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Fabrication &Characterization Of Zns Microparticulate Filled Glass And Jute Fiber Reinforced Hybrid Polymer Composites

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Abstract

Hybrid composites are one of the prominent materials being extensively developed and are gaining momentum due to features like greater flexibility in design, high specific strength and reduced cost of manufacturing. Hybrid composites exhibit better mechanical properties when compared to traditional composites. This research work is concerned with the fabrication and evaluation of the physical and mechanical properties of a new polymer hybrid epoxy composite consisting of glass fiber, jute fiber mat, ZnS micro particles and LY556 Epoxy resin with HY951 Hardener. The specimens was prepared using hand lay-up technique as per ASTM standard & was tested for Brinell Hardness, Water Absorption, Tensile Test and SEM micrograph analysis.

Keywords: *Hybrid Composites, E-Glassfiber, Jute Mat, Epoxy, ZnS Microparticles, Compression Moulding, Alkali Treatment.*

1. INTRODUCTION

Polymeric based composites materials are being used in many application such as automotive, sporting goods, marine, electrical, industrial, construction, household appliances, etc. Polymeric composites have high strength and stiffness, light weight, and high corrosion resistance. This kind of composite is used in the greatest diversity of composite applications due to its advantages such as low density, good thermal and electrical insulator, ease of fabrication, and low cost. The properties of polymer matrix composites are mainly determined by three constitutive elements such as the types of reinforcements (particles and fibres), the type of polymer, and the interface between them [1]. Natural fiber reinforced composite materials are considered as one of the new class of engineering materials. Interest in this area is rapidly growing both in terms of their industrial applications and fundamental research as they are renewable, cheap, completely or partially recyclable, and biodegradable. Among all the natural fiber reinforcing materials, jute appears to be a promising material because it is relatively inexpensive and commercially available in the required form [2]. Hybridized composites demonstrated better tensile, flexural and resistance to water absorption when compared to standalone composites. Thus authors concluded that hybrid natural fibre composites are a potential alternate to synthetic fibre composites. Test results reported by authors indicated that stack sequence of the composites is significantly affecting inter laminar shear, flexural and tensile strength. Hybrid laminate with two extreme glass plies on either side resulted in an optimum arrangement with a decent balance between the properties and cost [6]. On hybridization of fibers, better properties were obtained due to the supportive nature of the fibers. Further chemical treatment of natural fibers improves the properties by improving bonding strength between fibers and matrix. Results revealed that hybridization of fibers improved tensile and flexural strength of composites by 65.01% and 89.56% in comparison to pure epoxy due to the combined effect of jute fiber in terms of better bonding and date leaf in terms of higher strength. The developed hybrid composite allowed a cost saving of 30.43% in comparison to single jute reinforced composites. Overall results supported the effective utilization of low cost hybrid composite for various structural applications including doors, ceilings, walls and furniture [3]. Glass Fiber Reinforced Polymers is a fiber reinforced polymer made of a plastic matrix reinforced by fine fibers of glass. Fiber glass is a lightweight, strong, and robust material used in different industries due to their excellent properties. Hybridization of glass fiber with Oil palm empty fruit bunch (OPEFB) resulted in composites having a superior mechanical performance. A positive hybrid effect is observed in the elongation property. Thus, glass and OPEFB hybrid fiber reinforcement in Phenol formaldehyde resin resulted in a cost effective and a lightweight composite having good performance qualities [4]. Fillers are used to impart special properties to the end product. Some examples of fillers include Zinc Sulfide, calcium carbonate, hydrous aluminum silicate, alumina trihydrate and calcium sulfate. In some circumstances, fillers and additives play a critical role in lowering the cost of compounds by diluting expensive resins and reducing the amount reinforcements. Furthermore, fillers and additives improve compound rheology, fiber loading uniformity, enhance mechanical and chemical performance and reduce shrinkage. ZnS filled composite shows significantly good results than TiO2 filled composites. ZnS filled composite shows more tensile load in comparison with unfilled and TiO2 filled composites. TiO2 and ZnS filler material makes material harder and brittle which is the reason for reduction in impact toughness value. ZnS filled composite shows significantly higher values than TiO2 filled composites [5]. The purpose of this study is to make use of natural fiber like jute fiber, which is abundantly available in India and to incorporate with synthetic fiber like glass fiber to enhance the mechanical properties. In this paper, an effect of hybridization of jute/E-glass fiber reinforced epoxy composites is evaluated. The results of the tests help in determining the potential applications of the jute/E-glass fiber reinforced epoxy composites.

2. EXPERIMENTAL DETAILS

2.1 Materials

In this present study, commercially available woven roving fabric E-glassfiber of 360gsm was purchased from Sun Tech Fiber Private Limited Bangalore, India. Epoxy resin of trade name LY556 and Hardener HY951 was purchased from Zenith Industrial Supplies Bangalore, India. Bidirectional Jute Fiber Mats of thickness 0.4mm was purchased from Prince Enterprise, Chikpet, Bangalore. Epoxy resin is mixed with ZnS microparticles which was purchased from Nano Wings Private Limited, Telangana, India.

Figure 1.1:E-Fiber Glass

Figure1.2: Epoxy and Hardener

Figure 1.3:Jute Mat

Table 1.1:Physical properties of jute fiber and glass fiber

Physical Property	Jute Fiber
Density [g/cm^3]	1.4
Elongation at break [%]	1.8
Cellulose Content [%]	50-57
Tensile Strength [Mpa]	700-800
Young’s Modulus	30

Physical Property	Glass Fiber
GSM	360
Orientation	Woven Roving
UTS [Gpa]	40
Modulus [Gpa]	1.0
Density [g/cm^3]	1.9

2.2 Alkali Treatment Of Jute Mat

The natural fibers arehydrophilic and have polar groups in their structure. Moreover, natural fibers also consistof several elementaryfibers associated with cellulose, hemicellulose, pectin,lignin, etc. Hence, they cannot beconsidered as the mono-filament fibers. To remove the unwanted elementsfrom the fiber, specific treatments arenecessary.On the alkali treatment of jute fibers reports on the removal of lignin and hemicellulose which affects the tensile characteristics of the fibers. When hemicelluloses are removed, the interfibrillar region is likely to be less dense and less rigid and thereby makes the fibrils more capable of rearranging themselves along the direction of tensile deformation.When jute fibers are stretched, such rearrangements among the fibrils would result in better load sharing and hence in higher stress development in the fibers. The increase in the percentage crystallinity index of alkali-treated fibres occurs because of the removal of the cementing materials, which leads to better packing of the cellulose chains. The mechanical properties of jute fibres were optimized by using NaOH-treatment process with different alkali concentrations and shrinkages. Shrinkage of the fibres during treatment had the most significant effect on the fiber structure and, as a result, on the fiber mechanical properties such as tensile strength, modulus and toughness.

Figue 1.4: Mixing of NaOH

Figure 1.5: Immerssion of Jute Mat

2.3Specimen Preparation

Hand Layup process was adopted to fabricate the composite panels of 220 mm x 200 mm with varying ZnSmicroparticles. Laminate preparation was started by cleaning the mould surface with a cotton cloth followed by application of wax layer so as to facilitate easy removal of the laminate. Glass/Jute reinforcement of required weave pattern were placed on the mould. Calculated amount of epoxy and hardener were emptied into a container and mixed for 10 minutes. Resin was then poured into the mould and evenly spread by a roller. The laminates were cured for 24hours at room temperature. Cured part was then released from mould and trimmed to remove the undulating edges. The thickness of the composite laminate was 3 mm. The specimen are cut as per ATSM standards, ASTM D638 with dimension of 216X19X3mm^3 for tensile test, ASTM D790 of dimension 80X8X3mm^3 for flexure test, ASTM D256 of dimension 65X12.5X3mm^3 for impact test, ASTM D2344 of dimension 45X6X3mm^3 for inter laminar shear strength.Figure 1 shows the cured polymer composite panel.

Figure 1. 6: Cured polymer composite panel

Table 1. 2: Designation and composition of hybrid composites

Designation of composites	Jute [g]	Jute [mass %]	GF [g]	GF [mass %]	Matrix [g]	Matrix [mass %]	ZnS [g]	ZnS [mass %]
C1	14	8.4	33	19.7	120.3	71.9	0	0
C2	14	8.2	33	19.3	118.86	69.5	5.13	3
C3	14	8	33	18.9	117.36	67.1	10.49	6
C4	14	7.8	33	18.4	115.9	64.8	16.1	9
C5	14	7.6	33	18	114.26	62.4	21.97	12

3. RESULTS AND DISCUSSION

3.1 Brinell Hardness Test

Hardness: Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may also refer to resistance to bending, scratching, abrasion or cutting.
The Brinell hardness test method consists of indenting the test material with a 2.5mm diameter hardened steel or carbide ball. The full load is normally applied for 10 to 15 seconds. The diameter of the indentation left in the test material is measured with a low powered microscope. The Brinell harness number is calculated by dividing the load applied by the surface area of the indentation.

$$\text{BHN} = \frac{F}{\frac{\pi}{2} D(D - \sqrt{D^2 - Di^2})}$$

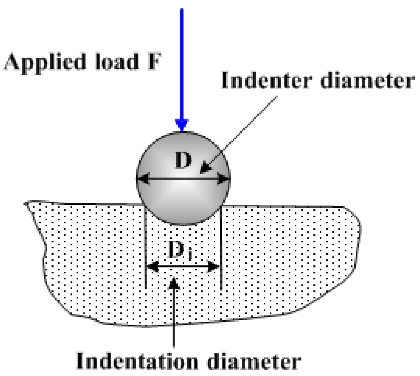

Figure1.7.:Brinell Hardness Test

Table 1.3: Effect of ZnSmicroparticles on Hardness of the composite.

Sl. No	Designation of composites	Diameter of Indentation (D_i)	BHN in Kg-f/mm^2	Average BHN
1	C1	2.2	19.40	17.64
		2.2	19.40	
		2.4	14.14	
2	C2	2.2	19.40	18.51
		2.3	16.75	
		2.2	19.40	
3	C3	2.2	19.40	19.47
		2.3	16.75	
		2.1	22.26	
4	C4	2.1	22.26	23.32
		2	25.46	
		2.1	22.26	
5	C5	2.1	22.26	24.39
		2	25.46	
		2	25.46	

Figure 1.8:Brinell Hardness Testing Machine

Figure 1.9: Measuring Indentation using Microscope

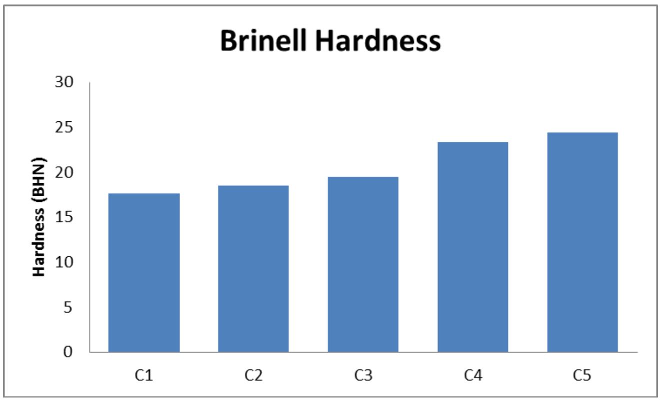

Figure 1.10:BHN v/s Composites

Figure 1.10 shows the variation of BHN of PMC for various weight % of ZnS. As compared to the base composite the percentage increase in hardness for ZnS, fiber glass, jute and epoxy varied from 17.64 BHN for C1 (0% ZnS) to 24.39 BHN for C5 (12% ZnS). The hardness increased 38% compared to the base composite. This increase in hardness is due to higher hardness of dispersed ZnSmicroparticles.

3.2Water Absorption Test

Water absorption testcovers the determination of the relative rate of absorption of water by composites when immersed in distilled water.The Water absorption test is done by cutting the composite specimen as per ASTM: D570-98 standard (sample dimension is 76.2×25.4×3.2 mm).

1. **Conditioning:**Specimens of materials whose water-absorption value would be appreciably affected by temperatures in the neighborhood of 110°C (230°F), shall be dried in an oven for 24 h at 50°C (122°F), cooled in a desiccator and immediately weighed to the nearest 0.001 g.

2. **Reconditioning:**When materials are known or suspected to contain any appreciable amount of water-soluble ingredients, the specimens, after immersion, shall be weighed, and then reconditioned for the same time and temperature as used in the original drying period. They shall then be cooled in a desiccator and immediately reweighed.

Procedure: Twenty-Four Hour Immersion-The conditioned specimens shall be placed in a container of distilled water maintained at a temperature of 23°C (73.4°F), and shall rest on edge and be entirely immersed. At the end of 24, +1⁄2, −0 h, the specimens shall be removed from the water one at a time, all surface water wiped off with a dry cloth, and weighed to the nearest 0.001 g immediately.

Calculation:

(1)Percentage increase in weight during immersion, calculated to the nearest 0.01 % as follows:

Increase in Weight,%=[(wet weight-conditioned weight)/conditioned] ×100

(2)Percentage of soluble matter lost during immersion, calculated to the nearest 0.01 % as follows:

Soluble matter lost,%=[(conditioned weight-reconditioned weight)/conditioned weight] ×100

Table 1.4: Effect of ZnSmicroparticles on Water Absorption property of the composite.

Sl.No	Designation of Composites	Conditioned Weight [gm]	Wet Weight [gm]	Re-conditioned Weight [gm]	Increase in Weight [%]	Soluble Matter Lost [%]
1	C1	8.3	8.5	8.3	1.8	0
		8.2	8.3	8.2		
2	C2	9	9	9	0.56	0
		8.9	9	8.9		
3	C3	8.9	9	8.9	0.56	0
		8.8	8.8	8.8		
4	C4	9	9	8.9	0.58	0.55
		8.6	8.7	8.6		
5	C5	9.3	9.4	9.3	1.09	0.55
		9	9.1	8.9		

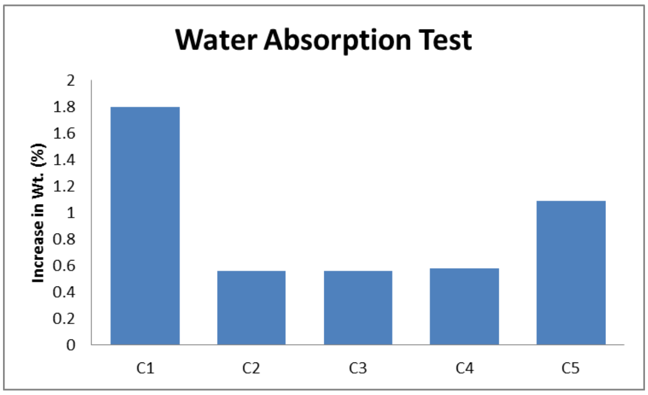

Figure1.11: Weight % vs Composites

Figure1.11 shows the effect of ZnS microparticles on the water absorption of the composites. In water absorption test, the absorption of water decreases in C2 (3% ZnS), C3 (6% ZnS) as compared to base composite C1 (0 % ZnS). There is a decrease of 69 % water absorption as compared to base composite. It is due to increase in % of ZnS microparticles.

3.3Tensile Test

Tensile strength is the maximum stress that a material can withstand on the application of tensile load before breaking. The highest point of the stress-strain curve is the ultimate tensile strength of the specimen. The tensile test is done by cutting the composite specimen as per ASTM: D3039 standard, sample dimension is ($250\times25\times3mm^3$). A universal testing machine (UTM) (Model: AI-UTE(C)) is used for testing with a maximum load rating of 400 KN. Composite specimens with varying ZnSmicroparticle and epoxy combinations are tested. In each case, four samples are tested and the average is determined and noted. The specimen is held in the grip and load is applied and the corresponding deflections are noted. The load is applied until the specimen breaks and break load, ultimate tensile strengths are noted. Tensile stress and strain are recorded, load vs length graphs are generated.

Table 1.5: Effect of ZnSmicroparticles on Tensile strength of the composite.

Designation of Composite	Maximum Load [KN]	Tensile Strength [Mpa]
C1	11.20	149.33
C2	11.28	150.40
C3	11.46	152.80
C4	10.88	145.07
C5	10.38	138.40

As compared to base composite, tensile strength increased from 149.33 MPa for C1 (0% ZnS) to 152.8 MPa for C3 (6% ZnS) and then a decrease in tensile strength observed after C3 (6% ZnS) till C5 (12% ZnS). This is due to agglomeration of ZnSmicroparticles with the epoxy resin and increase in brittlness.

Figure 1.12. Tensile test

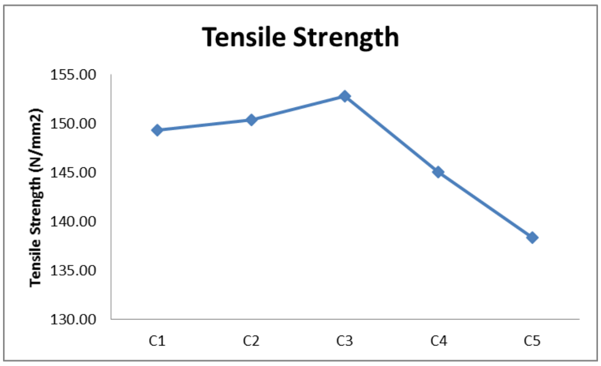

Figure 1.13. Tensile strength v/s composites

3.4 SEM Analysis

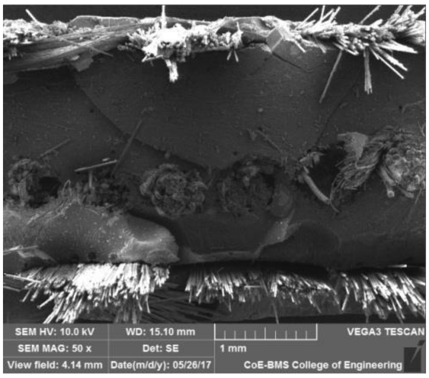

Figure 1.14: SEM micrograph of fractured tensile specimen at 50X

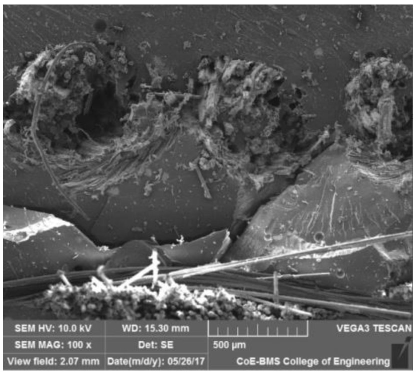

Figure1.15:SEM micrograph of fractured tensile specimen at 100X

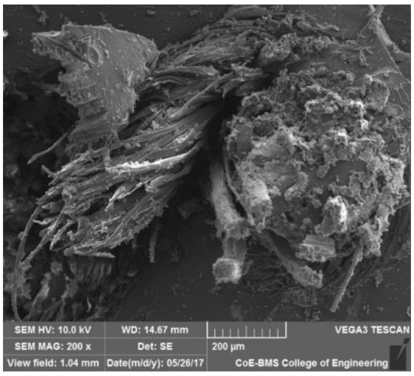

Figure 1.16:SEM micrograph of fractured tensile specimen at 200X

It is observed from SEM micrograph that the jute and glass fibers are evenly distributed.It is observed from SEM micrograph that there is no agglomeration of ZnSmicroparticles during mixing of the microparticles with epoxy. Fig 14 to 16 has shown the strong bonding between fibers, ZnSmicroparticles and epoxy.

4. CONCLUSION

Glass & Jute fiber reinforced polymer matrix composites have been successfully fabricated by hand lay-up technique by addition of ZnS micro particulate

- The hardness of the composite was found to increase with increase in the weight % of Zns micro particulate. The hardness is more for composition C5 (12 % Zns).
- In water absorption test, the absorption of water decreases as compared to base composite C1 (0 % ZnS). It is because of increase in % of ZnS.
- The ultimate tensile strength was found to increase with increase in ZnS micro particulate content significantly increases up to C3 (6 % ZnS) but decreases thereafter due to increase in the brittleness or reduction in ductility.
- SEM micrograph shows the strong bonding between fibers, ZnS and epoxy.

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