

Mechanical Behaviour of Glass Fiber/Epoxy Modified with Nano Composites: A Review

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ABSTRACT: Composite material plays a vital role as it is a combination of two or more materials that results in better properties than those of the individual components used. Major proportion of engineering materials consists of composite materials. Composite materials have been used in vast applications ranging from day-to-day articles to highly sophisticated applications. This present investigation is to study the mechanical properties of glass fiber/epoxy resin modified with nano composite which is been manufactured by hand layup and compression molding method. The glass fiber used in this investigation is E-glass fiber : orientation(0°-90°). The composite samples are made in the form of laminates and the weight percentage of nano material added to the specimen is varied from 1%wt-7%wt. The mechanical properties are studied for all samples and optimum nano material weight percentage is determined.

KEYWORDS: Glass fiber, Epoxy, Nanoclay, Compression molding.

I. INTRODUCTION

A composite is combination of two materials in which one of the materials is called the reinforcing phase, is in the form of fibers, sheets, or particles, and is embedded in the other materials called the matrix phase. The reinforcing material and the matrix material can be metal, ceramic, or polymer. Composites typically have a fiber or particle phase that is stiffer and stronger than the continuous matrix phase and serve as the principal load carrying members. The matrix acts as a load transfer medium between fibers, and in less ideal cases where the loads are complex, the matrix may even have to bear loads transverse to the fiber axis. The matrix is more ductile than the fibers and thus acts as a source of composite toughness. The matrix also serves to protect the fibers from environment damage before, during and after composite processing. When designed properly, the new combined material exhibits better strength than would each individual material. Composites are used not only for their structural properties, but also for electrical, thermal, tribological, and environmental applications.

The following are some of the reasons why composites are selected for certain applications: 1. High strength to weight ratio (low density high tensile strength) 2. High creep resistance 3. High tensile strength at elevated temperatures 4. High toughness. Over 95% of the fibers used in reinforced plastics are glass fibers, as they are inexpensive, easy to manufacture and possess high strength and stiffness with respect to the plastics with which they are reinforced. Their low density, resistance to chemicals, insulation capacity are other bonus characteristics, although the one major disadvantage in glass is that it is prone to break when subjected to high tensile stress for a long time.. However, it remains break-resistant at higher stress-levels in shorter time frames. This property mitigates the effective strength of glass especially when glass is expected to sustain such loads for many months or years continuously.

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Epoxy resin is one of the excellent thermosetting polymer resins. The cost-to-performance ratio of epoxy resin is outstanding. Epoxy resins possess characteristics such as high strength low creep, good adhesion to most of the substrate materials, low shrinkage during curing and low viscosity. Due to these reasons epoxy resins are significantly used as matrix material in many applications such as aerospace, structural applications, ship building, and automobile industries and so on. Glass fiber and epoxy are mixed in the ratio of 1:1 for better mechanical properties[1]. The tensile strength and the tensile modulus of Glass fiber/Epoxy composite increases in fiber loading and the addition of Nanoclay particles to the Glass fiber/ Epoxy composite increases the inter fiber fracture strength[4]. Agglomeration of Al₂O₃ micro particles in the matrix is because of bigger particle size of Alumina [6]. Nanoclay particles possess good properties because of smaller particle size. When the content of Nanoclay is increased beyond an optimal level then the mechanical properties of the resultant composites decreases. The percentage of Nanoclay to be used should be restricted to 5 wt% in order to get good mechanical properties of the composites[8].

Fibre	Specific density	Modulus of elasticity (GPa)	Tensile strength (GPa)
E-glass	2.50	75	5.5
Carbon	2.00	75	0.5-1.0
Boron	2.60	170-200	3.0-3.5
Asbestos	2.5	160	2.0

Table 1: Tensile strength of fibers



Figure 1: Glass fiber in woven fabric form



Figure2: Glass fiber in string form

II. LITERATURE REVIEW

Pyeong-Su Shin et al [1] has investigated according to mixing ratio of two epoxy matrices. Novolac type epoxy and isocyanate modified epoxy were used as composites matrix. Based on chemical composition of mixing matrix, optimum mixing ratio of epoxy resins was obtained through FT-IR instrument. In order to investigate thermal stability and interface of epoxy resin, glass transition temperature was observed by DSC instrument, and static contact angle was measured by reflecting microscope. Change of IR peak and T_g was conformed according to different epoxy mixing ratios. After fabrication of glass fiber/epoxy composites, tensile, compression, and flexural properties were tested by UTM by room and high temperature. The composites exhibited best mechanical properties when epoxy mixing ratio was 1:1.

J.L. Thomason et al [2] said that the present work focuses on further investigation of the hypothesis that a significant fraction of apparent interfacial shear strength (IFSS) in fibre-reinforced composites can be attributed to a combination of residual radial compressive stress and static friction at the fibre-polymer interface. The temperature dependence of the interfacial properties of a glass fibre-epoxy system has been quantified using the laboratory developed TMA-microbond technique. The temperature dependence of apparent IFSS of glassfibre-epoxy in the range 20°C up to 150°C showed a significant inverse dependence on testing temperature with a major step change in the glass transition region of the epoxy matrix. It is shown that the magnitude of the residual radial compressive stress at the interface due to thermal and cure shrinkage is of the same order of magnitude as the measured IFSS. It is concluded that it possible to suggest that residual stress combined with static adhesion could be the major contributor to the apparent interfacial adhesion in glass fibre-epoxy systems.

Rim Ben Toumi et al [3] have performed static and fatigue tension testson continuous E-glass fibre reinforced epoxy composite. All tests were followed by non-destructive techniques: acoustic emission records (AE) and microscopic observations in addition to stiffness monitoring with an extensometer in order to investigate damage mechanisms occurring under both static and fatigue loadings. The data obtained were used to identify the modes of damage and its effects on the macroscopic behaviour of the composite material under both static and fatigue loading. Then, a fatigue model was used to predict the fatigue life of the composite under tension-tension cyclic tests. This model reduces drastically the number of fatigue tests required to obtain S-N curves. Experimental data were in excellent agreement with model predictions.

Lars Böger et al [4] said that fatigue properties of glass fibre reinforced epoxy laminates modified with small amounts (0.3 wt.%) of nanoparticles (fumed silica SiO₂ and multi-wall carbon nanotubes (MWCNT)) were evaluated by means

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of static (90-tensile and stepped tensile) and dynamic fatigue tests. For the MWCNT-modified matrix, the electrical conductivity was measured in situ. The addition of nanoparticles lead to increases in inter fibre fracture strength of up to 16%. More significantly, the high cycle fatigue life is increased by several orders of magnitude in number of load cycles. The increased inter fibre fracture strength could be correlated to the improved fatigue behaviour, as final failure in high cycle fatigue is strongly correlated to matrix cracks. For the MWCNT-modified composites, the state of load and damage state was monitored by conductivity measurements. A correlation between the onset of matrix cracking and increase in electrical resistivity could be drawn enabling self sensing capabilities.

L.P. Borrego et al [5] Nanoparticle reinforcement of the matrix in laminates has been recently explored to improve mechanical properties, particularly the interlaminar strength. This study analyses the fatigue behaviour of nanoclay and multiwalled carbon nanotubes enhanced glass/epoxy laminates. The matrix used was the epoxy resin Biresin_ CR120, combined with the hardener CH120-3. Multiwalled carbon nanotubes (MWCNTs) 98% and organo-montmorillonite Nanomer 130 E nanoclay were used. Composites plates were manufactured by moulding in vacuum. Fatigue tests were performed under constant amplitude, both under tension-tension and three points bending loadings. The fatigue results show that composites with small amounts of nanoparticles addition into the matrix have bending fatigue strength similar to the obtained for the neat glass fibre reinforced epoxy matrix composite. On the contrary, for higher percentages of nanoclays or carbon nanotubes addition the fatigue strength tend to decrease caused by poor nanoparticles dispersion and formation of agglomerates. Tensile fatigue strength is only marginally affected by the addition of small amount of particles. The fatigue ratio in tension-tension loading increases with the addition of nanoclays and multi-walled carbon nanotubes, suggesting that both nanoparticles can act as barriers to fatigue crack propagation.

Ramesh K. Nayak et al [6] has said that fiber reinforced polymer composite is an important material for structural application. The diversified application of FRP composite has taken centre of attraction for interdisciplinary research. However, improvements on mechanical properties of this class of materials are still under research for different applications. In this paper we have modified the epoxy matrix by Al_2O_3 , SiO_2 and TiO_2 micro particles in glass fiber/epoxy composite to improve the mechanical properties. The composites are fabricated by hand lay-up method. It is observed that mechanical properties like flexural strength, flexural modulus and ILSS are more in case of SiO_2 modified epoxy composite compare to other micro modifiers. This may be because of smaller particle size of silica compare to others. Alumina modified epoxy composite increases the hardness and impact energy compare to other modifiers. Agglomeration of Al_2O_3 micro particles in the matrix is observed in SEM. This may be because of bigger particle size of Alumina. SEM analysis clearly indicates the mode of failure is the combination of crack in matrix, matrix/fiber debonding and fiber pull out for all types of composites.

C.M. Manjunatha et al [7] has modified anhydride-cured thermosetting epoxy polymer by incorporating 10 wt% of well-dispersed silica nanoparticles. The stress-controlled tensile fatigue behaviour at a stress ratio of $R = 0.1$ was investigated for bulk specimens of the neat and the nanoparticle-modified epoxy. The addition of the silica nanoparticles increased the fatigue life by about three to four times. The neat and the nanoparticle-modified epoxy resins were used to fabricate glass fibre reinforced plastic (GFRP) composite laminates by resin infusion under flexible tooling (RIFT) technique. Tensile fatigue tests were performed on these composites, during which the matrix cracking and stiffness degradation was monitored. The fatigue life of the GFRP composite was increased by about three to four times due to the silica nanoparticles. Suppressed matrix cracking and reduced crack propagation rate in the nanoparticle-modified matrix were observed to contribute towards the enhanced fatigue life of the GFRP composite employing silica nanoparticle-modified epoxy matrix.

Sivasaravanan.S et al [8] has said that composite materials possess high strength and high strength to weight ratio, and due to these facts composite materials are becoming popular among researchers and scientists. The major proportion of engineering materials consists of composite materials. Composite materials are used in vast applications ranging from day-to-day household articles to highly sophisticated applications. In this present investigation hybrid composites of Epoxy/Nanoclay/Glass fiber were prepared by Hand-layup technique. The glass fiber used in this present investigation

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is E-glass fiber bi-directional: 45° orientation). The composite samples were made in the form of a plate. The wt% of nanoclay added in the preparation of sample was varied, ranging from 1wt% to 5wt%. The fabricated composite materials in the form of plate were cut into corresponding profiles as per standards for impact testing.

Marino Quaresimin et al [9] has said that present work illustrates the experimental results of a project aiming to assess the benefits deriving from the matrix nanomodification of composite laminates made by vacuum infusion of woven glass fabrics. The following properties have been investigated: mode I fracture toughness and crack propagation resistance for neat and clay-modified epoxy, interlaminar shear strength, mode I delamination resistance for base and clay-modified epoxy laminates. Available results indicate a significant improvement in the fracture toughness and crack propagation threshold of clay-modified epoxy. However, due to the nanofiller morphology, the behaviour of clay-modified laminates is still almost comparable to that of the base laminates.

S. Helmy et al [10] has investigated tensile fatigue behavior of tapered glass/epoxy laminates. The effect of nanoclay addition into the epoxy resin is examined. It is shown that the relative orientation between the adjacent belt layer and the cut layer has important influence on the fatigue life. The fatigue crack starts at the resin pocket and propagates along the interface between the belt layer and the core layer in the thicker section of the laminate. Crack propagation is mainly due to mode II crack failure. The addition of the clays enhances the resistance against this mode II crack propagation, and thus prolongs the fatigue life of the laminate.

M. S. Senthil Kumar et al [11] has performed to profoundly study the tribological property of various nano clay (Cloisite 25A) loaded epoxy, with and without inclusion of E- Glass fiber using Taguchi's technique. For this purpose, the test Samples were prepared according to the ASTM standard, and the test was carried out with the assistance of Pin-on-Disc machine. To proceed further, L25 Orthogonal array was constructed to evaluate the tribological property with four control variables such as filler content, normal load, sliding velocity and sliding distance at each level. The results indicated that the combination of factors greatly influenced the process to achieve the minimum wear and coefficient of friction. Overall, the experiment results depicted least wear and friction coefficient for fiber reinforced laminates. In the same way, appreciable wear and friction coefficient was noted for without fiber laminates. Additionally, the S-N ratio results too exhibited the similar trend. Moreover, ANOVA analysis revealed that the fiber inclusion on laminates has lesser contribution on coefficient of friction and wear when compared to without fiber laminates. At last, the microstructure behavior of the test samples was investigated with an assistance of scanning electron Microscope (SEM) to analyze the surface morphology.

B Sharma et al [12] has investigated that polymer composites have been the mainstay of high-performance structural materials, but these materials are inherently sensitive to environmental factors such as temperature, exposure to liquids, gases, electrical fields and radiation, which significantly affects their useful life. Addition of layered silicate nanofillers in the polymer matrix has led to improvements in the elastic moduli, strength, heat resistance, decreased gas permeability and flammability. In the present work epoxy modified with Cloisite 30 B® nanoclay (at 1, 3 and 5 wt% of resin) and E-glass unidirectional fibers are used to prepare fiber reinforced nanocomposites using hand lay-up method. The nanocomposites have been characterized by X-ray diffraction (XRD) and scanning electron microscopy (SEM). XRD results show that the interlayer spacing between the clay platelets increased significantly indicating that the polymer is able to intercalate between the clay layers. The mechanical properties are measured by carrying out tensile, hardness and flexural tests and values are compared with those found for fiber reinforced neat epoxy composites. The tests show that an addition of nano-clay up to 3 wt% increases tensile strength and micro-hardness and there is a decrease in values with further clay addition up to 5 wt%. The flexural strength increased significantly with clay loading and the highest value is observed for specimens with 5 wt% of clay. Further, durability studies on nanocomposites have been performed in water and NaOH baths under accelerated hygrothermal conditions. During the exposure it is observed that the degradation in NaOH environment is more severe than in water.

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III.CONCLUSION

Thus it is clear from the literature survey that glass fiber/epoxy resin reinforced with nano material has improved mechanical properties. Thus the proper orientation of fiber and bonding is done with nano material weight percentage (1%,3%,5%). Addition of Nanoclay to Glass fiber/Epoxy composites increases the interfacial shear strength tremendously. When the addition of filler materials to Epoxy/Glass fiber composite is increased then the thermal expansion coefficient of the corresponding composite gets reduced. The fiber/matrix interface plays a vital role in determining the mechanical properties of glass fiber composites. When the content of Nanoclay is increased beyond an optimal level then the mechanical properties of the resultant composites decreases. The percentage of Nanoclay to be used should be restricted to 5 wt% in order to get good mechanical properties of the composites.

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