Evaluation of Mechanical, Tribological and Water absorption behaviour of Glass fiber reinforced epoxy composites with and without Silicon-Di-oxide (SiO_2) as a filler Material

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Abstract - *Composites are frequently used now a day in engineering applications. Polymer composites are largely used in applications like aerospace, automotive and marine. Where mechanical and tribological behavior are the main concern In this present research work similar attempt is made to study the effect of Silicon di oxide or silica as filler on the Mechanical, Tribological and water absorption behavior of the Glass fiber reinforced epoxy composites, in many primary or advanced applications*

Mechanical properties like Tensile strength, Flexural strength, Impact strength and tri-bological (wear) behavior of composite was studied. The tensile properties such as young's modulus and ultimate tensile strength increased for glass epoxy material with 5%, 7.5%, 10% silicon dioxide compared to Glass epoxy composite without silica. Tensile properties were more in case of glass epoxy composite with 10% silica. Among the composites studied, Glass Fiber Reinforced Epoxy filled with 10 wt. % Silicon dioxide (SiO_2) the Composite Shows an enhanced Wear Resistance when compared to unfilled Glass-Epoxy Composites and 5%, 7.5%, 10% SiO_2 filled Glass-Epoxy composites. The water absorption is more with increasing filler content is compared with unfilled composites.

Key Words*: *Glass Fiber, Epoxy, SiO_2 Filler, Mechanical, tribological and water absorption behaviour, wear mechanism, Scanning Electron microscope (SEM).

1. INTRODUCTION

Glass fiber reinforced polymer matrix composites have been extensively used in various fields such as aerospace industries, automobiles, marine, and defense industries. Their main advantages are good corrosion resistance, lightweight, dielectric characteristics and better damping characteristics than metals. A possibility that the incorporation of both particles and fibers in polymer could provide a synergism in terms of improved properties and performance has not been adequately explored so far. However, some recent reports suggest that by incorporating micro hard filler particles into the polymer matrix of fiber reinforced composites, synergistic effects may be achieved in the form of higher modulus and reduced material cost, yet accompanied with decreased strength and impact toughness. The present paper is experimental study on Glass-Epoxy based composite materials with and without addition of filler materials are fabricate. The filler used for the purpose of study is silicon dioxide (SiO_2) the study focuses on the determination of mechanical properties.

2. EXPERIMENTAL DETAILS

2.1 Materials

Plain weave fabrics made of 360 g/m². Containing E-glass fibers of diameter of about 12 μm have been employed. The epoxy resin was mixed with the hardener (HT 972) in the ratio 100:12 by weight. The filler chosen was Silicon Di-oxide (SiO_2) modified using a silane coupling agent and the average particle size is 15-20 μm. The details of the mechanical properties of the constituent (Epoxy, Glass fiber & SiO_2 filler) selected for the present work are shown in the Table 1. In the current study the organic oxide fillers Silicon di-oxide (SiO_2) with weight percentage 0%, 5%, 7.5%, 10% and Glass-Epoxy 0%, 5%, 7.5%, 10% used for the preparation of composite.

Table 1: Mechanical properties of the constituents selected for present work.

Property	Epoxy	Glass fibers	SiO_2 filler
Density (gm/cm³)	1.20	2.54	2.19
Tensile strength (N/mm²)	110	3400	55
Tensile modulus	4.1	72.4	70

Table 2: The details of material combination as shown below

Constituents	Specifications
Reinforcement	E-Glass fiber
Epoxy	LY-556

Hardener	HT 972
Filler material	Silicon di-oxide (SiO_2)

Table 3: Composition of0materials required for fabrication of0composite 0% SiO_2

Sample	Epoxy (wt. %)	SiO_2 (wt. %)
G-E	40	0
5% SiO_2 -G-E	35	5
7.5% SiO_2-G-E	32.5	7.5
10% SiO_2-G-E	30	10

2.2 Specimen Preparation

The specimens are prepared by hand layup process. The Glass fibers cut from glass fiber revolve and are weighed. To prepare composite plate without filler, calculated amount of epoxy resin is weighed and taken in a container, and then the hardener HT 972 which is heated to bring it from solid to liquid state is also weighed and taken in a separate container in calculated quantity. To prepare laminates with filler, calculated amount of epoxy resin is weighed and taken in a container, and then calculated quantity of hardener HT 972 which is initially heated is also weighed and taken in a separate container. Silica powder is also weighted and calculated amount is taken in a separate container. Silica powder is first added to the epoxy resin and stirred well; once the silica powder is equally dispersed, the hardener is added and stirred well using a glass rod to prepare the matrix phase. Care should be taken such that overheating of hardener should not be carried out for fabrication process of composites.

Once the materials are prepared for fabrication the next step is to prepare the composite plates using hand lay-up procedure. A flat and clean surface is selected for hand lay-up process. A thin coat of wax is applied on a polythene sheet which has dimensions more than the Glass fiber mesh used for fabrication.

A single mesh of glass fiber is placed on the polythene sheet then epoxy is poured on the glass fiber mesh and is equally distributed using a roller brush (a slight load is applied while rolling to prevent the formation of air gaps), on top of this fiber another glass fiber mesh is placed and epoxy is poured and distributed along the length of the fiber, this process is carried out till all 8 meshes of Glass fibers are placed on top of each other. Another polythene sheet which contains a coat of wax is placed on top of this glass epoxy layers to complete the hand lay-up process. The figure 1 shows the hand lay-up procedure carried out for Glass epoxy composites.

Fig 1: shows the hand lay-up procedure carried out for Glass epoxy composites.

This procedure is carried out for three different compositions (0% SiO_2 glass Epoxy, 5% SiO_2 Glass Epoxy, 7.5% SiO_2 Glass Epoxy, 10% SiO_2 Glass Epoxy) as mentioned in the previous sections. Once the Hand lay-up method is complete the next step is to cure the composite. HT 972 is a hardener where hot curing must be carried out. The hot curing stage is carried out in a Hydraulic press. All the Eight plates which are fabricated using hand layup process are placed between two metallic sheets, next to each of the composite plate along with spacers to ensure uniform thickness of the composite plate and then are placed in the Hydraulic press. A load of $30kg/cm^2$ is applied on the composite plates along with high temperature of 85 to 90 degree centigrade. The composite plates are cured at high temperature along with high pressure. Once the composite plates are cured they are once again placed in an oven which is maintained at a temperature of about 80 degree centigrade, to improve the mechanical properties of the composite plates. After above steps, composite is machined to required dimensions. Composite material fabricated is machined into dimensions of length 330mm width 330mm and the thickness of the plate obtained is 3mm (330x330x3mm).

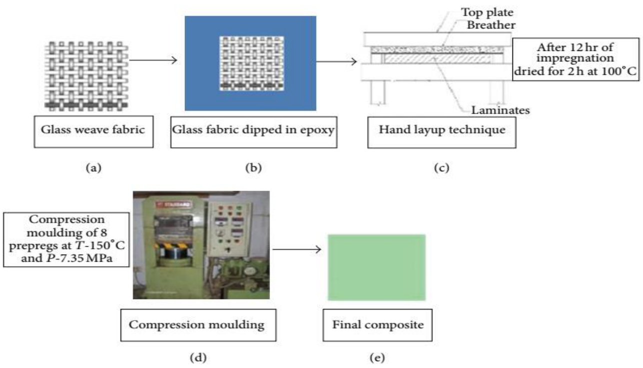

Fig 2: Schematic Representation of composite fabrication process

3. TESTING OF MECHANICAL, TRIBOLOGICAL AND WATER ABSORPTION PROPERTIES

The mechanical property of composite normally depends on the direction of fibers oriented and is different in different direction. In unidirectional fibers the strength of the fibers will great high along oriented direction and very less in a direction perpendicular to it. It also depends on top of the kind of medium material used and the dimension of filler material used.

3.1 Tensile Properties

Tensile strength is amount of material strength to resist pull. Tensile Strength is also the Measurement of Materials Strength when force is functional in two opposite direction. The direction of applied force will forever be opposite to each other. Tensile strength is usually measured as the primary material strength of the material as different values can be obtained from it such as Poisons ratio, young's modulus, yield strength which are the measure material ability. These results can be used to obtain the material charteristics such as brittleness or ductility. Tensile test was conducted according to ASTM standard D638

3.20Flexural Properties

The Flexural strength is recognized as bend strength, It is a physio0mechanical property characteristic of a fragile material. Flexural strength is defined as the0Material's Ability towards resist twist under Load. The transverse bending is commonly Applied, in which the specimen be either having rectangular shape or circular shape is yielded or bent using a three point bending method. Flexural strength is also expressed in terms of stress similar tensile strength. Flexural strength decide the utmost value stress that practiced by a material at its moment of rupture. In flexural test of single material rectangular wooden beam or a rectangular cross section steel rod is situated between two supports at a distance of gauge length; load is applied correctly at the centre of the gauge length. Most of the materials will fail below tensile0stress only before they hold up the compressive0stress so it can be defined as the utmost Tensile Stress that can be permanent earlier than the Beam fail is its Flexural Strength. The Specimen prepared and tested According to ASTM D-790 Standards.

3.30Impact Properties

Impact strength is defined as the ability of material to resist impact. It is calculated in terms of energy absorbed. There are two methods for testing impact strength they are Izod impact test and Charpy impact test both the tests are-used to measure Impact Energy necessary to break the Specimen and usually expressed in terms of joules (J). Impact energy sometimes is also calculated in terms of Pascal (N/mm^2) by taking into consideration the force required across the notch These two methods have different way of testing according to Charpy the test specimen is support at both ends, according to Izod the specimen is clamped only on one side like a cantilever the dimension of the testing component is done as per ASTM standard. The specimen prepared and tested according to ASTM D-256 Standards.

3.4 Water Absorption Test

Water absorption test is very significant to determine the water absorptivity of the water absorption of the material. Moisture absorption studies were performing according to ASTM D-570. The effect of moisture absorption causes the degradation of fiber matrix interface region as resulting in decrease of mechanical properties along with the change in dimensions of composites. The water absorption characteristics such as diffusion co-efficient, permeability co-efficient.

The content of water absorption sample is found out using a precise 4-digit balance. The percentage of water absorption is given by

$$\text{Water absorption } (\%) = \frac{W_2 - W_1}{W_1} \times 100$$

W_1= Weight0before soaking into water
W_2= Weight0after soaking into water

3.5 Wear Test

The tribological test is conducted to study the various factors like friction and Lubrication and wear. To find the wear rate. Abrasive wear test is commonly employed.

This test is done by two methods.

- Two Body abrasive wear
- Three body abrasive wear.

3.5. 1 Two0body0abrasive0wear

For this test pin-on-disc apparatus is generally used. The tribological performance is different from that of metals. In the current study we are paying concentration only on the wear charteristics of composite material with filler. Hence the test conducted was two0body0abrasive0wear0test & taguchi test on the selected samples. Wear is distinct as failure of material due constant contact with the heartrending component. Abrasive wear is at most important on which cause almost 60% of the total loss of the material due to wear. Abrasive wear is caused when thaw surface of abradant passes over the smooth0surface. First clean the specimens, and weight the specimens.

4. RESULTS AND DISCUSSION

4.1 variation of density

The following changes in density are absorbed by adding filler to the Glass-Epoxy composite. By observing all density variation graphs, it is observed that the density increases by increase in filler percentage because the density of filler (SiO_2) is greater than resin. It also observes that the combination of Glass and epoxy shows the lesser density values than compared to Glass epoxy with SiO_2.

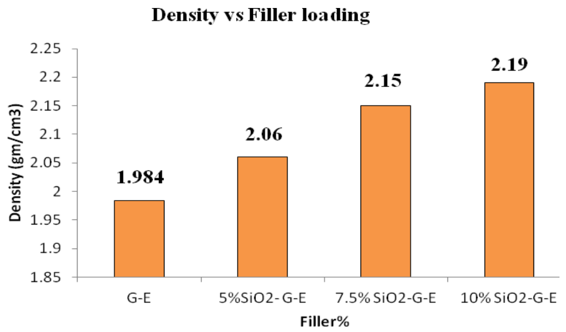

Fig 3: Density variations with SiO_2

The Typical the Load vs. displacement diagram for SiO_2 filled composites as shown in fig 7. The measured mechanical test results are listed in table. The tensile strength SiO_2 filled with increased0with0increasing SiO_2 up to 7.5 wt%, because the uniform dispersion of SiO_2 filler in G-E. However the increase in tensile strength is marginal beyond 7.5 wt% of SiO_2 filler loading. The surface modified SiO_2 react with the fiber surface and leads to improved interaction with glass0fiber and0epoxy.

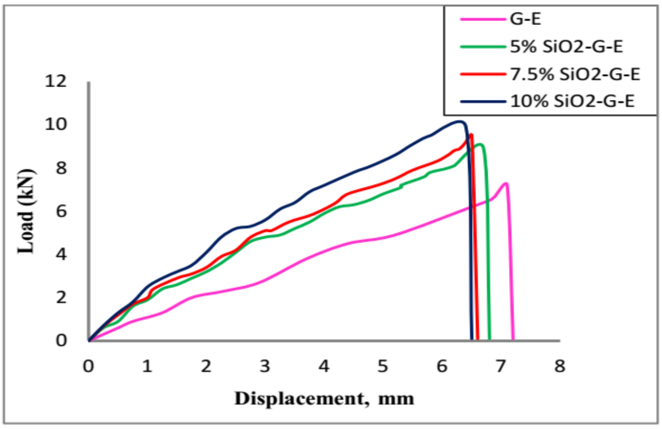

Fig 4: Load vs. displacement graph for SiO_2 G-E composites

4.2 Tensile Strength

The tensile test results are shown in table 4 & 5. The0Maximum tensile strength in the current study is obtained for 10% SiO_2-G-E composite and is establish to be 263.35 MPa. Addition of ceramic filler cause increase in density of the composite which also modifies the tensile0strength of the composites. The difference in the ultimate tensile0strength suggest that as the filler material increases the material becomes more strong and resist the load and the deformation/elongation of the composites decrease with increase in filler material.

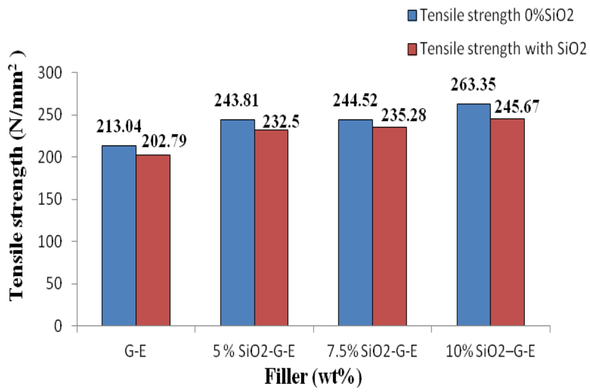

Fig 5: Comparison of Tensile strength behavior of with and without silica powder (SiO_2)

Table 4: Mechanical testing results of composite without SiO_2 (0%SiO_2)

Samples	Density (gm/cm³)	Tensile strength (N/mm²)	Flexura0 strength (N/mm²)	Impact strength (J)
G-E	1.8	20.79	19.58	2.9
5% G-E	1.8625	232.5	20.21	3.4
7.5% G-E	1.893	235.28	23.8	4.3
10% G-E	1.925	245.67	24.52	3.5

Table 5: Mechanical Testing Results of composites with SiO_2

Samples	Density (gm/cm³)	Tensile 0strength (N/mm²	Flexural strength	Impact 0strength (J)
G-E	1.984	213.04	26.5	11
5%SiO_2-G-E	2.06	243.81	27	12

7.5% SiO_2-G-E	2.15	244.52	27.53	16
10% SiO_2-G-E	2.19	263.55	30.59	18

4.3 Flexural Strength

The flexural strength if the specimen filled with silica powder (SiO_2) filler increases till the weight % is about 10% later on with adding of the filler material the flexural strength decreases. between fiber and matrix.

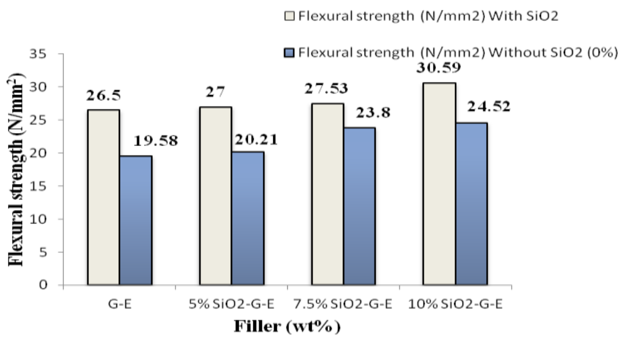

Fig 6: Flexural strength behavior of with and without silica powder (SiO_2)

Same tendency is followed by the specimens that are 0% filler. The difference of flexural strength is shown in the graph given below. The test results indicate that the laminate filled by 10% SiO_2 exhibited maximum flexural strength 30.59Mpa. The reduction of flexural strength observed due to increase in filler material and may be change in matrix properties reduce their strength between fiber and matrix.

4.4 Impact Strength

The impact strength of the composite also increases till 7.5% SiO_2 later on Imapct strength decreases.

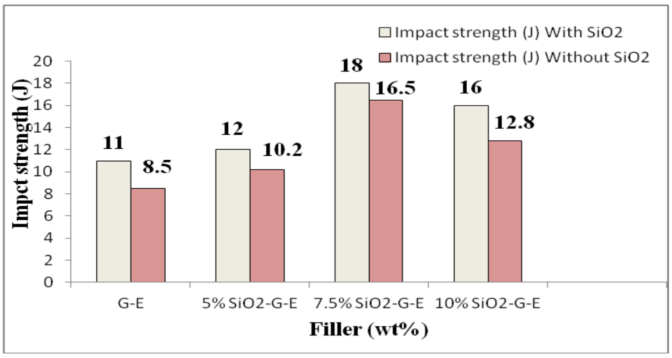

Fig 7: impact test behavior with and without silica powder (SiO_2)

Compared to all the samples of the composite measured 7.5% SiO_2 filled Galas-Epoxy composites shows advanced tensile strength followed by 5% and 10% SiO_2 filled and the least strength is unfilled Glass-Epoxy composites. Because the percentage of the filler in the composite increases beyond 7.5% the strength reduces due increase in brittleness of the specimen.

4.5 Water Absorption Test

It is0observed that with increase0the percentage of glass0fiber. The water absorption steadily0increases the water absorption of these composites is mainly due to the occurrence of glass0fibers. It is found that the maximum water absorption is observed in Laminate 5% SiO_2 Glass epoxy and minimum water absorption in Glass epoxy.

Table 6: Water absorption test results for distilled water

Laminates	Initial weight in grams	Percentage increases in			
		Day 6	Day 12	Day 18	Day 24
G-E	3.502	2.12	4.26	7.85	10.32
5% SiO_2-G-E	4.489	6.75	8.48	14.2	15.12
7.5% SiO_2-G-E	4.148	5.1	8.20	10.1	14.56
10% SiO_2-G-E	4.734	4.46	7.20	9.25	13.25

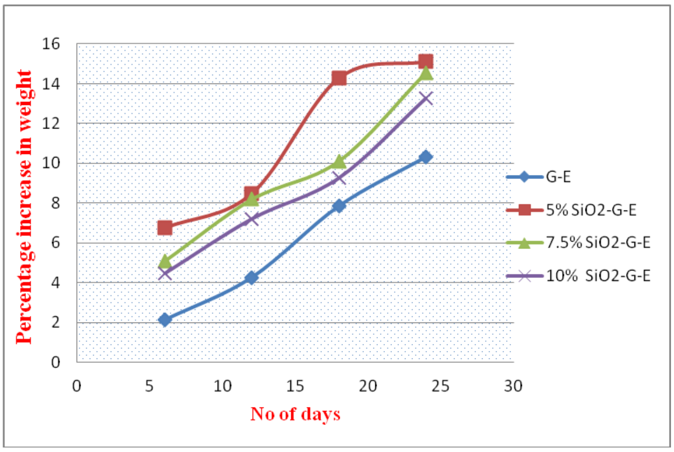

Fig 8: Water absorption of composites during 24days of immersion in distilled water

4.6 Tribological Test Behaviour

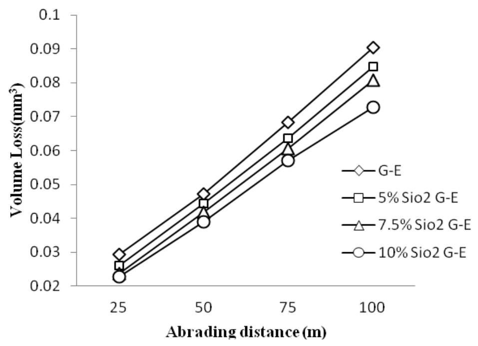

Fig 9: Wear test for 20N load

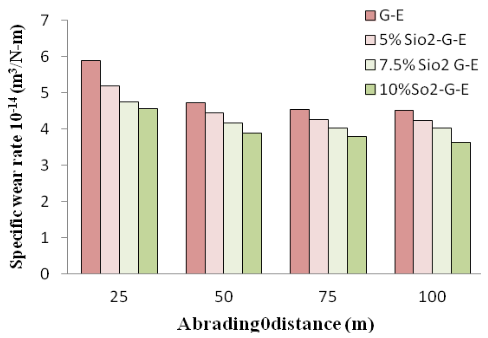

Fig 10: Specific wear rate for 20N load

Fig 9 show the wear volume data for both unfilled glass epoxy and different weight percentage of SiO_2 filled glass epoxy composite's at 20N loads with Aluminum oxide 100 Girt size sand paper as an abrasive. Investigational data of wear volume are plotted for composites shown in Fig and as of the above Figures. It is obvious that SiO_2 filled glass epoxy composites have smaller wear volume than the neat Glass Epoxy composites. alike to SiO_2 filled composites even here 10 wt. % of Sio_2 filled composites shows better resistance followed by 7.5%, 5% and glass epoxy composites. Better wear loss was noticed for Glass Epoxy composites on comparison with the particulate filled Glass Epoxy composites. On addition fiber material the material has become brittle and offers resistance to wear.

4.7 Scanning Electron Microscope (SEM)

Using scanning electron microscope the microstructure of the sample is observed. The figure 11 shows the tensile fractured surfaces of Glass-Epoxy and SiO_2 Glass-Epoxy composites respectively. The SEM micrographs exposed the linear0elastic0behavior brittle type rupture for the test samples along with instant many instant0fractures.

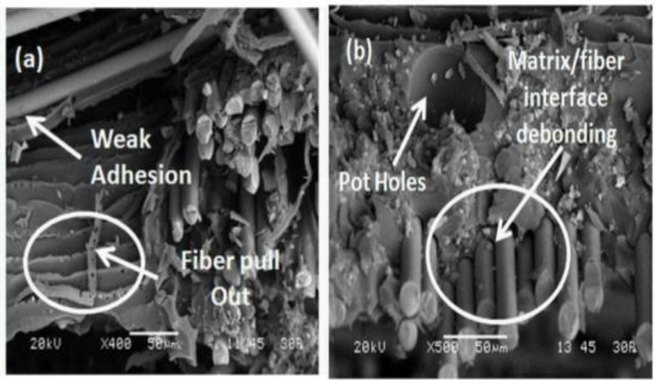

Fig 11: SEM micrographs of tensile fractured surfaces of Unfilled G-E composites

5. CONCLUSION

The fabrication and experiment of Glass fiber reinforced epoxy resin with Silicon dioxide (SiO_2) were successfully carried out and the results were tabulated along with the compared results Tensile, Flexural, Impact tests were conducted on three compositions of Glass fiber epoxy with and without silica powder as a filler material, the three compositions were Glass epoxy with 5%, 7.5%, 10% silica powder as a filler material.

- The Ultimate tensile strength and young's modulus of the GFRP increased successfully with growing the filler Silicon dioxide (SiO_2) loadings.
- Flexural test results also Increase through Increase during Filler material and maximum Flexural Strength was found for 10% SiO_2 filled G-E composites.
- Impact0Strength of the composite Materials increases with enhance0within filler0material till & 7.5% of filler used later with increase in filler percentage the impact strength decreases both for specimen.
- The water absorption is more with increasing filler content is compared with unfilled composites.
- The Wear amount was a smaller amount in the composite material through 10% Silicon dioxide (SiO_2) Filler as0compared0to0that of Unfilled. Superior precise wear resistance (1.5times) is notice for Silicon dioxide, the Glass-Epoxy composite than Glass–Epoxy composite.

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