ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Characterization of Epoxy Hybrid Composition: Effect of Glass/Carbon Fibre on Mechanical & Thermal Properties

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Abstract:

Many of a modern technology require materials with unusual combinations of properties that cannot be met by the conventional metal alloy, ceramics and polymeric materials. Now a day a material with a light weight and high strength have more demand and such materials are suitable for more applications. In order to achieve full fledged requirements, today the technology make to final new materials called composite materials.In the present work, the epoxy-based hybrid composites have developed by combining the Carbon and Glass fibres into epoxy matrix. Hardness, tensile strength, compression strength and chemical resistance of hybrid composites without alkali treatments have been studied. Variations of the mechanical properties and chemical resistance have to study with different combinations of Carbon and glass fibers as reinforced into epoxy matrix.

Mechanical properties like Impact strength, Flexural strength, Tensile strength, Compressive strength of the micro hybrid composite should study by UTM (Universal Testing Machine). Thermal properties of micro hybrid composites have to study using Thermo Gravimetric Analysis (TGA) and Differential Scanning Calorimetry (DSC). Optical microscopic images of fracture surfaces after hardness test have studied.

Keywords:

Flexural Test, Tensile test, Tensile Modulus, Thermo Gravimertri Analysis(TGA), Differential Scanning Calorimetri (DSC),Morphology.

Introduction:

Man always wants to live in comfort for that, he needs new and useful materials. Search for the new materials has been going on since times immemorial many new materials have been developed in the 20th century.

The tremendous progress in science and technology brought about the industrial revolution in the 19th century. As this revolution progressed and encompassed, every aspect of human life, be it travel, was felt for materials capable of resisting fatigue, environmental. Corrosion, opessoure, stress and exposure to chemicals.

They also have to be adaptable for use under extreme temperature versatile, marine engineering chemical industry and machinery, construction, electrical and electronic equipment, space technology sports goods and medical engineering. The aerospace and deference industries were also benefited greatly from the light weight yet extremely hard composites that have evolved a lot. materials in the form of composite were evolved as answer to this need.

Their emergence has a tremendous impact in several fields like transportationIn 1995, the advanced composite materials found a major market in aerospace field to the tune of 67% Followed by sports (16%) and automobiles industry (14%). The field-wise distribution of the consumption of the advanced composite materials is shown in figure.

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International Journal & Magazine of Engineering, Technology, Management and Research
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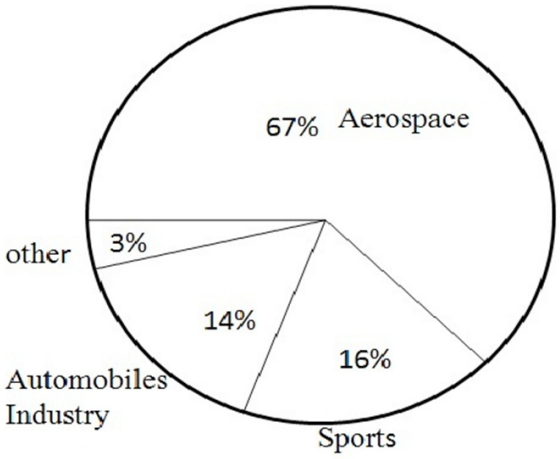

Fig1: Advanced composite materials

1.MATERIALS AND METHODS:

In the present work, epoxy resin (LY-556) thermo-setting polymer is used as a matrix, epoxy is the most common thermosetting polymer used as matrix in the polymer composites. It is obtained from Araldite LY-556 Huntsman, Ciba-Geigy India Ltd. Company. Epoxy is a clear liquid with viscosity at 250C. Epoxies are used by the plastic industry in several ways.

Epoxy is in combination with glass fiber to produce high-strength composites or reinforced plastics that provide improved mechanical, chemical properties and heat resistance. Carbon fibre is a composite made from Carbon and Silica or glass fibres. The glass fibre is used as a filling between layers of Carbon, this method of construction allows us to utilise the excellent strength and stiffness properties of Carbon fibre at the more critical outside surfaces.

2 Composite Manufacturing:

A glass mold with required dimensions as shown in figure was used for making the sample on par with ASTM standards, and it was coated with a mold releasing agent (wax) to enable the easy removal of the sample. The resin and hardener were taken in the ratio of 10: 1 parts by weight, respectively. Then, a pre-calculated amount of hardener was mixed with the epoxy.

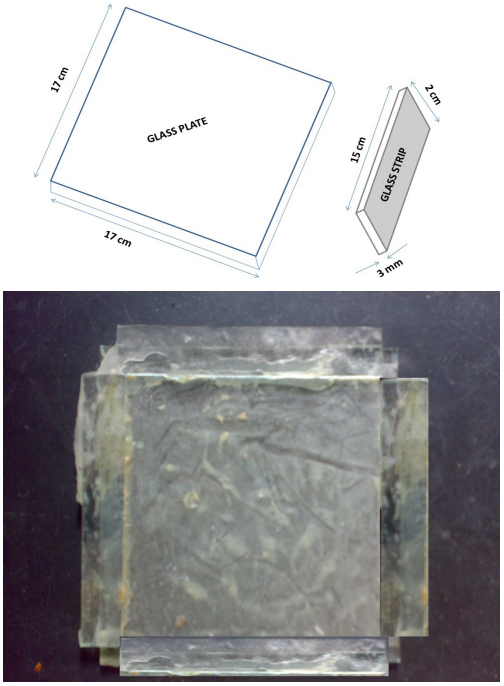

Fig 1 : glass moulds

Synthesis of Carbon Fiber / Glass Fiber Epoxy Hybrid Composites:

Resin and hardener stirred for 1 hr before pouring into the mold. The hand lay-up technique was used to impregnate the composite structures. In this technique, the glass fiber and the Carbon fibers were wetted by a thin layer of epoxy suspension in a mold. A stack of hybrid fibers were carefully arranged in a unidirectional manner after pouring some amount of resin against the mold to keep poor impregnation at bay. Clay was mixed with stipulated quantity of resin based on the a fore mentioned ratio mixed thoroughly with mechanical shear mixing for about 1 h at ambient temperature conditions. Then the epoxy and clay composition was kept in a high intensity ultra-sonicator for one and half hour with pulse mode (50s on / 25s off).

External cooling system was employed by submerging the beaker containing the mixture in a water bath to avoid temperature rise during the sonication process. As shown in figure belowThen a pre-calculated amount of hardener was mixed and stirred for 20 min before pouring into the mold. The remaining mixture was poured over the hybrid fiber. Brush and roller were used to impregnate fiber. The closed mold was kept under pressure for 24 hrs at room temperature. To ensure complete curing, the composite samples were

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post-cured at 700C for 1 hr and test specimens of required size were cut out from the sheet. Composites with different fiber weight ratio are viz.4:1, 3:2, 2.5:2.5, 2:3 and 1:4 percentages, were prepared by keeping the weight of resin is 95%.After pouring the epoxy on the glass mould the OH paper is kept on the glass mould and paper of good surface finish is taken and rolled on the glass mould .These process is done to get good surface finish on the upper layer of the specimen. The glass mould and emery paper weren`t be disturbed for 24 hours .After 24 hours the OH paper is removed and kept 800C for 1 and half hour. After this process the specimen should be removed from glass mould. This procedure is applied for all the specimens.

System I: - Different Proportions of Carbon Fiber reinforced with Silicon

Specimen 1:

EPOXY + CARBON FIBER + SILICON
90% 5% 5%
In these specimen 90% of Epoxy, 5% of Carbon fiber and 5% of Silicon is used. And hardener used 10:1% of epoxy. The glass mould is having the volume 13*13*0.4=67.6gm/cm3.
The total volume of glass mould is =67.6 gm/cm3
Weight of Epoxy = 60.84 gm
Weight of Carbon Fiber = 3.38 gm
Weight of Silicon Filler = 3.38gm

Specimen 2:

EPOXY + CARBON FIBER + SILICON
90% 7% 3%
In these specimen 90% of Epoxy, 7% of Carbon fiber and 3% of Silicon is used. And hardener used 10:1% of epoxy. The glass mould is having the volume 13*13*0.4=67.6gm/cm3.
The total volume of glass mould is =67.6 gm/cm3
Weight of Epoxy = 60.84 gm
Weight of Carbon Fiber = 4.732 gm
Weight of Silicon Filler = 2.028gm

Specimen 3:

EPOXY + CARBON FIBER + SILICON
90% 9% 1%
In these specimen 90% of Epoxy, 9% of Carbon fiber and 1% of Silicon is used.
And hardener used 10:1% of epoxy. The glass mould is having the volume 13*13*0.4=67.6gm/cm3.
The total volume of glass mould is =67.6 gm/cm3
Weight of Epoxy = 60.84 gm
Weight of Carbon Fiber = 6.084 gm
Weight of Silicon Filler = 0.676gm

System II: - Different Proportions of Glass Fiber reinforced with Silicon

Specimen 1:

EPOXY + GLASS FIBER + SILICON
90% 5% 5%
In these specimen 90% of Epoxy, 5% of Glass fiber and 5% of Silicon is used. And hardener used 10:1% of epoxy. The glass mould is having the volume 13*13*0.4=67.6gm/cm3.
The total volume of glass mould is =67.6 gm/cm3
Weight of Epoxy = 60.84 gm
Weight of Glass Fiber = 3.38 gm
Weight of Silicon Filler = 3.38gm

Specimen 2:

EPOXY + GLASS FIBER + SILICON
90% 7% 3%
In these specimen 90% of Epoxy, 7% of Glass fiber and 3% of Silicon is used. And hardener used 10:1% of epoxy. The glass mould is having the volume 13*13*0.4=67.6gm/cm3.
The total volume of glass mould is =67.6 gm/cm3
Weight of Epoxy = 60.84 gm
Weight of Glass Fiber = 4.732 gm
Weight of Silicon Filler = 2.028gm

Specimen 3:

EPOXY + GLASS FIBER + SILICON
90% 9% 1%
In these specimen 90% of Epoxy, 9% of Glass fiber and 1% of Silicon is used. And hardener used 10:1% of epoxy. The glass mould is having the volume 13*13*0.4=67.6gm/cm3.
The total volume of glass mould is =67.6 gm/cm3
Weight of Epoxy = 60.84 gm
Weight of Glass Fiber = 6.084 gm
Weight of Silicon Filler = 0.676gm

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3 RESULTS AND DISCUSSION:

3.1 Flexural Test:

Flexural strength and Flexural modulus is done on the different specimens. The flexural strength and flexural modulus is calculated by using following formula.

F .S = (3*F*L) / (2*b*d2) ---------- (I)

F.M = (L3*F) / (4*b*h3*d) ---------- (II)

F is the load (force) at the fracture point.
L is the length of the support span.
b is width.
d is thickness.
h is height.

The results are tabulated at table 3.1.and 3.2. And the graphs are plotted for the specimens. It is shown in figure 3.a and figure 3.b.

Table 3.1: Flexural Strength and Modulus of CF Reinforced Silicon (System I)

Specimen combinations	Flexural strength (N/mm^2)	Flexural modulus (N/mm^2)
Epoxy + CF + Silicon (S1) 90% 5% 5%	209.36	1163.5
Epoxy + CF + Silicon (S2) 90% 7% 3%	210.12	1182.9
Epoxy + CF + Silicon (S3) 90% 9% 1%	209.09	1159.2

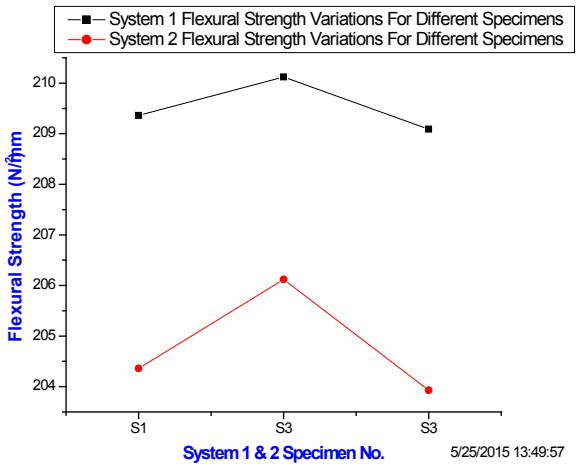
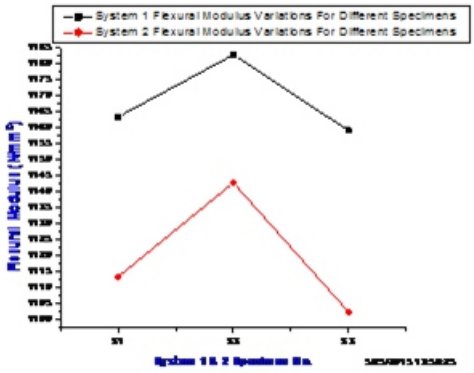


Fig 3.a: Flexural strength Graph for different Specimens of System 1 & 2

Table 3.2: Flexural Strength and Modulus of GF Reinforced Silicon:

Specimen combinations	Flexural strength (N/mm^2)	Flexural modulus (N/mm^2)
Epoxy + GF + Silicon (S1) 90% 5% 5%	204.36	1113.5
Epoxy + GF + Silicon (S2) 90% 7% 3%	206.12	1142.9
Epoxy + GF + Silicon (S3) 90% 9% 1%	203.93	1102.5

Fig 3.b: Flexural Modulus Graph for different Specimens of System 1 &2



The above result says that the flexural strength and flexural modulus are increases by increasing the percentage of Carbon Fiber and Glass Fiber (i.e. Specimen S3 7% wet. of Carbon fiber and 3% wet. of Silicon) duo properties. The higher Carbon fiber increases the flexural strength & modulus and decreases with further increase in Carbon fiber content.

3.2 Tensile Test:

The Tensile strength and tensile modulus are done on the different specimens by the UTM (Universal Testing Machine). The results are tabulated (table 3.3, 3.4) and graphs also plotted as shown in figure 3.c and figure 3.d.

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Table 3.3: Tensile Strength and Modulus for different specimens of CF, Silicon:

Specimen combinations	Tensile Strength	Tensile Modulus (N/mm^2)
Epoxy + CF + Silicon (S1) 90% 5% 5%	106.21	1620
Epoxy + CF + Silicon (S2) 90% 7% 3%	109.19	1677
Epoxy + CF + Silicon (S3) 90% 9% 1%	105.23	1592

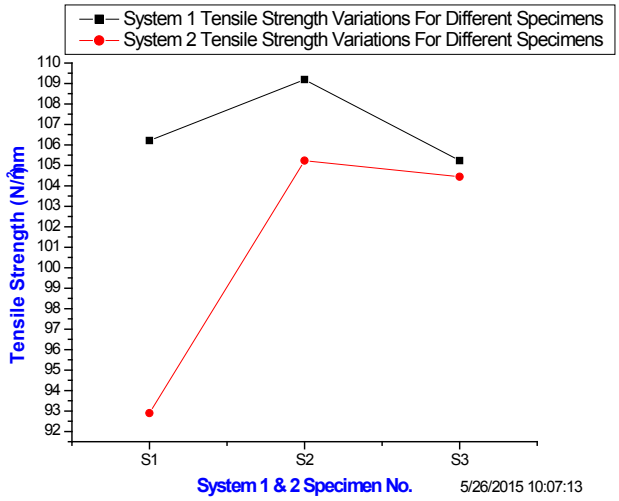

Fig 3.c: Tensile Strength Graph for different specimens of System 1 & 2

Table 3.4: Tensile Strength and Modulus for different specimens of GF, Silicon

Specimen combinations **(System 2)**	Tensile Strength (N/mm^2)	Tensile Modulus (N/mm^2)
Epoxy + GF + Silicon (S1) 90% 5% 5%	92.89	1285
Epoxy + GF + Silicon (S2) 90% 7% 3%	105.23	1592
Epoxy + GF + Silicon (S3) 90% 9% 1%	104.44	1475

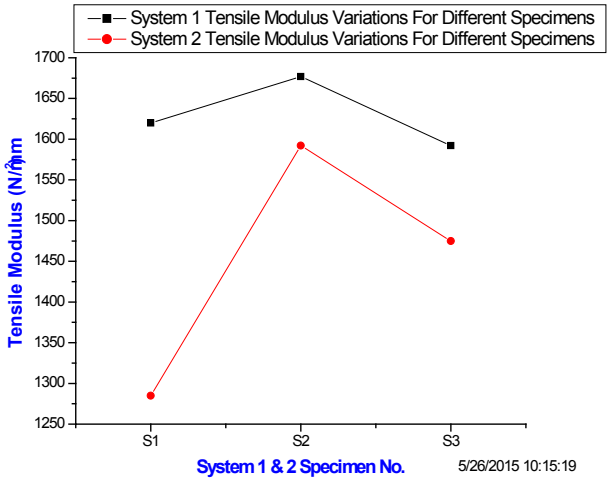

Fig 3.d: Tensile Modulus graph for different specimens of System 1 & 2

The above result depicts the change in tensile strength and tensile modulus with varying Glass fiber and Carbon fiber compositions as the Carbon fiber concentration with Silicon increases, the tensile strength increases up to the proportions of 7% CF, 3% Silicon (4.732 gm of CF and 2.028gm of CF) concentration has good tensile strength and Tensile modulus. From the graphs it is observed that the Specimen S2 showed highest tensile strength and Tensile modulus compared to remaining specimens and decreases with further increase in Carbon fiber content.

3.3 Thermal Analysis:

TGA analysis was carried out to estimate the amount of resin present in the Polymer composite and their thermal stability. Figure 3.e shows the weight loss curve of specimen S3 of hybrid composite materials of different combinations as a function of temperature. It is clear that the decomposition temperature of the composite shifted towards the lower temperature due to increase in Carbon fiber. The derivative weight loss shows only one peak. The decomposition temperature is 535°C for 7% CF, 3% Silicon (4.732 gm of CF and 2.028gm of CF), and 510°C for 2Gf 3CF hybrid composite whereas not much variation was found for other loadings. It is clearly noted that decomposition temperature was increased up to 10°C. It is clear that the decomposition temperature of the composite is shifting towards higher temperature indicating higher thermal stability of the polymer with higher Carbon fiber loading.

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The existence of inorganic materials present in the polymer matrix, generally enhance thermal stability of the composite. In the present case also, the thermal stability increases due to presence of inorganic phase and its interaction with the polymer. The weight loss vs temperature curves shows that the residue left after 510°C is in line with the epoxy content of each sample. Thermal transition of the pure polymer and the hybrid composites were also investigated by DSC.

3.4 Thermo Gravimetric Analysis (TGA):

Thermo Gravimetri Analysis is done for the specimen2 (Epoxy (60.84gm) + (Carbon fiber (4.732gm) + Silicon (2.028 gm)) and specimen2 (Epoxy (60.84gm) +E-glass fiber (4.732gm) + Silicon (2.028 gm)) which has high flexural strength. The specimens are maintained up to 5200C. % Weight loss for both the specimens for temperature variations is obtained in the form of graph as shown in the fig. 3.e. And fig. 3.f.

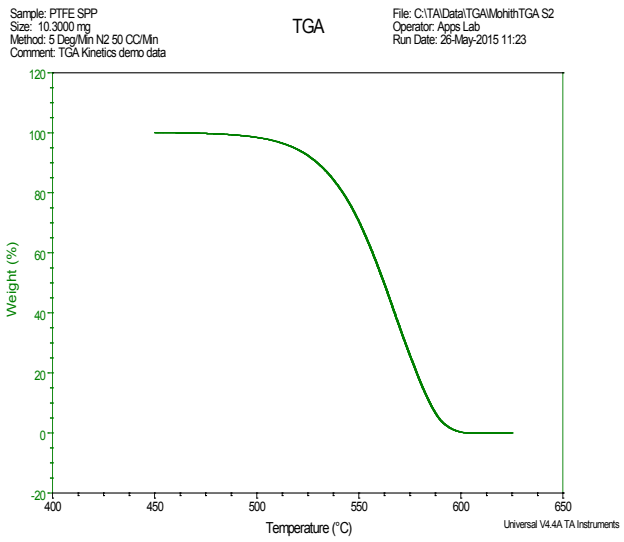

Fig 3.e: Thermo Gravmetri Analysis for Specimen 2 of System 1

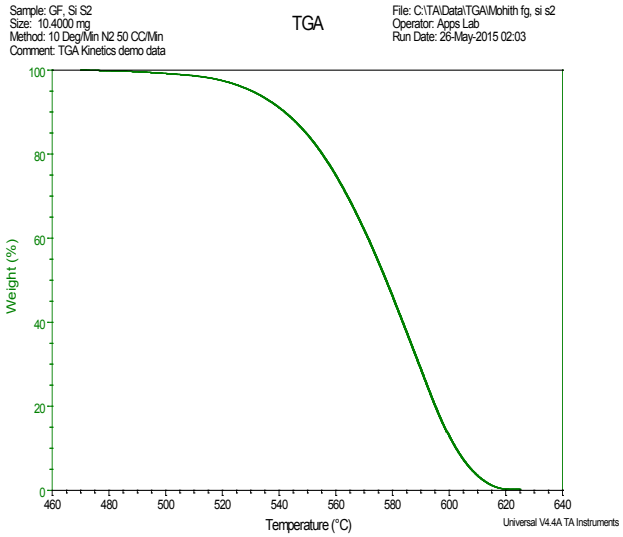

Fig. 3.f Thermo Gravmetri Analysis for Specimen 2 of System 2

From the above figures 3.e and 3.f is observed that specimen2 (Epoxy (60.84gm) + (Carbon fiber (4.732gm) + Silicon (2.028 gm)) can resist up to 5350C. The weight loss takes place above 5350C. The specimen2 Epoxy (60.84gm) +E-glass fiber (4.732gm) + Silicon (2.028 gm)) can resist up to 5200C. The weight loss takes place above 5200C. The specimen2 of Carbon Fiber Reinforced silicon has good thermal stability compared to specimen2 of Glass Fiber reinforced epoxy silicon.

3.5 Differential Scanning Calorimetric (DSC):

Differential Scanning Calorimetri (DSC) analysis is done to the Carbon fiber / glass fiber reinforced epoxy composites of specimen2 (epoxy Epoxy (60.84gm) +E-glass fiber (4.732gm) + Silicon (2.028 gm)) which has highest flexural strength and flexural modulus. The graphs shown in figure 3.g are obtained showing the glass transition temperature variation for specimen2.

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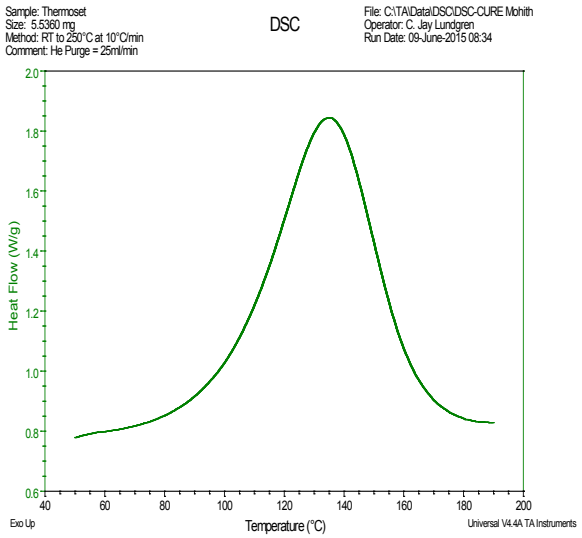

Fig. 3.g Graph showing the Glass transition temperature for Specimen2 (Epoxy (60.84gm) + (Glass fiber (4.732gm) + Silicon (2.028 gm))

From the above graph figure 48 it is observed that the composite specimen2 of system 2 (Epoxy (60.84gm) + (Glass fiber (4.732gm) + Silicon (2.028 gm)) properties degrade as the heat flow and temperature increases. The specimen2 has the higher glass transition temperature 1300C hence it has more durability.

3.6 Optical Microscope:

The micro structures can be seen in the optical microscope. The resolution of the optical microscope is 1000m. The fractured surfaces can be seen using optical micro scope. The micro hardness test can be done by intending the load on the surface it is calculated by Vickers hardness.When doing the hardness tests the minimum distance between indentations and the distance from indentation to the edge of the specimen must be taken into account to avoid interaction between the work-hardened regions and effects of the edge. The Least Count of microscope is first noted. It is normally 0.4. The number of divisions on the micrometer is noted. The Vickers hardness calculated by the following formula.

Vickers Hardness = 1.854* load(Kg)

(Micrometer reading (mm))2 (5.4)

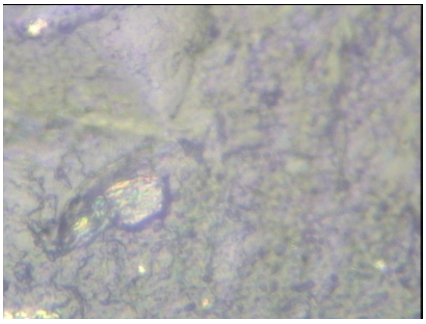

Fig 3h: Image taken by optical microscope of Specimen S2 GF, Silicon

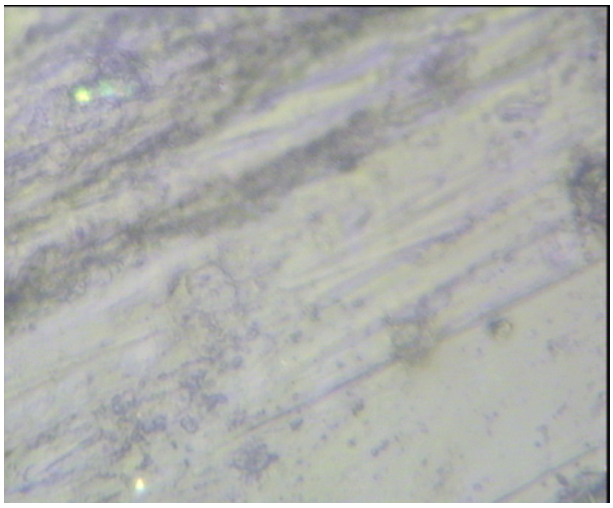

Figure 3i: Image taken by optical microscope of Specimen S2 CF, Silicon.

Photographs of the Micro structures of the fractured surfaces of the specimens are taken by using of Optical microscope.

3.7 Morphology

3.7.1 Scanning Electron Microscope (SEM) Analysis

Scanning Electron Microscope (SEM) Analysis is done for the specimen3 (Epoxy 60.84 gm + Carbon Fiber 6.084 gm + Silicon Filler = 0.676gm) and specimen3 (Epoxy 60.84 gm + Glass Fiber 6.084 gm + Silicon Filler = 0.676gm) which has good flexural & Tensile strength. The images of fractured surfaces are taken so as to check the interface and homogeneous dispersion of fiber in the matrix. Fig.3.h and Fig. 3.i shows the images of the fractured surfaces.

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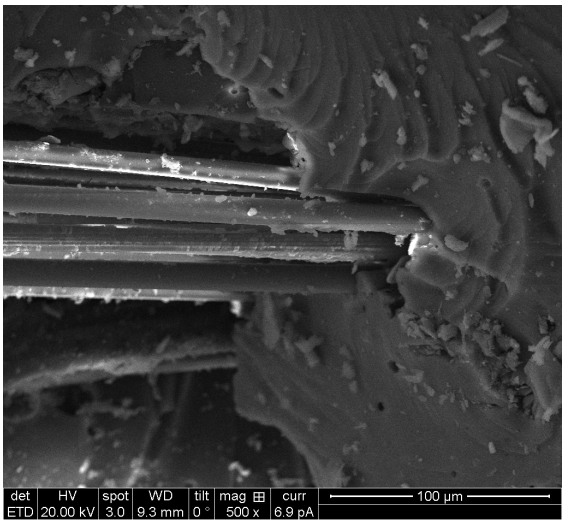

Fig. 3j: SEM image of fractured surface of specimen3 of Carbon Fiber, Silicon .

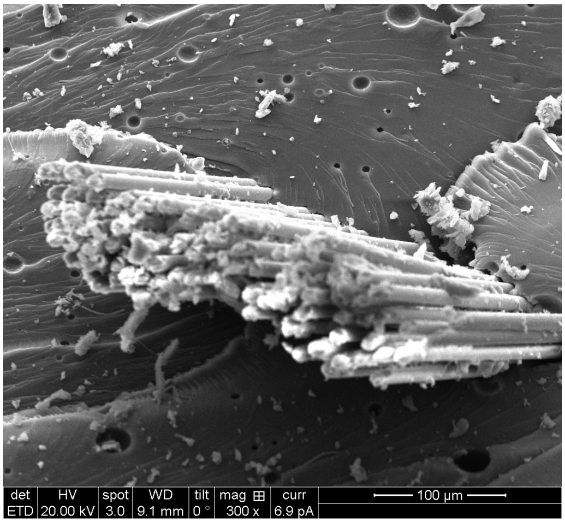

Fig. 3k: SEM image of fractured surface specimen3 of Glass Fiber, Silicon

From the fig. 50 and fig. 51 it is observed that the good interface is obtained for both the specimens. The observation established good miscibility of Epoxy and Homogenous dispersion of Specimen3 of system 1 i.e., (Epoxy 60.84 gm + Carbon Fiber 6.084 gm + Silicon Filler = 0.676gm) in the matrix.

CONCLUSION:

The following conclusions have been drawn from the present study. The tensile and flexural property of Glass Fiber/Carbon Fiber reinforced hybrid composites was improved by increasing percentage of CARBON FIBER in epoxy resin.

The optimum strength improvement was observed in the composition of specimen2 (Epoxy (60.84gm) + (Carbon fiber (4.732gm) + Silicon (2.028 gm) composite. Epoxy filled with silicon reinforced with Carbon fiber showed remarkable improvement in flexural and tensile strength and modulus. Finally, it can be concluded that the addition of the small and stiff uniform fiber played the vital role in bringing up the performance as good reinforcement in optimum amount and structure can be adjusted so that the composites act as an effective damper at that temperature range of interest with high processing and mechanical performance. Decomposition and glass transition temperatures were also lifted on TGA and DSC respectively.

» The mechanical (tensile and flexural) properties were increased for Carbon Fiber reinforced epoxy silicon composites of Specimen 2 has higher than the remaining specimens
» System 1 specimen 2 (Epoxy (60.84gm) + (Carbon fiber (4.732gm) + Silicon (2.028 gm) composite showed remarkable improvement in flexural strength and flexural modulus.
» The Thermal properties of specimen2 Carbon fiber reinforced composite have higher than the specimen2 of Glass fiber reinforced with silicon composites.
» Both the Glass Fiber and Carbon Fiber composites are well dispersed in the epoxy.
» System 1 specimen 2 (Epoxy (60.84gm) + (Carbon fiber (4.732gm) + Silicon (2.028 gm) has high glass transition temperature.
» Both the Fibers are reinforced with epoxy system with different proportions of specimens can be used in reverse engineering process. Specimen2 in system 1 compositions (Epoxy (60.84gm) + (Carbon fiber (4.732gm) + Silicon (2.028 gm) composites are more efficient.

It can be used in the manufacture of automobile fuel tanks, car doors, and aero plane wings also in high strength to less weight applications.

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