation properties. The concept of incorporating a strong fibre or whiskers into a tough or ductile matrix yields a very high strength to the composite as they carry load [7].

Polymer nanocomposites reinforced with lower volume fraction of nanoceramics and carbon nanotubes have attracted steadily growing interest due to their peculiar and fascinating properties as well as their unique applications in commercial sectors. The incorporation of nanoceramics such as layered silicate clays, calcium carbonate or silica nanoparticles arranged on the nanometer scale with a high aspect ratio and/or an extremely large surface area into polymers improves their mechanical performances significantly. The properties of nanocomposites depend greatly on the chemistry of polymer matrices, nature of nanofillers, and the way in which they are prepared. The uniform dispersion of nanofillers in the polymer matrices is a general prerequisite for achieving desired mechanical and physical characteristics [8]. The introduction of filler leads to an obvious reinforcement of the matrix elastic modulus: the observed increase depends on the modulus difference between the various phases present, the filler content and its dispersion state. In the same way, the yield point, in both compressive and tensile tests, is found to be sensitive to the latter parameters. Complementary experiments enable to suggest possible local events leading to the rupture of these composite systems [9].

Titanium oxide nanoparticles are one of the most interesting materials at the present time. Under ongoing development, they attract increasing attention not only for their unique properties, but also for their potential applications in industries such as pigments, cosmetics, catalysts, photocatalysts etc. [10]. The incorporation of nanoparticles into a polymer can lead to a considerable improvement of mechanical properties. Results indicate an enhancement in the vinyl ester composite mechanical properties due to the addition of small fraction of titanium dioxide particles [11].

Experimental

In the present work, nano titanium dioxide (TiO_2) particles with an average particle size of 50 nm were used as filler material to modify the polyester matrix. A commercially available E-glass fiber chopped strand mat (GFCSM) of 450 gsm was used as the reinforcement material. The weight fractions of the nano TiO_2 particles filler in the glass fiber reinforced plastic (GFRP) were 2%, 4% and 6%, based on the ratio of weight of the nano TiO_2 particles to the total weight of the GFCSM, polyester resin and nano TiO_2 particles. The nano TiO_2 particle fillers were mixed into the polyester resin by mechanical stirring, followed by mixing of methyl ethyl ketone peroxide hardener and cobalt naphthenate accelerator; to form the nano TiO_2 mixed polyester resin. The GFRP composites were manufactured by hand layup method with 3 layers of GFCSM; consisting of bottom, intermediate and top layers of GFCSM. Initially a releasing agent is spread over a flat mould to enable easy removal of the manufactured GFRP. Above this releasing agent layer, a thin layer of the nano TiO_2 mixed polyester resin is applied. Reinforcement in the form of GFCSM cut as per the mould size, is then placed at the surface of mould. The nano TiO_2 mixed polyester resin is then poured onto the surface of GFCSM already placed in the mould and it is uniformly spread with the help of brush. A roller is moved with a mild pressure on the GFCSM-nano TiO_2 mixed polyester resin layer to remove any air trapped. Again a thin layer of nano TiO_2 mixed polyester resin is applied. The next layer of GFCSM is then placed above. The process is repeated for each layer of nano TiO_2 mixed polyester resin and GFCSM, till the three layers of GFCSM are stacked. Finally a thin layer of the nano TiO_2 mixed polyester resin is applied. A weight is placed over the manufactured GFRP specimen and the entire setup is left for 24 hours. Thus GFRP specimens with three different nano TiO_2 particles filler proportions were manufactured separately. Also, the GFRP specimen without TiO_2 particle fillers was manufactured. The total thickness of the all the manufactured GFRP specimen was 3 mm. The scanning electron microscopy (SEM) photograph of the GFRP specimen is shown in figure 1.

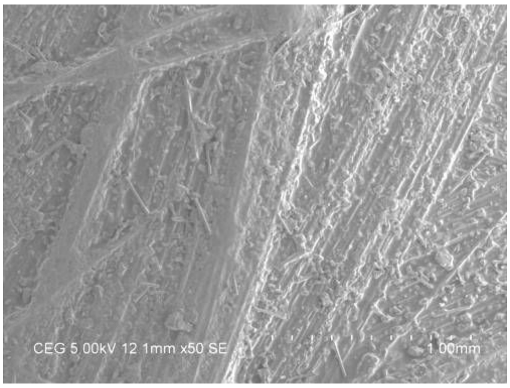

Figure 1.SEM photograph of specimen FRP2

The mechanical testing of the GFRP specimen were conducted in a Universal testing machine. The tensile test was conducted in the Universal testing machine as per ASTM: D638 standard. The three point flexural test was conducted in the Universal testing machine as per ASTM: D790. The double shear test is conducted in the universal testing machine as per ASTM: D5379 standard.

Results and Discussion

The tensile test, flexural test and shear test of the GFRP during testing in the Universal testing machine is presented in figure 2, 3 and 4 respectively.

Figure.2. Tensile test (FRP2) **Figure.3.Flexural test (FRP4)** **Figure.4.Shear test (FRP3)**

The tensile strength, flexural strength and shear strength of the GFRP specimen are presented in table 1.

Table 1. Tensile strength, flexural strength and shear strength

Specimen Code	GFCSM, wt %	Polyester resin, wt %	Nano TiO_2 filler, wt %	Tensile strength, MPa	Flexural Strength, MPa	Shear Strength, MPa
FRP1	33	67	0	86	138	66
FRP2	33	65	2	91	157	73
FRP3	33	63	4	95	175	79
FRP4	33	61	6	98	191	84

The test specimen after testing for tensile test (FRP3), flexural test (FRP2) and shear test (FRP4) of the GFRP specimen are presented in figures 5, 6 and 7 respectively.



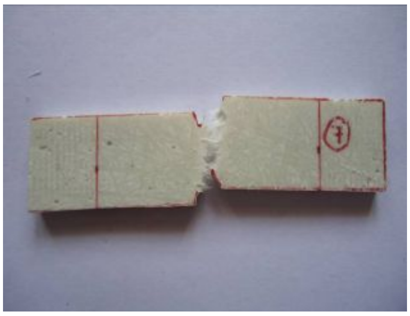

Figure.5.Tensile test specimen **Figure.6.Flexural test specimen** **Figure.7.Shear test specimen**

The tensile strength, flexural strength and shear strength of the GFRP improved very much with addition of nano TiO_2 filler particles. The tensile strength, flexural strength and shear strength of the GFRP also increased with weight percentage of nano TiO_2 particles content in the matrix.

The toughening mechanisms due to the addition of particles to polymers are localised inelastic matrix deformation and void nucleation, particle debonding, crack deflection, crack pinning, crack tip blunting, particle deformation or breaking at the crack tip [12]. Addition of alumina nanoparticles to the epoxy resin matrix material was shown to lead to improved tensile properties. However, amount, type and distribution of nanoparticles seem to determine whether the matrix properties will improve or deteriorate [13]. The quality of the interface in composites, i.e. the static adhesion strength as well as the interfacial stiffness, usually plays a very important role in the materials' capability to transfer stresses and elastic deformation from the matrix to the fillers. This is especially true for nanocomposites, because they impart a high portion of interface compared to microcomposites. If the filler matrix interaction is poor, the particles are unable to carry any part of the external load. In that case, the strength of the composite cannot be higher than that of the neat polymer matrix. If the bonding between the fillers and matrix is instead strong enough, the yield strength of a particulate composite can be higher than that of the matrix polymer [14]. The mechanical properties of the GFRP improve with addition of nano TiO_2 filler particles because of higher resistance to forces, due to good distribution of high strength nano TiO_2 filler particles and decrease of polyester in the matrix. The gradual increase in tensile strength, flexural strength and shear strength of the GFRP reveals that the stresses are efficiently transferred via interface. The synergistic effect of nano TiO_2 filler particles, GFCSM and polyester results in enhancement of the mechanical properties.

Conclusion

In the present work glass fiber reinforced plastics with nano TiO_2 particle fillers was manufactured by the hand layup method. The tensile strength, flexural strength and shear strength of the GFRP improved very much with addition of nano TiO_2 filler particles. The tensile strength, flexural strength and shear strength of the GFRP also increased with weight percentage of nano TiO_2 particles content in the matrix.

References

1. Vogelesang, L.B., Vlot, A., Development of fibre metal laminates for advanced aerospace structure. J. Mater. Process. Technol., 2000; 103: 1–5.
2. Kim, K.S., Bae, K.M., Oh, S.Y., Seo, M.K., Kang, C.G., Park, S.J., Trend of carbon fiber reinforced composites for lightweight vehicles, Elastomers Compos., 2012; 47: 65–74.
3. Caminero, M.A., Lopez-Pedrosa, M., Pinna, C., Soutis, C., Damage monitoring and analysis of composite laminates with an open hole and adhesively bonded repairs using digital image correlation, Composites Part B, 2013; 53: 76–91.
4. Singha, A.S., Thakur, V.K., Mechanical properties of natural fibre reinforced polymer composites, Bull. Mater. Sci., 2008; 31: 791–799.
5. Lei, Y., Wu, Q., Clemons, C.M., Yao, F., Xu, Y., Influence of nanoclay on properties of HDPE/wood composites, J. Appl. Polym. Sci., 2007; 106: 3958–66.

6. Lingaraju, D., Ramji, K., Mohan Rao, N.B.R., Rajya Lakshmi, U., Characterization and prediction of some engineering properties of polymer - Clay/Silica hybrid nanocomposites through ANN and regression models, Procedia Eng., 2011; 10: 9–18.
7. Adam Khan, M., Senthil Kumar, A., Machinability of glass fibre reinforced plastic (GFRP) composite using alumina-based ceramic cutting tools, J Manuf. Processes., 2011; 13: 67–73.
8. Tjong, S.C., Structural and mechanical properties of polymer nanocomposites, Mater. Sci. Eng. R, 2006; 53 : 73-197.
9. Reynaud, E., Jouen, T., Gauthier, C., Vigier, G., Varlet, J., Nanofillers in polymeric matrix: a study on silica reinforced PA6, Polymer, 2001; 42 : 8759-8768.
10. Wei-Ning, Wang., Wuled Lenggoro, I., Yoshitake Terashi., Tae Oh Kim., Kikuo, Okuyama., One-step synthesis of titanium oxide nanoparticles by spray pyrolysis of organic precursors, Mater. Sci. Eng. B, 2005; 123: 194–202.
11. Hamed Salehian., Seyyed Ahmad., Jenabali Jahrom., Effect of titanium dioxide nanoparticles on mechanical properties of vinyl ester-based nanocomposites, J. Compos. Mater., 2014; 0021998314546140, doi:10.1177/0021998314546140.
12. Battistella, M., Cascione, M., Fiedler, B., Wichmann, M.H.G., Quaresimin, M., Schulte, K., Fracture behaviour of fumed silica/epoxy nanocomposites, Composites Part A, 2008; 39: 1851–1858.
13. Drescher, P., Thomas, M., Borris, J., Riedel, U., Arlt, C., Strengthening fiber/matrix interphase by fiber surface modification and nanoparticle incorporation into the matrix, Compos. Sci. Technol., 2013; 74: 60–66.
14. Abdul Khalil, H.P.S., Fizree, H.M, Bhat, A.H., Jawaid, M., Abdullah, C.K., Development and characterization of epoxy nanocomposites based on nano-structured oil palm ash, Composites Part B, 2013; 53 : 324–333.

*****