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# Influence of ZnO and SiC Micro Fillers on Mechanical Properties of E-Glass/Polyester Composites

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**Abstract:**
Fiber reinforced polymer composite is an important material for structural application. The diversified application of FRP composite has taken centre of attraction for interdisciplinary research. However, improvements on mechanical properties of this class of materials are still under research for different applications. Nowadays, polymer matrix composite plays a vital role in industries namely automotive, aerospace and marine. Polymer matrix modification is one of the approaches to develop new class of polymer structural materials. This modification can be done by addition of different ceramic powders of different sizes to achieve the required mechanical properties. In this paper we have modified the polyester matrix by $SiO_2$ and ZnO micro particles in glass fiber/polyester composite to improve the mechanical properties. This paper involves the fabrication of polyester resin composites using zinc oxide, silicon carbide with different proportion of ZnO and SiC along with GFRP. A mixing unit has been fabricated for making reinforcement mixtures by using hand lay-up technique. Mechanical testing like tensile, impact hardness flexural strengths are conducted in order to know the properties of fabricated composites. The result shows that composites with filler material show higher strength as compared to composites with unfilled ones.

**Keywords:** Glass fiber, Polyester resin, Silicon carbide, Zinc oxide, Mechanical Properties

## I. INTRODUCTION

Development of new composite materials or modification of existing composite material is the real challenge for most of the materials engineers. Epoxy base matrix composite has tremendous potential to substitute the traditional metallic materials. Polymer matrix modification is one of the approaches to develop new class of polymer structural materials. This modification can be done by addition of different ceramic powders of different sizes to achieve the required mechanical properties. McGrath et al. (2008) studied the effect of alumina powder in epoxy on mechanical properties. Nafisa Gull *et al.* [1] have studied that mechanical and thermal properties of GFRP composite are improved with incorporation of ZnO filler. Flexural modulus, flexural, Impact energy & hardness are enhanced gradually by increasing the filler concentration in fiber reinforced composites. S. Srinivasa Moorthy *et al.*

[2] have investigated on the composite specimens were carried out to determine the tensile strength, impact strength, hardness and chemical resistance. The effect pull load on the composites was studied with scanning electron microscope images. Andrzej *et al.* [3] have investigated the influence of the type of reinforcing fiber, fiber and microvoid content on the mechanical properties of composites. Increasing the fiber content persuades an increase in the impact strength and shear modulus. Though, increasing the microvoid content in the matrix results in decreased impact strength and shear modulus. K. Trinath *et al.* [4] have studied stir processing method is used to increase the strength of polymer with the addition of reinforcements such as micro and nano silica, ZnO and chitin powder. They concluded that the tensile property and hardness of polyester composite was increased for ZnO and SiC. Guirong Peng *et al.* [5] have investigated the degradation behaviour of ZnO-glass fiber-unsaturated polyester composite under exposure to a metal halide lamp. Results show that the UV photons can increase the carbonyl group on the surface, but ZnO can decrease the carbonyl content. Suresh J S *et al.* [6] have studied that mechanical properties of Epoxy and polyester based composites reinforced with Glass Fiber and filled with the natural fille Arabic Gum Tree Coal Powder (A.C.P). results demonstrate that tensile strength is more for the composite of designation Epoxy/Glass fiber. 52.5wt% polyester and 40wt% G.F with 7.5wt% A.C.P composite exhibited maximum flexural strength. K.Devendra *et al.* [7] have studied that mechanical behaviour of E-glass fiber reinforced epoxy composites filled with varying concentration of Al2O3, Mg(OH)2 and SiC. Results show that 10% Mg (OH) 2 exhibited maximum ultimate tensile strength and SiC filled composites exhibited maximum impact strength, flexural strength and hardness. S. Rajesh *et al.* 8] have studied that the fabrication of epoxy and polyester resin composites using aluminium oxide, silicon carbide with different proportion of Al2O3 and SiC along with GFRP. They reported that tensile, biaxial and shear strength of the composites with varying % of filler materials.

## II. MATERIALS & EXPERIMENTAL DETAILS

### A. Glass fiber:

Glass fibre is a material that contains extremely 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 with small diameters. Its bulk strength and weight properties are also very favorable when compared to metals, and it can be easily formed using molding processes. It is used as a reinforcing agent for composites to form a very strong and light fibre reinforced polymer (FRP) composite material.

**B. Polyester Resin:**

Polyester resin is a liquid which will cure into solid when the hardener is added. It has been specially formulated to cure at room temperature. The hardener, MEKP (Methyl Ethyl Ketone Peroxide) is added to cure and also to harden the resin.

**C. Silicon carbide:**

Silicon carbide (SiC) is produced by combining silica sand and carbon in an Acheson graphite electric resistance furnace at a high temperature. It can also be prepared by the thermal decomposition of a polymer under an inert atmosphere at low temperatures. It has low density, high strength, high hardness, high thermal conductivity and also excellent thermal shock resistance. Silicon carbide is the one of the best filler material that is being used in composite.

**D. Zinc Oxide (ZnO):**

Zinc oxide is an inorganic compound with the formula ZnO. ZnO is a white powder that is insoluble in water, and it is widely used as an additive in numerous materials and products including rubbers, plastics, ceramics, glass, cement, lubricants, paints, ointments, adhesives, sealants, pigments, foods, batteries, ferrites, fire retardants, and first-aid tapes. ZnO is a relatively soft material with approximate hardness of 4.5 on the Mohs scale. Although it occurs naturally as the mineral zincite, most zinc oxide is produced synthetically.

## III. FABRICATION PROCEDURE

Resin transfer moulding is a method of plastic casting in which the mould is filled with a liquid synthetic resin, which then allowed hardening. It is mainly used for small-scale production like industrial prototypes and dentistry.

It can be done by amateur hobbyists with little initial investment, and is used in the production of toys, models and figures, as well as small-scale jewellery production. The synthetic resin for such processes is a monomer for making a plastic thermosetting polymer. During the setting process, the liquid monomer polymerizes into the polymer, thereby hardening into a solid.

1. To ensure your mould doesn't fall over during the casting process, secure your mould to a base.
2. Carefully pour out required amount of reinforcement to completely fill the mould (allow small amount extra, better to be too much than not enough).
3. Mix the reinforcement thoroughly into the resin using mixing head.
4. After carefully measuring the correct amount of catalyst (1 to 2%) stir into resin completely, minimum surrounding temperature 16ºC.
5. Pour catalysed resin mixture into the mould as slowly as possible to reduce the risk of introducing unwanted air into the sample.
6. Allow casting to cure (approx. 4 hours in normal room temperature 25º C).
7. Pure resin castings can be quite brittle so care must be taken when affixing them, using an polyester adhesive or similar.

8. Resin part filled with mineral powder is opaque but can still be pigmented and is tougher, with care it can be drilled and tapped if required.

**Table .I. Different composition of Composite materials**

| S.No. | Designation | Composition |
|---|---|---|
| C1 | Pure GFRP | 55 wt% polyester + 45 wt% glass fiber |
| C2 | GFRP+5%SiC | 50 wt% polyester+ 45 wt % glass fiber + 5 wt % SiC |
| C3 | GFRP+5%ZnO | 50 wt% polyester+ 45 wt % glass fiber + 5 wt % ZnO |
| C4 | GFRP+3% SiC | 52 wt% polyester + 45 wt % glass fiber +3 wt % SiC |
| C5 | GFRP+3% ZnO | 52 wt% polyester + 45 wt % glass fiber +3 wt % ZnO |

## IV. TESTING OF COMPOSITES

**A. Tensile Test**:
The tensile behavior of prepared samples was determined at room temperature using Universal testing machine in accordance with ASTM D638. Test specimens having dimension of length 165 mm, width of 15 mm and thickness of 3.5 mm. The specimen was loaded between two manually adjustable grips of a 40 KN computerized universal testing machine (UTM) with an electronic extensometer. Each test was repeated thrice and the average value was taken to calculate the tensile strength of the composites.

**B. Flexural Test:**
Flexural strength is determined by 3-point bend test. The test specimen of dimension 127 mm × 13mm×3mm were used for test. This test method determines the flexural properties of fiber reinforced polymer composites.
The flexural strength of composites was found out using the following equation

$$S = \frac{3PL}{2bd^2}$$

Where *S* is the flexural strength, *P* is the load, L is the gauge length, *b* is the width and *d* is the thickness of the specimen under test.

**C. Impact Test:**
The charpy impact strength of composites was tested using a standard impact machine as per ASTM D 256 standard. The standard test specimens 63.5 x 12.7 x 10mm 2 cross section, having 450 V - notch and 2mm deep were used for the test. Each test was repeated thrice and the average values were taken for calculating the impact strength.

**D. Hardness Test:**

The Vickers hardness test method consists of indenting the test material with a diamond indenter, in the form of a right pyramid with a square base and an angle of 136 degrees between opposite faces subjected to a load of 1 to 100 kgf.

## V. RESULTS AND DISCUSSION

**A. Tensile Test:**

Tensile test was carried out on UTM machine in accordance with ASTM D 638 M standard. All the specimens were of dog bone shape of dimension (165x15x3.5) mm. The tensile test results obtained were plotted in the figure below.

**Table .II. Tensile strength on composites**

| S.NO | COMPOSITION | Ultimate Tensile Strength (Mpa) |
|---|---|---|
| C1 | Pure GFRP | 146.007 |
| C2 | GFRP+5%SiC | 210.793 |
| C3 | GFRP+5%ZnO | 297.037 |
| C4 | GFRP+3%SiC | 203.141 |
| C5 | GFRP+3%ZnO | 260.94 |

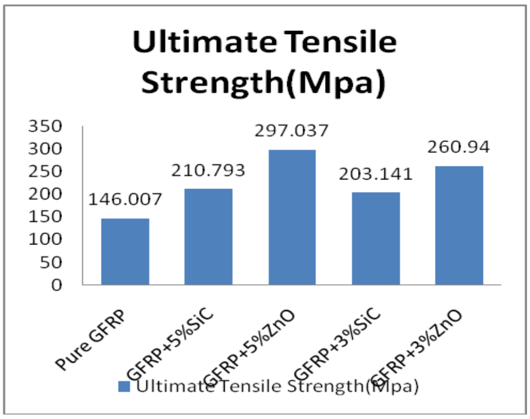


**Figure.1. Variation of Tensile strength on composites**

It is obvious from the figure that the glass fiber reinforced polymer with 5% ZnO obtained maximum tensile strength of 297.037 MPa compared to other filled composites and unfilled pure GFRP. This is due to the good interfacial bonding between the filler and matrix.

**B. Flexural Strength:**

Three point bend test was carried out in an UTM machine in accordance with ASTM standard to measure the flexural strength of the composites. All the specimens (composites) were of rectangular shape having dimension of (127x13x3) mm. The span length was 70mm. The experiment was conducted on all the samples of filler and fiber combinations. The results are plotted in the figure 4.2

**Table .3. Flexural strength on composites**

| S.NO | COMPOSITION | FLEXURAL STRENGTH(Mpa) |
|---|---|---|
| C1 | Pure GFRP | 38.93 |
| C2 | GFRP+5%SiC | 53.64 |
| C3 | GFRP+5%ZnO | 61.64 |
| C4 | GFRP+3%SiC | 50.95 |
| C5 | GFRP+3%ZnO | 55.04 |

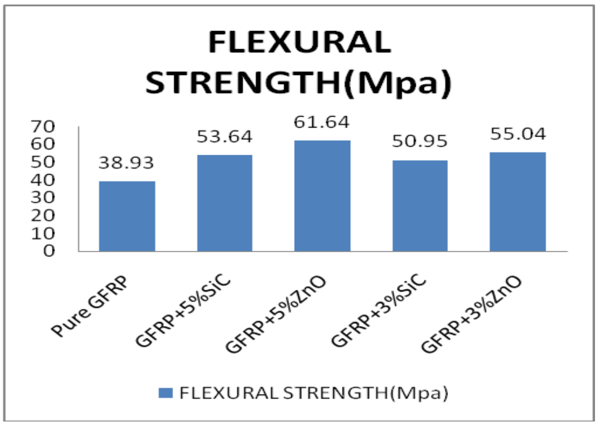


**Figure.2. Variation of Flexural strength on composites**

So by calculating flexural strength for all samples it was found that the GFRP with 5% ZnO has the highest value i.e., 61.64 MPa.

**C. Impact Strength:**

The test samples were cut to recommended shapes and sizes according to ASTM D 256 dimensions. The arm of the Charpy impact machine was allowed to swing freely to ensure freedom of movement and that the pointers were completely freed. The results of the impact energy are shown in the below figure.

**Table.4. Impact strength on composites**

| S.NO | COMPOSITION | IMPACT STRENGTH(J) |
|---|---|---|
| C1 | Pure GFRP | 4 |
| C2 | GFRP+5%SiC | 6 |
| C3 | GFRP+5%ZnO | 5 |
| C4 | GFRP+3%SiC | 7 |
| C5 | GFRP+3%ZnO | 6 |

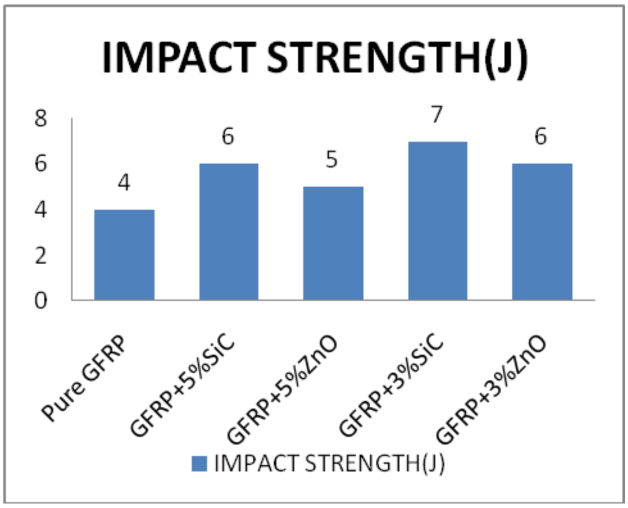


**Figure.3. Variation of Impact strength on composites**

From the above figure it is observed that the highest value for impact strength is for GFRP with 3% SiC i.e., 7 Joules. Due to the higher particle size compared to other fillers it possessed highest energy. It is also been observed that compared to pure GFRP i.e., the unfilled composites, the filled ones have improvement in impact energy.

**D. Hardness:**

The Vickers hardness may be calculated from the formula When the mean diagonal of the indentation has been determined. The determined results in the same manner is plotted in the below figure.

**Table .5. Hardness on composites**

| S.NO | COMPOSITION | HARDNESS(HV) |
|---|---|---|
| C1 | Pure GFRP | 28.75 |
| C2 | GFRP+5%SiC | 35.76 |
| C3 | GFRP+5%ZnO | 33.59 |
| C4 | GFRP+3%SiC | 32.92 |
| C5 | GFRP+3%ZnO | 30.96 |

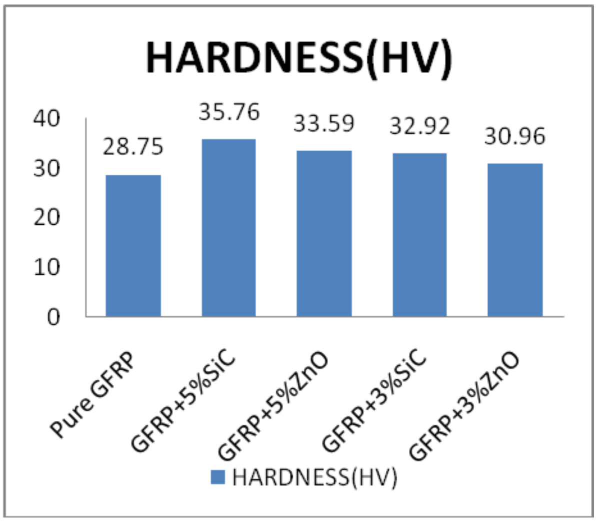


**Figure.4. Variation of Hardnes on composites**

Vickers hardness values has been depicted for the composites which has the highest value for the composite of 5% Sic with GFRP 35.76 Hv. It is observed that the hardness values of the composites of the filled ones got improved compared to the unfilled ones. It is due to the attraction of the fiber and filler material to the matrix.

**E. Water absorption test:**

Water absorption test is very important to determine the water absorptivity of the composite materials [9]. The effect of fibre loading on the water absorption of the filled and unfilled *Glass*-fibre reinforced composites with increase in immersion time is shown in Fig. V. It is evident from the figure that the rate of moisture absorption increases with increase in filler loading. Generally, the rate of water absorption is greatly influenced by the materials density and void content. It is clearly seen in the figure that 3 wt% of fibre loading results in higher water absorption rate as compared to 5 wt% fibre loading in both unfilled and filled composites. The reason may be explained from earlier observations that the *Glass* fibres contain abundant polar hydroxide groups, which result in a high moisture absorption level of natural fibre reinforced polymer matrix composites and are a major obstacle for preventing extensive applications of these materials [10]. The minimum water absorption rate is observed for composite with 5 wt% of fibre loading filled with ZnO micro filler. It is also observed from the figure that the water absorption rate generally increases with immersion time, reaching a certain value at a saturation point where no more water is absorbed.

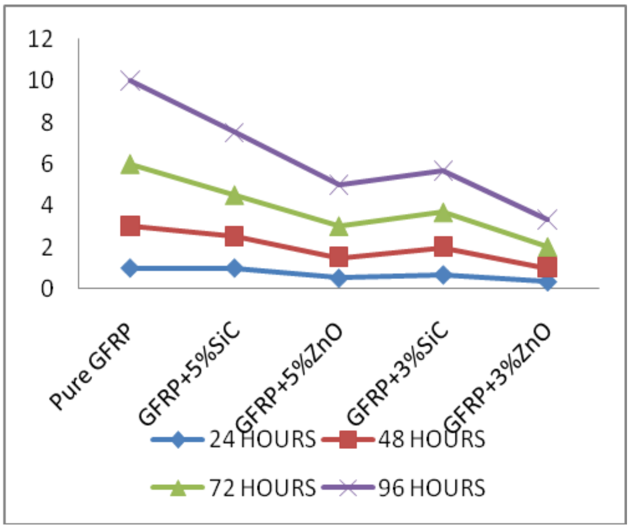


**Figure.5. Water absorption behaviour of composites**

## VI. CONCLUSIONS

### A. Conclusions

The present work deals with the preparation of Glass fiber reinforced polyester composite with and without filler materials. The mechanical behaviour of the composite lead to the following conclusions:

1. The successful fabrications of a new class of polyester based composites reinforced with glass fibers and filler materials have been done.
2. All the properties of the filled composites with SiC and ZnO compared to unfilled ones is higher.
3. ZnO possessed higher tensile and flexural strength values whereas SiC got highest values for impact and hardness tests.
4. Ultimately with the further increase in the filler content the impact strength got reduced whereas in other cases with the improvement of filler content the test results were also been increased.

**Scope for future work:**

There is a very wide scope for future scholars to explore this area of research. This work can be further extended to study other tribological aspects like abrasion, wear, SEM behavior of this composite. We can also study other aspects of such composites like use of other potential fillers for development of hybrid composites and evaluation of their mechanical and erosion behavior and the resulting experimental findings can be similarly analyzed. The results of the tensile test of all the five specimens are shown in table 4. From, the result it is concluded that C3, possess more tensile strength than other composition. Hence, it is clear that sample made with 5% ZnO filled polyester resin have higher strength as compared to sample made with polyester resin.

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