International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Physical and Mechanical Characteristic of Chopped E-Glass Fiber Reinforced Epoxy Composites

Yadram Singh[1], Sushil Kumar Bagga[2], O.P Jakhar[3], Dr. R.J. Patil[4]

[1]Research Scholar, Department of Mechanical Engineering, Bhagwant University, Ajmer, India

[2,3,4]Associate Professor, Department of Mechanical Engineering, Bhagwant University, Ajmer, India

Abstract

The consequence of addition of SiC filler in different w% on specific characterization of chopped glass fiber reinforced epoxy composites has been explored. Attempts have been made to investigate the possible use of Silicon Carbide (SiC) as filler materials in these composites. The glass epoxy composite without filler has strength of 90.92 MPa in tension at maximum load 4.64 kN and this value drops to 78.82 MPa with addition of 5wt% filler and increase with addition of 10wt% SiC respectively. The glass epoxy composites without filler have a maximum tensile modulus and also increase with increasing filler. The glass epoxy composite without filler has a flexural strength of 126.18 MPa at maximum load 2.57 kN,flexural strength increase with increasing particulate filler. Flexural modulus also increases with increasing load and particulate filler. Erosion characteristics of these composites have been successfully analyzed using Taguchi experimental design scheme.

Keywords: Mechanical properties, SiC filler, chopped E- glass fiber, epoxy resin,

1. INTRODUCTION

A composite material is made by combining two or more dissimilar materials. They are combined in such a way that the resulting composite material or composite possesses superior properties which are not obtainable with single constituent materials. the most common synthetic composite material is glass fiber reinforced plastics(GRP) due to high strength and sufficiently stiff and durable. Composites are materials consisting of two or more chemically distinct constituents on a micro- scale having a distinct interface separating them. One or more discontinuous phase are therefore, surrounded in a continuous phase to appearance a composites [1]. When the matrix is a a ceramic, the composite is called ceramic matrix composite (CMC) and when the matrix material is a polymer, the composite is called polymer matrix composite (PMC).

Due to operational requirements in grimy environment, the erosion characteristics of these composites have essential importance. Since erosive wear of engineering components caused by abrasive particles is a major industrial problem, a complete accepting of the effects of all system variables on the wear rate is necessary in order to assume appropriate steps in the design of machine or structural component and in the choice of materials to reduce/control wear. The most common synthetic composite material is glass fiber reinforced plastics (GRP) which is made out of plastics and glass fiber. Fiber reinforcement polymer composites used in aircraft, helicopters, space-craft, satellites, ships, submarines, automobiles and transportation industry, chemical engineering industry, defence industry, sporting goods and civil infrastructure. There is a potential for common use in medical prosthesis and micro devices. Composites are important materials because of their light weight, high strength, durability, stiffness, excellent fatigue resistance and outstanding corrosion resistance compared to most common metallic alloy such as steel and iron. Advantages of composites include the ability to fabricate, improves mechanical properties, low thermal expansion coefficients and high dimensional stability.

Composite materials are usually costlier as compared to conventional materials but at rest their use is becoming more and more popular because of their lightness, high specific properties, design and processing flexibility, functional superiority and durability. Mostly, composites used in engineering applications contain fibers made of glass, carbon or aramid. The fiber used in FRP materials can be in the form of small particles, whiskers or continuous filament. The matrix materials employed for fabrication of composite materials are usually polymers commonly called resins. Polymers are thermosetting(e.g.phenol- furfural, urea- formaldehyde, epoxy, polyester) and thermoplastic(e.g. cellulose nitrite,polymides, polyvinyl alcohol , polyisobutylene) resins.composite materials possess a unique combination of properties such as high strength to weight ratio,better toughness, fatigue and stiffness, better corrosion, fire resistance, electrical insulation and anti- friction properties,easy of fabrication or versatility of fabrication methods, better durability and low maintenance cost.Continuous fiber composites are characterised by a two- dimensional (2D) laminated stracture in which the fibers are aligned along the plane(x-and y- directions) of the material. The use of FRP composites continuous to grow at any impressive rate as these materials are used more in their exixting markets and become established in relatively new markets such as biomedical devices and civil structures [2].

Polymer matrix reinforced composites by woven fabrics is probably the most commonly used form of composites in structural application such as air craft, boats, automobiles, etc. The aircraft industry is an motivating application area for new types of quickly manufactured composites because they use prolonged high temperature curing processes for fabrication of composite parts, which is acceptable if high performance materials or high utilization temperatures are required [3].The physical and mechanical characteristics can further be modified by adding a solid filler phase to the matrix composite during the preparation. The improved performance of polymers and their composites in industrial and structural applications by the addition of particulate filler materials has shown a vast secure and so has lately been a subject of considerable interest. Fillers (additives) are added to enhance and modify the quality of composites. The filler play a major role in determining the properties and behavior of particulate reinforced composite materials .these are invariably used in reasonably large loadings (above 15%). Filler are commonly additional to reduce cost, to recover processing properties and mechanical /electrical/physical properties. The terms additives describes those materials usually added to matrix. The additives are usually added to improve some specific properties e.g surface, thermal, environmental-and they are added in smaller loadings(less than 10%).

There are many examples of these applications are pipe lines carrying sand slurries in Petroleum refining, Helicopter rotor blades [4], Pump impeller blades, high speed vehicles and aircrafts operating in desert environment, water turbines, air craft engines [5]. Studies made on the erosive wear of composites refer more on fiber reinforced polymers (FRP) and less on filler–reinforced – systems. The effect of fibers is considered more as modification of the matrix and less as reinforcement, possible because of the low % of fillers.

The focus has been on fabrication of a series of composites (glass- fiber-reinforced epoxy composites with and without fillers), evaluation of their mechanical and physical properties.

2. Materials Required

Chopped E-glass fiber (5 to 10 mm long, 200 gm/ m^3 density) manufactured by Ciba Geigy and locally supplied by northern polymers Ltd, is used as a Fiber Reinforcement. Commercially existing SiC powder also known as carborundum of particle size 30 to 120 μm (density 3.216 g/cm^3), is used as a particulate filler. The matrix material consist of a epoxy resin. LY 556 and room-temperature curing hardener HY95. The composites fabricated by blending epoxy resin, glass- fiber, and SiC filler in certain weight percentage reinforcement. Five different composition of composites were prepared by varying the SiC filler reinforcement with fixed weight percentage (wt.%) of chopped E- glass fiber reinforcement. SiC filler in five different weight percentage (0wt%,5wt%, 10wt%,15wt%,20wt%) are added with fixed 40 wt.% of chopped glass fiber and remaining epoxy so as to notice the effect of SiC reinforcement.

Table 1.1 Density and Young's Modulus of Materials

S.No	Materials	Density	Young's modulus
1	Chopped E – glass fiber	2.5 g/ cm^3	72.5 GPa
2	Epoxy Resign	1.2g/cm^3	3.42 GPa

3. Composite Fabrication

The fabrication of the composite slabs is done by conventional hand-lay-up technique followed by light compression moulding technique. The low temperature curing epoxy resin and corresponding hardener (HY951) are mixed in a ratio of 10:1 by weight as recommended. Each ply of fiber is of dimension 200 × 200 mm^2. A stainless steel mould having dimensions of 210 × 210 × 40 mm^3 is used. A releasing agent (Silicon spray) is used to make easy subtraction of the composite from the mould after curing. The composites were prepared by blending certain weight percentage of fiber/filler and epoxy resins in certain containers and then poured in a mold of desired dimensions. Labelling was done with the help of rollers, and suitable weights are applied on top of the mold. Similarly, five different compositions of fibers, filler and epoxy resins are poured in separate molds by varying five percentage of SiC filler contained with that of the epoxy resins keeping the chopped of glass fiber weight percentage as constant (40wt%). The composites are then left for solidification at room temperature for 24 hours. After the solidifications process, the composites are then removed from the mold and marking is done as per the test standards. Specimens of proper dimension are cut using a diamond cutter for physical/ mechanical characterization and erosion wear testing. Extreme care has been taken to maintain regularity and homogeneity of the composites Specimens were prepared as per the American society for testing materials (ASTM) test standards for tensile, flexural, tests.

Table 1.2 Chemical Composition and physical properties of filler materials

Filler	Composition/ chemical formula	Hardness(H_v)	Density (gm/cm^3)
Silicon Carbide	SiC	2800	3.22

Table 1.3 Designations and detailed compositions of composites

Designation	Composition
A	Epoxy (60wt%) + Glass Fiber (40wt%) + SiC (0wt%)
B	Epoxy (55wt%) + Glass Fiber (40wt%) + SiC (5wt%)
C	Epoxy (50wt%) + Glass Fiber (40wt%) + SiC (10wt%)
D	Epoxy (45wt%) + Glass Fiber (40wt%) + SiC (15wt%)
E	Epoxy (40wt%) + Glass Fiber (40wt%) + SiC (20wt%)

Table 1.4 Physical properties of various glass fibers

S. No	Fiber	Physical Properties

1	A glass	Higher durability,strength and electric
2	C glass	Higher corrosion resistance
3	D glass	Low dielectric constant
4	E glass	Higher strength and electrical resistivity
5	AR glass	Alkali resistance
6	R glass	Higher strength and acid corrosion
7	S glass	Highest tensile strength
8	S-2 glass	High strength, modulus and stability

4. Mechanical Characterizations

Density

The theoretical density (ρ_{ct}) of composite materials in terms of weight fractions of different constituents can easily be obtained as for the following equation given by Agarwal and Broutman [1].

$$\rho_{ct} = \frac{1}{\left(\frac{W_f}{\rho_f}\right) + \left(\frac{W_m}{\rho_m}\right)} \qquad \text{...... .... (1)}$$

Where, W and ρ present the weight fraction and density respectively. The suffixes f and m stand for the fiber and matrix respectively. Since the composites under this investigation consist of the components namely matrix, fiber and particulate filler, the expression for the density has been modified as

$$\rho_{ct} = \frac{1}{\left(\frac{Wf}{\rho f}\right)+\left(\frac{Wm}{\rho m}\right)+\left(\frac{Wp}{\rho p}\right)} \qquad \text{.......... (2)}$$

Where, the suffix p stands for particulate fillers. The actual Density (ρ_{ce}) of the composite, However, it can be determined experimentally by simple water immersion method. The volume fraction of voids (V_v) in the composites is calculated using the following equation

$$V_v = \frac{\rho_{ct}-\rho_{ce}}{\rho_{ct}} \qquad \text{............................. (3)}$$

Tensile Strength

The tensile test is normally performed on flat specimens. The dimension of the specimen is 175x17x3 mm and a uniaxial load is applied through both the ends. The ASTM Standard Test method for tensile properties of fiber resin composites has the description D 3039-76. In present work, this test is performed in the universal testing machine (UTM) INSTRON 1195 at a crosshead speed of 10 mm/min and the results are used to calculate the tensile strength of composite samples. Loading arrangement is shown in figure 3.3b.

Flexural Strength

The flexural strength of a composite is the maximum tensile stress that it can withstand during bending before reaching the breaking point. The three point bend experiment is conducted on all the composite samples in the Universal Testing Machine Instron 1195. The dimension of each specimen is 100x20x3 span length of 50 mm and the cross head speed of 10 mm/min are mentioned. The flexural strength of the composite specimen is determined using the following equation.

$$\text{Flexural Strength} = \frac{3PL}{2bt^2} \qquad \text{.................. (4)}$$

3. Mechanical Characterizations of the Composites

Glass fiber-epoxy composites

3.1 Density and volume fraction of voids

It may be noted that the composite density values calculated theoretically from weight fractions using Eq.(1) are not equal to the experimentally measured values. This variation is a measure of voids and pores nearby in the composites. It is obviously seen that with the decrease in fiber content from 0wt% to 10 wt%, there is a decrease in the void fraction. These things can lead to the swelling of the composite and reduce density. However, in all the three composites A, B and C, the volume fractions of voids are reasonably small (< 2.5%) and this can be recognized to the absence of particulate fillers in these composites.

$$\Delta V = \frac{[\rho_{ct} - \rho_{ex}]}{\rho_{ct}} \times 100 \qquad \text{....................... (1)}$$

3.2 Tensile Properties

The tensile test is normally performed on flat specimens. The dimension of the specimen is 175x17x3 mm and a uniaxial load is applied through both the ends. The ASTM Standard Test method for tensile properties of fiber resin composites has the description D 3039-76. In present work, this test is performed in the universal testing machine (UTM) INSTRON 1195 (figure 3.2a) at a crosshead speed of 10 mm/min and the results are used to calculate the tensile strength of composite samples. Loading arrangement is shown in figure 3.3b

3.2 (a) The Universal Testing Figure 3.2 (b) Loading arrangements for flexural test Machine (UTM) Instron 1195

3.3.3 Flexural Strength

The flexural strength of a composite is the maximum tensile stress that it can withstand during bending before reaching the breaking point. The three point bend experiment is conducted on all the composite samples in the Universal Testing Machine Instron 1195. The dimension of each specimen is 100x20x3 span length of 50 mm and the cross head speed of 10 mm/min are mentioned. The loading arrangement is shown in figure 3.2 (c). The flexural strength of the composite specimen is determined using the following equation.

Flexural Strength= $\frac{3PL}{2bt^2}$ .... (5)

Where, L = span length of the sample (mm)

P = Maximum load (Newton)

b = Width of specimen (mm)

t = thickness of specimen (mm)

Mechanical Characterization of the Composites

4.1 Glass fiber-epoxy composites (A, B, C, D, and E)

Density and volume fraction of voids

The hypothetical and precise densities along with the equivalent volume fraction of voids are presented in Table 4.1. It also may be distinguished that the composite density values calculated theoretically from weight fractions using Eq.1 are not equivalent to the experimentally measured values. This variation is a measure of voids and pores nearby in the composites. It is obviously seen that with the decrease in fiber content from 0wt% to 10 wt%, there is a decrease in the void fraction. These things can lead to the swelling of the composite and reduce density. However, in all the three composites A, B and C, the volume fractions of voids are reasonably small (< 2.5%) and this can be recognized to the absence of particulate fillers in these composites.

$$\Delta V = \frac{[\rho_{ct} - \rho_{ex}]}{\rho_{ct}} \times 100 \qquad .... (1)$$

Table 1.5 Measured and theoretical densities along with the void fractions of the Glass-epoxy composites with SiC particulate filler

Composition		Measured Density(ρ_{ex}) (gm/cm^3)	Theoretical Density(ρ_{ct}) (gm/cm^3)	Volume Fraction of voids(ΔV) = [ρ_{ct} - ρ_{ex}]/ ρ_{ct} × 100
A	Glass-Epoxy + 0 wt% filler	1.5342	1.5482	0.9042
B	Glass-Epoxy + 5wt% filler SiC	1.314	1.354	2.9542
C	Glass-Epoxy+10wt% filler SiC	1.628	1.717	5.1834
D	Glass-Epoxy+15wt% filler SiC	1.6307	1.748	6.7105
E	Glass-Epoxy+ 20 wt% filler SiC	1.745	1.897	8.0126

4.2 Tensile Properties

The data of sample test given in the below table: Rate – 10 mm/min; Temperature- 18 ºC;

Room temperature- 23.1 ºC

Table 1.6 Tensile Strength at Maximum Load

s.no	Specimen label	Modulus	Tensile stress at Yield (Offset 0.2 %)	Maximum Load	TS at Max Load
		[MPa]	[MPa]	[kN]	[MPa]
1	Sample A	12837.59	71.96	4.64	90.92
2	Sample B	4059.08	45.06	4.02	78.82
3	Sample C	4623.98	58.36	5.8	113.73
4	Sample D	4699.12	48.71	5.07	99.44
5	Sample E	4451.13	52.84	5.09	99.75

After experiment, the results for tensile strengths and moduli are shown in Figures. 4.2(a) respectively. It is seen that in every samples irrespective of the filler material the tensile strength of the composite decreases with increase in filler content. The unfilled glass epoxy composite (10wt% SiC Filler) has strength of 113.73 MPa in tension and it may be seen from Table 1.6 that this value drops from 113.73MPa to 99.44MPa with 15wt% and 20wt% respectively. Maximum tensile strength of the composites at 10wt% with particulate filler. respectively. There can be two reasons for this turn down in the strength properties of these particulate filled composites compared to the unfilled one. An alternative is that the edge bonding between the filler particles and the matrix may be too weak to transfer the tensile stress; another is that the corner points of the irregular shaped particulates result in stress concentration in the epoxy matrix. These two reasons are responsible for reducing the tensile strengths of the composites so extensively. Previous reports show that usually the fibers in the composite contain the deformation of the matrix polymer, reducing the tensile strain. The tensile strengths are dissimilar with different filler materials as their compatibility with the matrix and irregularities in shape are different from one another. The tensile modulus of these Silica filled composites B and C are also found to be less than the modulus of the unfilled one shown in figure (4.2b). The tensile strength at yield (offset 0.2%) of these Silica filled composites B and C, are also found to be less than the unfilled one shown in figure(4.2c).

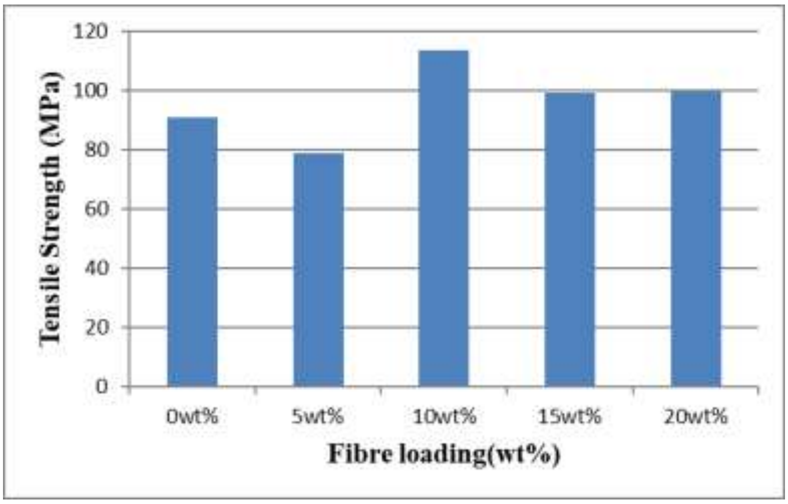

Figure 4.2(a) Tensile strength of composites with different wt% of particulate filler

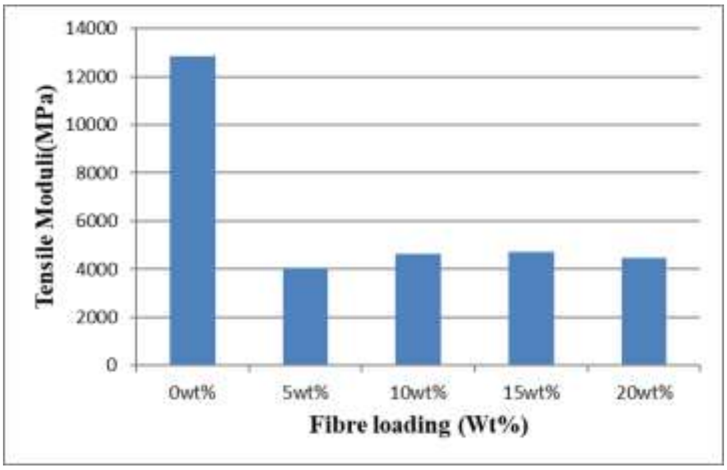

Figure 4.2(b) Tensile modulus of composites with different wt% with particulate filler

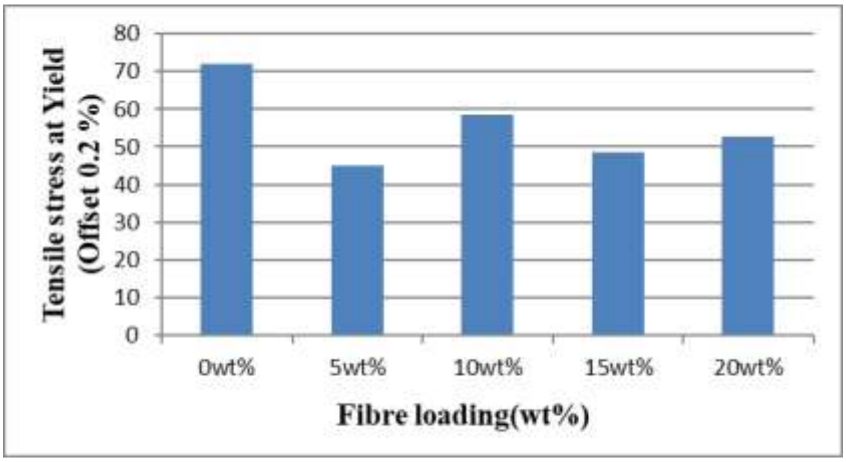

Figure 4.2(c) Tensile Strength at yield offset 0.2% (MPa) of composites

4.3 Flexural Strength

The data of sample test given in the below table: Rate – 10 mm/min; Temperature- 18 ºC Room temperature- 23.1 ºC

Table 1.7 Flexural strength of composites with different wt% of particulate fillers

S.No	Specimen label	Maximum Load	Maximum Stress	Flex Modulus
		[N]	[MPa]	[MPa]
1	Sample A	257.4	126.18	4615.47
2	Sample B	224.42	110.01	3609.83
3	Sample C	293.3	143.77	6238.45
4	Sample D	445.69	218.48	8419.75
5	Sample E	342.52	167.9	8082.61

The test results for flexural strengths and modulus are shown in Figs. 4.3(a) and 4.3(b) respectively. It is seen that in all the samples irrespective of the filler material the flexural strength of the composite increases with increase in filler content. The unfilled glass epoxy composite (40wt% Fiber loading) has a strength of 126.18 MPa in flexural and it may be seen from Table 1.7 that this value drops to 110.01 MPa with addition of 5 wt% of SiC and increase to 143.73 Mpa with addition of 10wt% SiC shown in figure 4.3(a) respectively. Reasons may be the edge bond between the filler particles and the matrix may be too much weak to transfer the tensile stress; another reason may be irregular shaped particulates effect in stress concentration in the epoxy matrix. The flexural modulus of these SiC filled sample B and sample C are also found to be more than the modulus of unfilled one. Flexural modulus of sample C is found to be more than sample a shown in figure 4.3(b) respectively.

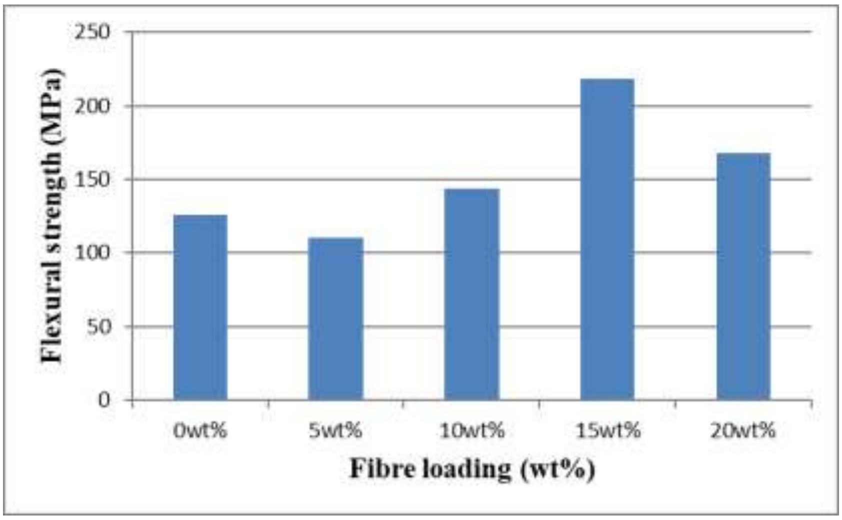

Figure 4.3(a) Flexural strength of composites with different wt% of particulate fillers

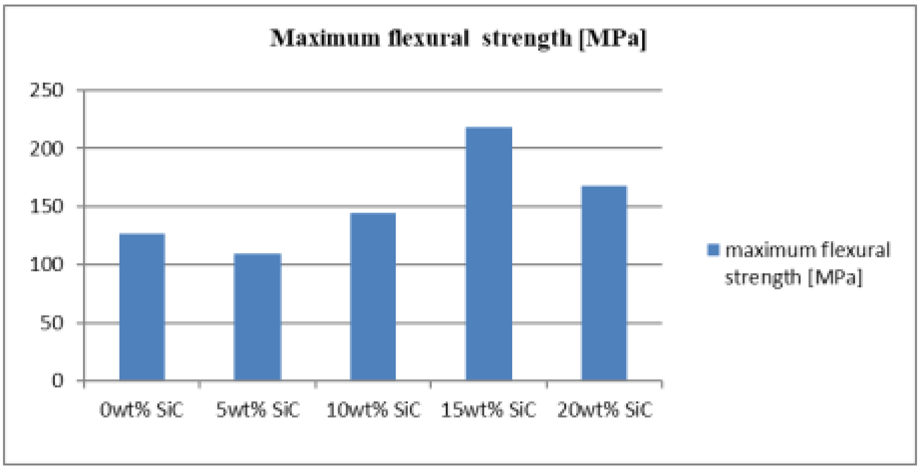

Figure 4.3(b) Flexural modulus of composites with different wt% of particulate fillers

The flexural modulus of these SiC filled sample B and sample C are also found to be more than the modulus of unfilled one. Flexural modulus of sample C is found to be more than sample A shown in figure 4.3(b) respectively.

Conclusions

Fabrication of glass-epoxy composites with reinforcement of conventional ceramic fillers such as SiC is possible. Incorporation of these fillers modifies the tensile, flexural, strengths of the composites for glass fiber reinforcement. Successful fabrication of glass-epoxy composites with reinforcement of ceramic filler such as SiC is possible. A- Glass fiber has good higher durability, strength and electric property, E- Glass has higher strength and electrical resistivity, C- Glass higher corrosion resistance. Physical properties of various glass fibers shown in Table 1.4.

1. The unfilled glass epoxy composite has a strength of 90.92 MPa in tension at maximum load 4.64 kN and it may be seen from Table 4.2 that this value drops to 78.82 MPa with addition of(40wt%glass fiber+55wt%epoxy+ 5 wt% SiC) and increase with addition of(40wt% glass fiber+50wt% epoxy + 10wt% SiC) respectively. The Maximum tensile strength of the composites at (40wt% glass fiber+50wt% epoxy + 10wt% SiC) respectively.

2. It is observed that the tensile moduli of glass-epoxy composites improve significantly with addition of (40wt% glass fiber+60wt% epoxy+0wt% SiC) respectively. It is further noted that without particulate fillers (0wt%SiC) tensile moduli is maximum and at (40wt% glass fiber+55wt%epoxy+5wt%SiC) particulate filler the tensile moduli is lower than (40wt%glass fiber+45wt%epoxy+ 15 wt% SiC)15wt% particulate filler.

3. It is seen that in all the samples irrespective of the filler material the flexural strength of the composite increases with increase in filler content. The unfilled glass epoxy composite (40wt% Fiber loading) has a strength of 126.18 MPa in flexural and it may be seen from Table 4.3 that this value drops to 110.01 MPa with addition of 5 wt% of SiC and increase to 143.73 Mpa with addition of 10wt% SiC shown in figure 4.3(a) respectively. Reasons may be the edge bond between the filler particles and the matrix may be too much weak to transfer the tensile stress; another reason may be irregular shaped particulates effect in stress concentration in the epoxy matrix. The flexural modulus of these SiC filled sample B and sample C are also found to be more than the modulus of unfilled one. Flexural modulus of sample C is found to be more

REFERENCE

[1] Agarwal,B.D and Broutman L.J.(1990),"Analysis and Performance of fiber Composites", Second edition, John wiley & Sons, Inc, pp.2-16.

[2] Tong L,Mouritz A.P and Bannister M.K,(2002)."3D Fiber Reinforced polymer Composites", Elsevier Science Ltd, The Boulevard, Langford Lane, Kindlington, Oxford OX5IDB,UK,1-2.

[3] Suhreta Husic,Ivan Javni, Zoran S, Petrovic,(2005),"Thermal and mechanical properties of glass reinforced soy - based polyurethane composites",composites science and Technology 65(2005),pp. 19-25.

[4] Pool K.V, Dharan C.K.H, and Finnie I, (1986). Erosion wear of composite materials, wear, vol.107, pp.1-12

[5] Aglan H.A and Chenock T.A Jr.(1993). Erosion damage features of polyimide Thermoset Composites, SAMPLE Quartery, pp.41-47.

[6] Patnaik A, Satapathy A, Mahapatra S. S and Dash R. R, (2008), A Modelling Approach for Prediction of Erosion Behaviour of Glass Fiber- Polyester Composites, Journal of Polymer Research, 15(2), pp. 147-160.