Effect of Silicon Carbide Fillers on the Mechanical Properties of Glass Fibre Reinforced Epoxy Polymer Composite

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Abstract - *Fiber reinforced polymer composites have excellent candidature for fulfilling the aspects with varying applications in most areas of automotive and aerospace industries. The current work deals with the fabrication and mechanical characterization of glass fiber reinforced epoxy polymer (GFREP) composites comprising Silicon carbide as Micro and Nano filler. Addition of varying particle size of fillers augments the mechanical properties of the polymer matrix composite. The composite with different fiber morphology (Micro filler & Nano filler) are fabricated by simple Hand layup method. The samples are processed according to ASTM standards. Experiments like tensile test, three-point bending testing and hardness test are conducted to find the significant influence of micro and nano Silicon Carbide filler material on mechanical characteristics of GFREP composite. The results of the tests relating to micro and nano fillers are correlated.*

***Key Words*: Glass Fibre, epoxy polymer, silicon carbide Micro and Nano Fillers, hand layup method, tensile test, three-point bending test, hardness test.**

1. INTRODUCTION

Composite materials are a mixture of two or more materials, which differ in chemical composition and physical properties which gives rise to material having properties such as high specific stiffness, specific strength, low thermal expansion, good fatigue resistance and stability for manufacturing of intricate shaped components. Composites commonly include matrix, such as polymer, fibers and fillers. K. Devendra et al. [1] found that the various types of glass fiber are used as reinforcements in polymer matrix composites. Among all of them, E-Glass fibers are most generally used fibers because of high strength, low weight and has good heat resistance, cold resistance, moisture and corrosion resistance.The assorted Glass fibre reinforcements like long longitudinal, woven mat, chopped fiber (distinct) and chopped mat within the composites are produced to reinforce the mechanical properties of the composites. S. Prabhakaran el al. [2] found that the efficiency of glass fiber reinforced epoxy composite bumper was more as compared to steel made bumper. It showed that the factor of safety was 64% higher for GFRP composite made bumpers. There was a reduction of 53.8% wt in case of composite as compared to steel made bumper. There was improvement in impact strength of composite. So it was concluded that glass fiber reinforced epoxy composite can be used for production bumper for saving fuel cost and strength purposes. The rigidity and strength of polymeric materials are less by 25 times compared to glass, while its thermal expansion is larger than 25 times that of glass. Generally, the diameter of those glass fibers is within the range of 5 to 15 mm. Godara et al. [3] studied the tensile behaviour of Glass fiber reinforced epoxy composite with three different woven fibers orientations such as [0], [45] and [90]. The 35 wt.% of short borosilicate glass fiber reinforced with multilayered cross woven composite with epoxy matrix. The stress versus strain curve indicated that the tensile strength was strongly based on the fiber orientation to the external load, [0/90] laminate composites had the highest failure strength (355MPa), low ductility and low strain failure (1.65%) than [45]. Patnaik A et.al. [4] have investigated that the mechanical behaviour of randomly oriented E-glass fiber reinforced epoxy composites with particulate filled with Al_2O_3, SiC and pine bark dust and the various composition of samples were produced such as glass fiber (50wt%) +epoxy (50wt%), glass fiber (50wt%) +epoxy (40wt%) +alumina (10wt%), glass fiber (50wt%) +epoxy (40wt%)+pine bark dust (10wt%), glass fiber (50wt%)+epoxy (40wt%)+SiC (10wt%). The test result indicates the glass fiber+epoxy had maximum tensile strength (249.6MPa) and flexural strength (368MPa) than other compositions, glass fiber+epoxy+pine bark dust combination having the maximum interlaminar shear strength (23.46MPa), glass fiber+epoxy+Silicon Carbide combination having greater impact strength (1.840J) and higher hardness (42 Hv). Epoxy resins are universally used as matrix in most of the fibre reinforced composite as they are a category of thermoset materials which provide ionic balance between chemical and mechanical properties. Chandra Sarath et al. [5] noted a similar decrease in the value of tensile strength when blending glass fiber with that of SiC filler. This is because Silicon Carbide particles behave as a barrier during elongation as the tensile force is applied at both ends of the composite sample. Though the composite is strengthened by fibrous material the micro and nano load sharing fillers are very important in high strength composite preparation. Silicon carbide commonly called as carborundum is extensively used as abrasives or fillers in ceramic refining abrasives, resin polishing wheels, and diamond polishing wheels. Thanks to its excellent properties like high hardness, high strength, outstanding oxidation resistance and wear resistance, SiC micro powder is additionally employed in non-grinding applications like refractory materials, engineering ceramics, and structural materials. Kavitha et al.(2012) [6] evaluated the impact behaviour of epoxy reinforced with micro and nano sized SiC particles and found that nano sized silicon Carbide particles are having higher impact strength compared to micro sized particles. Naeimirad et al. [7] evaluated the effect of filler content and filler shape on the physical and mechanical properties of silicon carbide or epoxy nanocomposites using Silicon Carbide nanoparticles and nanowhiskers. They identified that mechanical properties improved by 20% and 40% in Silicon Carbide nanoparticles (1 wt%) and nanowhisker (2 wt%) reinforced specimens respectively. A nanoparticle size that has a higher aspect ratio of surface area to volume than that of large-sized particles makes nano-size distinctions in the physical network. These characteristics are reflected as advantages in enhanced thermo-mechanical properties of the composite. Therefore, the current work objective is to identify so as how the incorporation of micro and nano Silicon Carbide fillers alter the mechanical properties of the glass fibre epoxy reinforced composites. Much research work has been already carried out for testing the mechanical properties of the Glass Fiber Reinforced Polymer composites and this section focuses on it. Literature review of such work needs to be done in a way to understand the background information accessible, the work already done and also to show the implication of the current work.

2. MATERIAL AND METHODS

Different kinds of material categories are employed in this work. Details about these materials are presented in Table 1-3. These materials are combined and reinforced to form the desired composite.

2.1 Materials

Raw Materials used:- E class glass fibre is a material that comprises exceedingly fine fibres of glass. It is light in weight, extremely strong and robust. It is formed when thin strands of silica glass are extruded into many fibres. Its massive strength and weight properties are also immensely favorable when compared to metals, and it can be easily formed by molding processes. It is used as a supportive agent for composites to form a very strong and light fibre reinforced polymer composite material.

Table -1: Properties of E-Glass Fiber

Properties of E-Glass Fiber	
Property	E-Glass Fiber
Density (gm/cm^3)	2.55-2.6
Modulus of elasticity (GPa)	72-85
Tensile Strength (MPa)	1950-2050
Poisson’s Ratio	0.21-0.23

Epoxy resin has been an effective matrix material used in the improvement of advanced composite materials because of its exemplary properties like: high strength, high adhesion to substrates, high electrical insulation, low toxicity, low shrinkage, low cost and high compliance to various operations and applications. They bear fatigue strength higher than aluminum alloy.

Table -2: Properties of Epoxy Resin

Properties of Epoxy Resin	
Properties	Epoxy Resin
Density(gm/cm3)	1.2
Tensile Strength (MPa)	65
Young’s Modulus (GPa)	2.2
Flexural Strength (MPa)	95
Izod impact toughness(J)	0.43
Fracture toughness (MPa)	24.8

Silicon carbide is produced by combining carbon and silica sand in an Acheson graphite electric resistance furnace at an elevated temperature. Silicon carbide crystal lattice structure is a coordinated tetrahedron combination of carbon and silicon atoms with high covalent chemical bonding in the crystal lattice. Silicon carbide is the one of the best filler materials that is being employed in composite for it's hard synthetic nature and in addition to hardness, silicon carbide crystals have fracture characteristics that make them exceedingly useful in grinding wheels , cloth products and in abrasive paper. Its high thermal conductivity, along with its high-temperature strength, low thermal expansion, and resistance to chemical reaction, makes silicon carbide notable in building of high-temperature bricks and other refractories.

Table -3: Properties of Silicon Carbide

Properties of Silicon Carbide	
Properties	Silicon Carbide
Density(gm/cm^3)	3.3

Tensile Strength (MPa)	586
Elastic Modulus (GPa)	410
Hardness (Kg/mm^2)	2800
Flexural Strength (MPa)	550

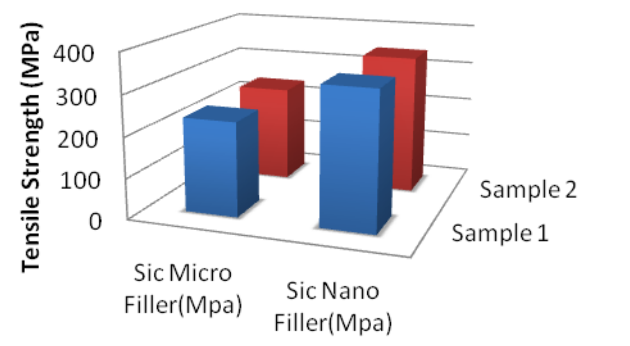
2.2 Fabrication of samples

The mechanical behaviour of a composite purely falls on the strength and modulus of the fiber and matrix which in turn depends upon the chemical interface bonding between the fiber and matrix. Studies over a decade have shown that the hand layup process of making composites is more efficient than other composite making methods. Woven glass fibre having elastic modulus of 75 GPa and 2.56 gm/cm3 density is utilised for reinforcement. The commercially available epoxy resin Lapox L12 having 1.20 gm/cm3 density is used as matrix material. Lapox L12 is a liquid, unmodified epoxy resin of medium viscosity which can be used with various hardeners for making glass fibre reinforced composites. Micro and nano SiC particles used as filler material in this study are 25-40μm and 30-50nm respectively. The selected percent of SiC micro and nano filler is 5 wt.-%, added to the known amount of Epoxy resin. Hardener K6 is a low viscosity room temperature curing liquid hardener. It is commonly employed for hand layup applications. Being rather reactive, it gives a short pot life and rapid cure at normal ambient temperatures. It is used as hardener and is mixed completely in the mixture of resin and SiC fillers before the reinforcement process. The mixtures are stirred mechanically to ensure uniform distribution of SiC fillers. The composites were prepared by blending 5% weight percentage of fiber/filler and epoxy resin in separate containers and then poured in a mold of desired dimensions. The composite laminates having size of 250 mm × 250 mm × 4 mm are prepared. Water Jet machining is used to cut the samples into suitable dimensions of the specimens for experimental work. Samples thus created are used for testing.

3. TESTS, RESULTS AND DISCUSSION

3.1 Tensile Strength

The tensile test is normally performed on flat specimens. The specimen is subjected to uniaxial load through both the ends. The ASTM Standard Test method for tensile properties of fibre resin composites has the description D638. In present work, this test is performed in the universal testing machine (UTM) maximum of 100 kN at a crosshead speed of 10 mm/min and the results are used to calculate the tensile strength of composite samples. Tensile strength of micro and nano filler filled composites is represented in Figure 1. Tensile strength of nano filler filled composite is higher than micro filler filled composite for 5 wt% SiC filler loading. Tensile strength differs with micro and nano filler materials because of variation in fillers size and compatibility of fillers with the matrix material.

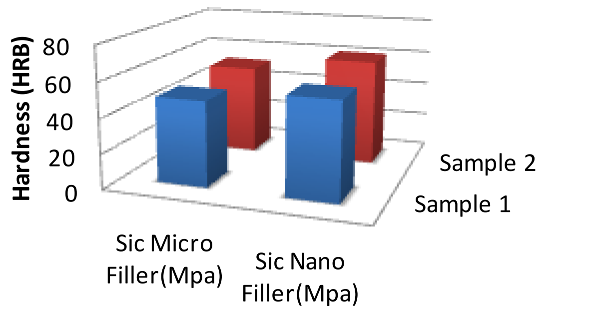


	Sic Micro Filler(Mpa)	Sic Nano Filler(Mpa)
Sample 1	232.7	337.5
Sample 2	239	344.26

Chart -1: Tensile strength of micro and nano SiC filled composites

3.2 Hardness

Hardness is generally considered as resistance to penetration. The harder the material, the greater is the resistance for penetration. Hardness is directly related to the mechanical properties of the material. Factors influencing hardness include crostructure, grain size, strain hardening, etc. The samples were operated in a standard Rockwell B hardness tester (981N).The 1.59mm diameter steel ball indenter with an applied load of 100 kg was used. Four different areas in the composite sample surface were used to determine the hardness value, and after the determination of hardness the mean value was obtained for further calculation. Hardness of the fabricated composites is plotted in Figure 3. It is witnessed from Figure 3 that the woven glass fibre-epoxy composites manifest superior hardness with the reinforcement of the fillers. Micro filler reinforced composites have lower value of hardness than nano filled composites for 5 wt% SiC filler loading.

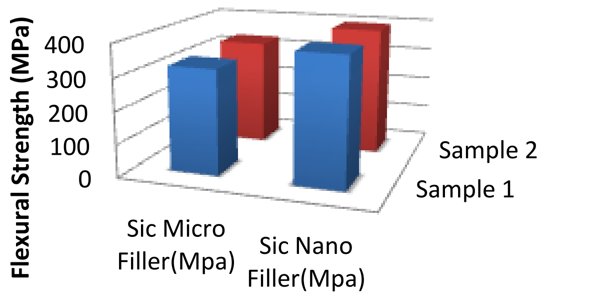


	Sic Micro Filler(Mpa)	Sic Nano Filler(Mpa)
Sample 1	49	56
Sample 2	52	61

Chart -2: Hardness of micro and nano SiC filled composites

3.3 Flexural Strength

The flexural test is used to evaluate the required power to bend a beam under a three-point loading system. Flexural strength is the capacity of the material to defy the bend under load. Specimens were prepared as per the ASTM D790 Standards of dimension 3.2mm x 12.7mm x 125mm. Under flexural loading, load bearing capacity of composites is enhanced by the fillers, which is contradictory to tensile loading where they act as stress raisers. Consequently, the compressive stresses generated act to shut micro-cracks and flaws in a direction perpendicular to the direction of applied stress, which is contradictory to the crack widening phenomenon in a tensile loading condition. Nano filler filled composites show greater flexural strength than micro filler filled composites because of stronger interface between the epoxy and SiC nano filler. Flexural strength increases by 21% and 19.77% for the two samples for nano filler filled composites in comparison with the flexural strength of micro filler reinforced composites. Flexural strength increases due to the presence of micro and nano fillers located at the interface of the matrix material and fibre.



	Sic Micro Filler(Mpa)	Sic Nano Filler(Mpa)
Sample 1	323	391
Sample 2	330.45	395.8

Chart -3: Flexural strength of micro and nano SiC filled composites

4. CONCLUSIONS

Reinforcing of glass fibers in polymer matrix composites is very common and material thus created is used in many engineering applications. Addition of small amounts of foreign particles (silicon carbide) of micro-size and nano-size improves the mechanical properties of the composites significantly. The vital finding of this research work on mechanical properties of micro and nano SiC filler filled glass fibre reinforced epoxy polymer composite are synopsized below for better acknowledgment :

1. Integration of precise filler in epoxy improved the load bearing capacity (tensile strength) of the glass fibre epoxy composites. The increase in tensile strength with the inclusion of fillers can be observed because under the action of a tensile force, the filler-matrix interface is strong in bonding depending on interfacial bond strength and this may lead to strength in the composite. The tensile strength of nano filled composites is found to be higher than micro SiC filled composites, certainly the crack arresting capacity of nanocomposites is increased with more number of particles per unit volume as compared to microcomposites.
2. A hardness of 58 HRB is observed for SiC 5 wt% Nano composite which is highest in this experiment. Hardness of nano SiC filled nanocomposites is higher than micro SiC filled microcomposites. This has probably happened because the number of particles in per unit area of nanocomposites is high when compared to microcomposites, and therefore enhances the resistance of these composites to the indenter of the machine. Hardness test results provide a scope for grading different materials which will be of use in deciding the suitability of material for a specific application.
3. Integration of precise filler in epoxy improved the ability to survive bending (flexural strength) of the

glass fibre epoxy composites. Nano SiC filled composite at 5 wt% filler loading performed better as compared to micro SiC filled composites. Better interfacial bonding of nano fillers with the matrix material is a prime reason to enhance the flexural strength of nanocomposites. Nano SiC composite has maximum flexural strength compared to Micro SiC filled composite, i.e., 393 MPa and 327 MPa, respectively.

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