Evaluation of Mechanical and Water Absorption Behaviour of Al_2O_3 and SiC Filled Hollow Tubular Glass Fiber Reinforced Epoxy Composite

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Abstract - *Composite materials are widely used in the various engineering application due to their better mechanical and physical behaviour. Polymer matrix composite are emerging as promising materials and plays a vital role in industries like automotive, aerospace and marine. Filler materials are the inert materials which are used in polymer composite for modifying the chemical and physical properties of the matrix polymer to reduce material cost, to improve behaviour of the material. Present work involves the fabrication of epoxy composite using aluminum oxide and silicon carbide with different weight properties of* Al_2O_3 *and SiC along with glass fiber reinforced polymer. The mechanical properties like flexural strength and torsional strength of composite was studied and water absorption behaviour like normal water and sea water absorption properties was studied. Result showed that addition of filler to polymer matrix significant changes in mechanical and water absorption behaviour and scanning electron microscope (SEM) analysis on the fracture surface was studied.*

Keywords – Polymer composite, Glass fiber, Aluminum oxide, Silicon carbide.

1. INTRODUCTION

A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other. One constituent is called the reinforcing phase and the one in which it is embedded is called the matrix. The reinforcing phase material may be in the form of fibers, particles, or flakes. They consist of mainly three different types. Among them polymer matrix composite (PMC) and metal matrix composite (MMC) are the commonly used in large scale. Fibers place an important role in the field of industries, automobile, military applications. Over the past decades, polymer matrix composites are made and most widely used for structural applications in the aerospace, automotive, and chemical industries, and in providing alternatives to traditional metallic materials.

Fiber reinforced polymer composites (FRPCs) are used in almost all type of advanced engineering structures like aircraft, helicopters, boats, ships and off-shore platforms, automobiles, sporting goods, chemical processing equipment etc. A key factor driving the increased applications of composites over the recent years is the development of new advanced forms of FRPCs. These include developments in high performance resin systems and wide variety of fabric reinforcement

2. MATERIAL AND FABRICATION

2.1 MATERIAL

The composite consists of matrix and fiber, in this combination matrix consist of Epoxy resin LY556 with hardener HY 951, E-glass fabric of 360 gsm material are used. The density of epoxy is taken as 1.12 g/cc. The fillers materials added is aluminium oxide (Al_2O_3) and silicon carbide (SiC) is various weight percentage.Glass fiber material made from very fine fibers of glass and it's used because of light weight, higher strength & stiffness. Even though strength properties are slightly lower than carbon fiber and this is available cheaply. Its bulk strength & weight properties are very promising when compared to metals, and it will be easily formed using molding methods. Nowadays epoxy resin is most generally used polymer resin; they used as a matrix form in the applications of composite material like; aerospace structure, domestic application and organic coatings. Compared to the other material, the epoxy resin had supreme physical and chemical property. The selection of Resin and Hardener depending on the types of curing, temperature of curing, and curing time. Depending on the sort of filler forms the addition strength to the mechanical properties of the polymer composite materials. In this fillers SiC and Al_2O_3 are used as reinforcement it will increase the properties like flexural strength, young's modulus, torsional strength etc.

a

b

c d

Figure1: (a) Glass fabric (b) Al_2O_3 (c) SiC (d) Epoxy resin

2.2 FABRICATION

Fabrication is defined as the process of converting raw materials into finished products. The main objective of fabrication is to maintain all design conditions and specifications as per design considerations.

Following are the general stages of composite material fabrication

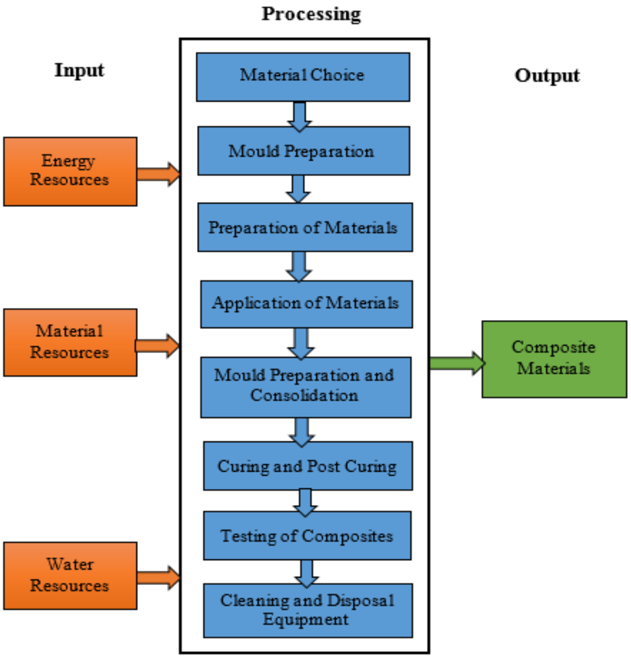


Figure 2: General stages of composite product fabricate

Table 1: Composition of composite materials

Material	Matrix (Epoxy) (Wt %)	Fiber (Glass) (Wt %)	Fillers Al_2O_3 + SiC (Wt %)	Density (gm/cc)
G+E	40	60	0	1.8
G+E+3%(Al_2O_3+SiC)	37	60	3	1.87
G+E+6%(Al_2O_3+SiC)	34	60	6	1.94
G+E+9%(Al_2O_3+SiC)	31	60	9	1.99

Polymer hallow tubular composites used in this project were made-up by the simple hand rolling machine methods. The fabrications of all Polymer Composite hallow tubes are used in this project were manufactured by "simple hand rolling machine". Fabrication is carried out by mixing calculation quantity of resin and amount of hardener in the ratio of 10:1 with the use of mechanical stirrer which is stirring at low speed to prevent bubble and vacuum generation.

Glass fabric are cut into required dimension of composite, brush were used to applied resin to the glass fabric. Composite are prepared by using the fillers which is varied to different weight percentage. Composite with 3%(Al_2O_3+SiC)-G-E, 6%(Al_2O_3+SiC)-G-E and 9%(Al_2O_3+SiC)-G-E, contains aluminium oxide and silicon carbide in 3 wt%, 6wt%, and 9wt% proportions respectively along with 60wt% of glass fibers used to fabricate. Composite materials are allowed to cure at room temperature up to 24 hours.

Simple hand rolling machine is designed for the purpose of producing hallow tubular composite and it consists of horizontal support to hold the removable mandrel. Proper ratio of epoxy and hardener to the glass fabric to obtain circular hallow tubes. Dummy mandrel is placed over the removable mandrel to squeeze the resin applied to the glass fabric it helps to spread resin uniformly in all direction. Mandrel are placed to room temperature to cure the fabricated composites. Composite having outer diameter of 26mm and inner diameter of 22mm.

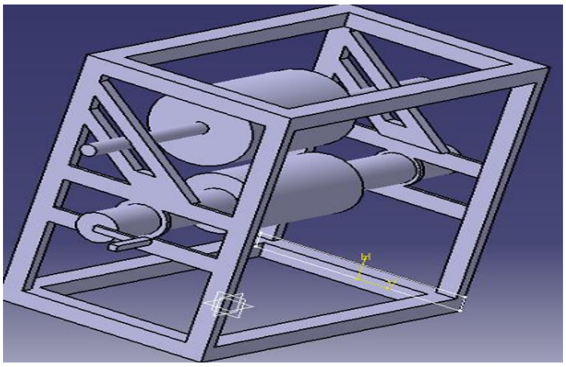


Figure 3: simple hand rolling machine

Figure 4: Materials used to prepare polymer composites and finished composites.

3. TESTING METHODS

The polymer composite materials fabricated were conducted the mechanical and water absorption tests.

3.1 FLEXURAL TEST

The specimen is prepared according to the ASTM standard. Three point bending method is followed in this testing of composites. The testing is carried out in flexural testing machine TUE-C- with displacement velocity at 2 mm/min. The gauge length for testing specimen is 90 mm. The output result is a load Vs displacement curve, from this the ultimate stress and break load is calculated. Four different percentage samples are tested for each fiber resin composition ratio.

Figure 5: Flexural tested composite samples

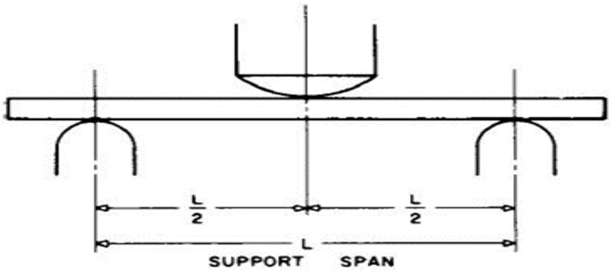


Figure 6: Schematic representation of three point bending of material

3.2 TORSIONAL TEST

Composite materials are subjected to the torsional test to measure the shear strength and shear modulus and this test is useful for the cylindrical shaped composite material to known their behaviour to torsion. Composite used in this test was fabricated by the simple hand rolling machine and data was taken down for the further calculation. Composite are prepared according to ASTM standard and component having gauge length of 60mm by using TTK- machine torsional test was conducted. Outer diameter and inner diameter is 26mm and 22mm respectively.

Figure 7: Components of torsional test

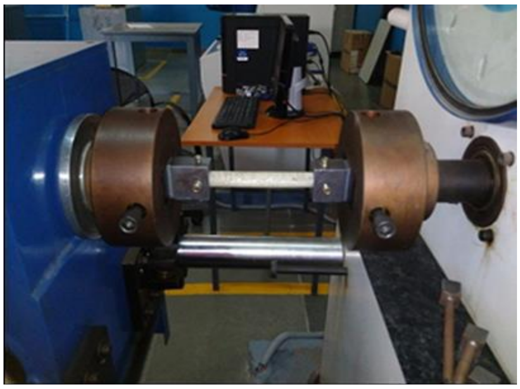


Figure 8: component loaded to torsional machine

3.3 WATER ABSORPTION TEST

Water absorption test was carried out as per the ASTM D570 standard. Composite was dipped into both normal and sea water at room temperature to determine the amount of water absorbed under preferred condition. Samples are taken out from water every 24 hour at equal interval of times and cleaned by using dry cloth then weighed.

Percent Water Absorption M %= [(Wet weight -Dry weight)/ Dry weight] x 100

a b

Figure 9: Water absorption samples (a) normal water (b) sea water

4. RESULT AND DISCUSSION

4.1 DENSITY VARIATION OF COMPOSITES

Table 2: Variation of Theoretical and Experimental Density

Samples	Theoretical Density (gm/cc)	Experimental Density (gm/cc)	Percentage of Porosity
G+E	1.8	1.74	3.334
G+E+3%(Al_2O_3+SiC)	1.87	1.81	3.2
G+E+6%(Al_2O_3+SiC)	1.94	1.88	3.09
G+E+9%(Al_2O_3+SiC)	1.99	1.92	3.517

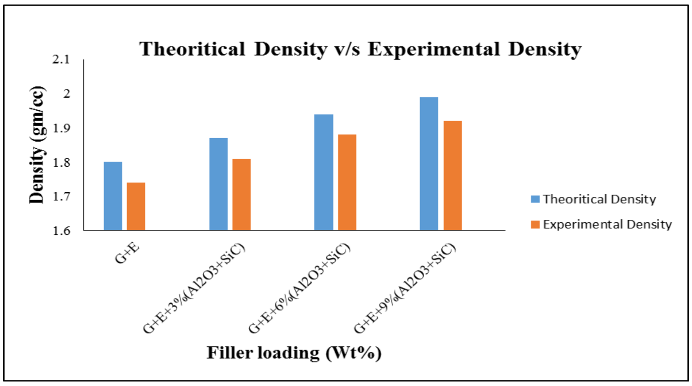


Figure 10: Density variation of composites.

By observing fig 10 shows that density of material varies by adding fillers to the composite and it's also shows that theoretical density higher than experimental density with respect these porosity is calculated.

4.2 FLEXURAL TEST

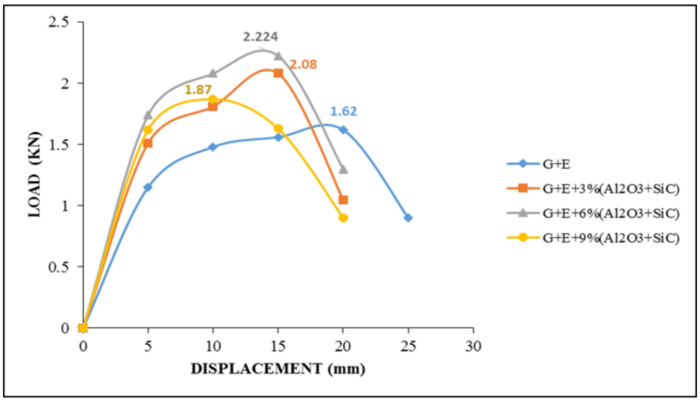


Figure 11: Load v/s displacement of composite

Fig 11 shows the flexural load withstand capacity of the prepared samples are subjected to bending and sample 3 which is filler by G+E+6%(Al_2O_3+SiC) of filler to glass epoxy composite shows highest load carrying capacity of 2.224KN.

Fig 12 and Fig 13 showing flexural strength and flexural modulus respectively. The flexural properties of composite increase with the increasing filler material percentage. By observing the result material filler with G+E+6%(Al_2O_3+SiC) shows higher flexural strength and flexural modulus.

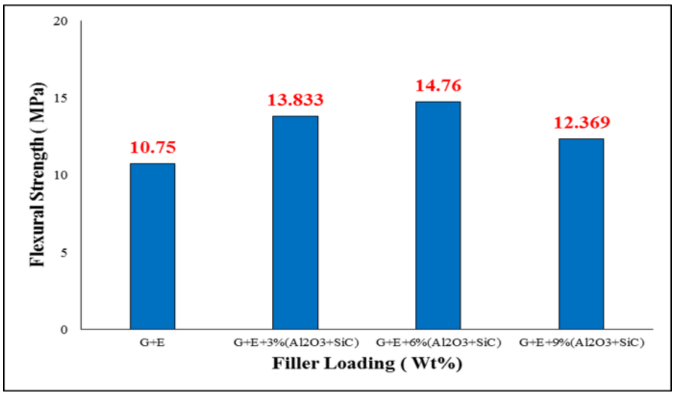


Figure 12: flexural strength result of samples

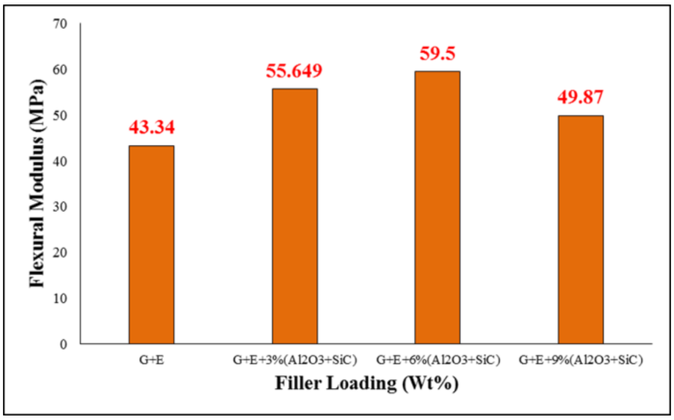


Figure 13: flexural modulus result of samples

4.3 TORSION TEST

Fig 14 and Fig 15 shows the torsional strength and torsional modulus respectively. Filler added to composite revels the significant increase in the properties of composite material. By observing figures sample3 shows the better torsional properties among all the component prepared.

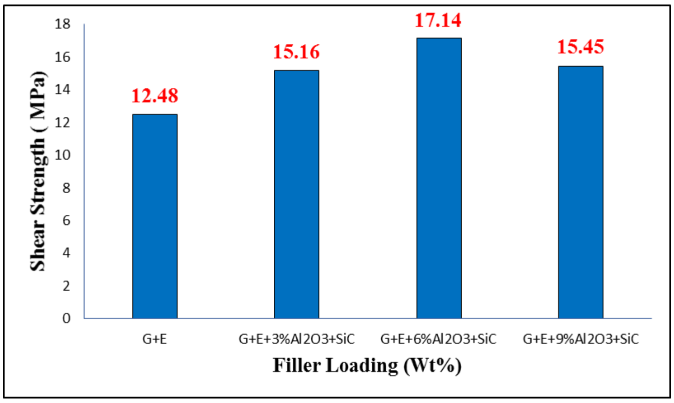


Figure 14: shear strength result of samples

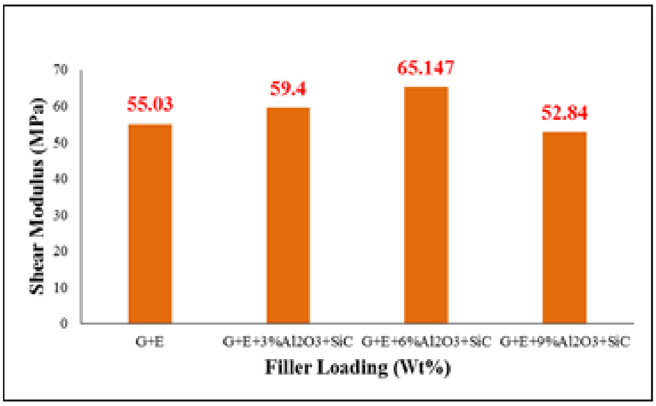


Figure 15: shear modulus result of samples

4.4 WATER ABSORPTION TEST

4.4.1 Normal water test

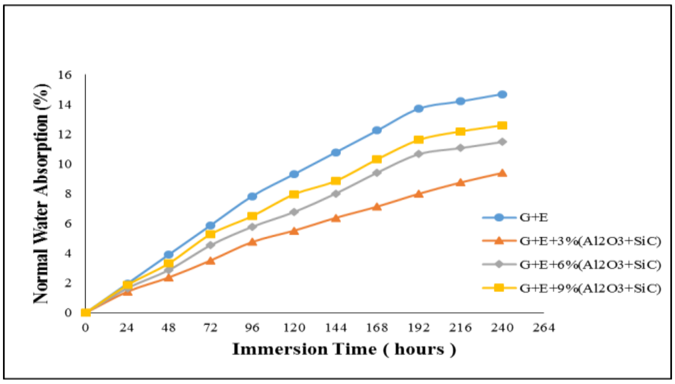


Figure 16: Normal water absorption

All the components are dipped into normal water and reading is taken out. By observing Fig 16 sample1 shows the highest water absorption of 14.7% and sample 2 shows the lowest water absorption of 9.4%, the main reason of water absorption are lumen, gap b/w fibers and epoxy resin used in components.

4.4.2 Sea water test

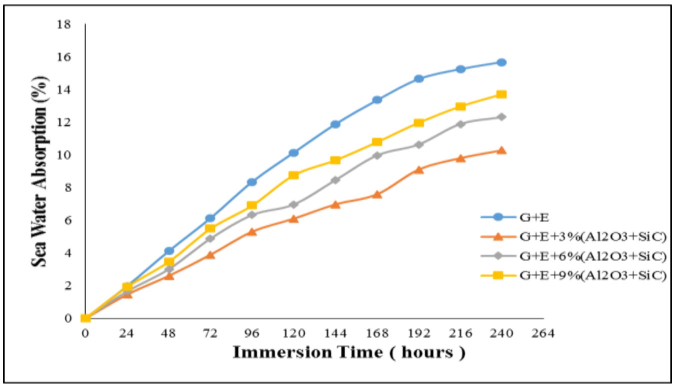
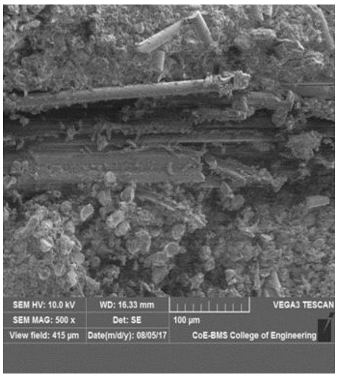


Figure 17: Sea water absorption

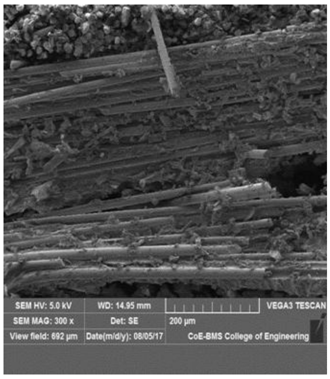
Fig 17 shows the result of sea water absorption of samples and comparing both water absorption behaviour sea water absorption of the sample are higher than approximately unite percentage. From this sample 1 shows the highest water absorption of 15.68% and sample 2 shows the lowest of 10.28%.

4.5 MICROSTRUCTURE STUDIES OF COMPOSITES

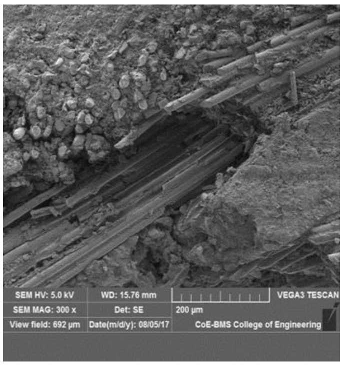
Fracture surface of the various weight percentage filler reinforced glass-epoxy composite materials after flexural test carried is showing bellow figures.



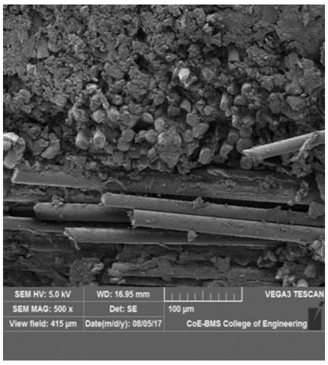
Sample 1



Sample2



Sample3



Sample4

Figure 18: SEM images of different composite samples

By observing all images obtained from SEM, it can be realized that they have some of voids, poor bonding, internal breaking and fibers pull outs in the materials.

5. CONCLUSIONS

Following are the conclusions made by observing the result of the fabricated component samples.

- Composite samples are fabricated successfully by using an Al_2O_3 and SiC filler particulates to Glass-Epoxy composite and properties of samples are significantly varied.

- Flexural test result shows that increasing in the flexural strength by increasing filled loading percentage and higher flexural properties of composite observed by the G+E+6%(Al_2O_3+SiC) sample.

- Sample 3 shows the better torsional properties among all the prepared composite materials.

- Water absorption behaviour of all the samples are studied and results shows that Glass-Epoxy composite having higher water absorption and G+E+3%(Al_2O_3+SiC) sample having lowest water absorption. Result reveal that sea water absorption is higher than normal water absorption in the components.

- All the SEM images of fracture surface was studied and observed that material having a poor bonding, voids and internal breakages.

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