International Journal of Engineering Research
Volume No.5 Issue: Special 2, pp: 350-354

ISSN:2319-6890)(online),2347-5013(print)
11-12 Feb. 2016

Preparation and Characterization of Mechanical Properties of Glass Powder Reinforced Composites with Isopthalic Polyester Resin as Matrix

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Abstract: Polymers are important matrix materials for forming advanced composites. The effect of the weight fraction of reinforced particles on mechanical properties in polymeric reinforced composites were investigated. In our work, Isopthalic Polyester is used as matrix material and glass powder with 200 mesh size as filler material to prepare composite lamina. Isopthalic Polyester resin was filled with glass powder with a view to increasing strength of the composite. This project varies the percentage by weight of the glass powder in the composites from 10% to 40% which are then subjected to Flexural and Tensile tests. The results show that composite with 30 % by weight of the glass powder produces the highest Flexural strength, Young's modulus and Ultimate Tensile strength; the highest deflection was achieved when the percentage by weight of glass powder is 10 %. Increase in addition of glass particles weight % from 0 to 30 % improved the observed mechanical properties relatively but found decrease in same properties for 40 % composite lamina.

Key words: GPRL (Glass Particle Reinforced Lamina), Lamina, Isopthalic Polyester.

1. Introduction

The reinforced materials in advanced composites take many forms and been a wide area of research and it is the preferred choice due to its superior properties like low density, stiffness, light weight and possesses better mechanical properties. This has found its wide applications in aerospace, automotive, marine , chemical industries etc…[1]

Particle reinforced composites have relatively isotropic properties compared to short fiber or whisker reinforced composites. The properties of the composites can be tailored by manipulating parameters such as reinforcement particle distribution, sizvolume fraction, orientation, and matrix microstructure [2–4].

Glass powder is generally the inert materials which are used in composite materials to reduce material costs, improve mechanical properties to some extent, toughness, high heat resistance, high sound, electric insulation, great chemical resistance and in some cases to improve process ability[5].

Glass powder of particle size 200 mesh size (74µm) added in the final of mixing a resin, gradually and slowly with the hardener and accelerator in a beaker at room temperature. Glass powder is most often added to polymers to improve tensile and compressive strength, abrasion resistance, toughness, dimensional and thermal stability of, and other properties. Because these inexpensive materials replace some volumes of the most expensive polymer, the cost of the final product is reduced.

Some Mechanical properties of clear cast (unreinforced) Isopthalic polyester resin are shown in Table1[6]

Table 1

Resin Type	Flexural strength(M.Pa)	Flexural modulus(G.Pa)
Isopthalic polyester	80	3.45

The main aim of the project work is to prepare a glass powder composite. In this context thermosetting resin is used for the preparation of lamina prepared by hand lay-up technique. Various polyester composite specimens with different percentage by weight of glass powder (10%, 20%, 30%, and 40%) are prepared. These are then characterized accordingly by conducting Flexural and Tensile Tests to study the mechanical properties. These properties are evaluated as per ASTM standards.

Intention of this project work is to replace a fiber with powder so that this composite material can be used where the moudling of fiber reinforced composite is difficult for small equipment design and complex shapes. For wich we investigate the flexural properties and tensile properties of polyester composites reinforced with varying percentage by weight of glass powder, the filler, with a view to finding out the optimum percentage by weight of the glass powder that can be added to the composite.

It is also hoped that the discussion and results in this work would not only contribute towards the development of glass powder reinforced polyester composites with better material properties, but also useful for the investigations of flexural properties in other composites.

II Material and Methodology

2.1 Material

2.1.1Types of Glass

Glass fall into two categories, low-cost general-purpose and premium special-purpose . Over 90% of all glass are general-purpose products. These are known by the designation E-glass and are subject to ASTM specifications. The remaining glass are premium special-purpose products.

Many, like E-glass, have letter designations implying special properties. Some have trade names, but not all are subject to ASTM specifications. Table 2 shows different glass designation with properties.

Table 2 Letter designation Property or characteristic

E, electrical	Low electrical conductivity
S, strength	High strength
C, chemical	High chemical durability
M, modulus	High stiffness
A, alkali	High alkali or soda lime glass
D, dielectric	Low dielectric constant
ECR	Electrical/Chemical resistance

E-glass ("E" because of initial Electrical application), is alkali free, and was the first glass formulation used for continuous filament formation. It now makes up most of the fiberglass production in the world, and also is the single largest consumer of boron minerals globally. It is susceptible to chloride ion attack and is a poor choice for marine applications**.** E Glass fibers have excellent resistance to all types of nuclear radiation.[6]

2.1.2 Resin description

Isopthalic resins are based on isopthalic acid and maleic anhydrade. The incorporation of isophthalic acid creates a high molecular weight resin with good chemical properties. The use of non-polar glycols contributes to improved aqueous resistance, which is required to protect the reinforced glass materials.[7]

2.2 Experimental Procedure

2.2.1 Preparation Of Lamina

The laminas are prepared by hand layup technique. The hand layup is the one of the Fabrication technique. First Wax polish is applied on the surfaces of the base plates and poly vinyl alcohol (PVA) is applied with a brush and allowed to dry for few minutes to form a thin layer. These two items will help in easy removal of the laminate from the base plates. PVA also provides a glossy finish to the surfaces of the laminate. The general purpose Unsaturated Isopthalic Polyester Resin is taken along with 2% each of catalyst-Methyl Ethyl Ketone Peroxide (MEKP) and accelerator- Cobalt Napthalate.[1]

The catalyst initiates the polymerization process and the accelerator speeds up this process. Initially the catalyst is added and then the accelerator. The resin is mixed with the glass powder initially next catalyst is mixed and finally accelerator is added. The total composite is now evenly distributed in the mould by hand layup method. It is always preferable to add lesser quantity of accelerator than the specified amount to avoid solidification of the contents before they are poured and evenly laid up in the mould. Then the top base plate that was already applied with the wax and PVA is placed on the laid resin and a weight of about 1000 N is placed over for about 24 hours. In general, oxygen inhibits surface cure so that the resin surface exposed to the air does not crosslink completely. Thus, the mold was covered with a glass plate and to make the surface of the composite smooth.[8]

Totally 4 laminas are prepared i.e., 10% GPRL, 20%GPRL, 30%GPRL, 40%GPRL by hand lay up method.

Figure 1. Mould covered with Glass plate with weights on it

2.2.2 Preparation Of Specimens

Specimens for Flexural Test and Tensile Tests are cut on a jig saw machine as per ASTM standards as shown in Table 3.[8]

Table 3

Properties	ASTM Test Method
Tensile strength, modulus, and % elongation	D 638
Flexural strength and modulus	D 790

Figure 2. Cutting the lamina for required dimensions

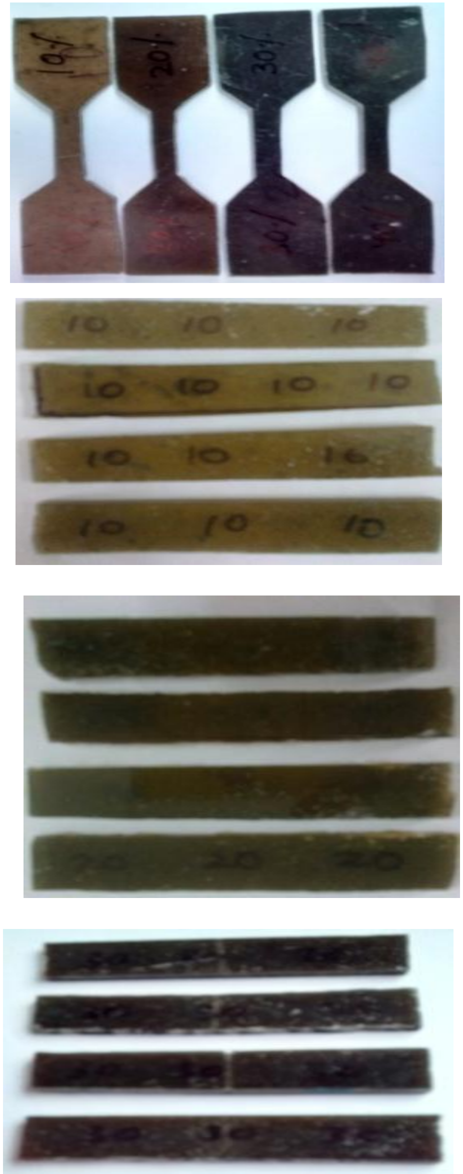

Figure 3. Tensile test samples

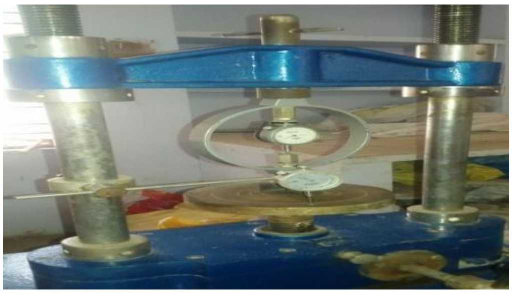

Figure 4. 10% 20%,30%,40% **GPRL** specimens for Flexural Test

2.3 Testing Procedure

2.3.1Flexural Testing [9]

Flexural strength is the ability of the material to withstand bending forces applied perpendicular to its longitudinal axis. Sometime it is referred as cross breaking strength where maximum stress developed when a bar-shaped test piece, acting as a simple beam, is subjected to a bending force perpendicular to the bar.

Flexural test was done on Load Frame **Figure 5**supplied by Hydraulic and Engineering Instruments, New Delhi, with a cross head speed of 1.25 mm/minute at standard laboratory atmosphere of 23°C ± 2°C (73.4°F ± 3.6°F) and 50 ± 5 percent relative humidity. There were two important parameters being determined in the flexural test, they are flexural strength and tangent modulus of elasticity in bending.

2.3.1.1 Flexural Strength

Flexural strength is the maximum stress in the outer specimen at the moment of break. When the homogeneous elastic material is tested with three-point system, the maximum stress occurs at the midpoint. This stress can be evaluated for any point on the load deflection curve using equation (1).

$$\sigma_f = 3PL/2bd^2 \qquad (1)$$

Where

σ_f = stress in the outer specimen at midpoint, MPa [psi]

P = load at a given point on the load deflection curve, N [lbf]

L = support span, mm [in]

b = width of beam tested, mm [in]

d = depth of beam tested, mm [in]

2.3.1.2 Flexural Modulus

Flexural modulus or Modulus of elasticity is a measure of the stiffness during the initial of the bending process. This tangent modulus is the ratio within the elastic limit of stress to corresponding strain. A tangent line will be drawn to the steepest initial straight line portion of the load deflection curve and the value can be calculated using equation.

$$E_B = L^3m/4bd^3 \qquad (2)$$

Where

E_B= modulus of elasticity in bending, GPa [psi]

L = support span, mm [in]

m = slope of the tangent to the initial straight line portion of the load deflection curve, N/mm [lbf /in] of deflection

b = width of beam tested, mm [in]

d = depth of beam tested, mm [in]

Figure 5. Load Frame for flexural test
(Courtesy:Strength of materials lab,KITS-Warangal)

2.3.2 Tensile Testing

Tensile testing, also known as tension testing, is a fundamental materials science test in which a sample is subjected to a controlled tension until failure. Tension test is widely used to provide basic design information on the strength of materials and is an acceptance test for the specification of materials. The experiments were conducted on Tensile Testing Machine **Figure:6** at a constant crosshead speed 3mm/min. The stress vs strain plots were obtained for each lamina specimen from the automatic computerized chart recorder. Tensile failure strength were recorded from machine for all lamina along the length of composite.

Figure: 6 Tensile Testing Machine
(Courtesy:MSME Testing Station,Hyderabad)

3.Results and Tables.

3.1 Flexural Test Results

The flexural test results on different composite lamina specimens prepared are tabulated in the tables shown below. Flexural strength of the lamina specimen found to increase relatively with glass powder weight ratio increase from 10% to 30 % in reinforced material and shown decrease in flexural strength for 40% glass powder composite specimen.

Load vs Deflection graph **Figure 7** is taken to find the initial slopes to determine Flexural modulus using equation (2). Flexural modulus of the lamina specimen found to increase relatively with glass powder weight ratio increase from 10% to 30 % in reinforced material and shown decrease in flexural modulus for 40% glass powder composite specimen.

Table 4. Flexural Test observations for **10% GPRL**

Deflection (mm)	load(P) N	Flexural Strength(σ_f) (M.Pa)	Flexural Modulus (G.Pa)
0.5	22.5	14.0625	3.74
1	46.25	28.90625	
1.5	70	43.75	
2	92.5	57.8125	
2.5	103.75	64.84375	
3	120	75	
3.5	132.5	82.8125	
4	137.5	85.9375	

Table 5. Flexural Test observations for **20% GPRL**

Deflection (mm)	load(P) N	Flexural Strength(σ_f) (M.Pa)	Flexural Modulus (G.Pa)
0.5	23.75	14.84375	4.2
1	53.75	33.59375	
1.5	76.25	47.65625	
2	96.25	60.15625	
2.5	110	68.75	
3	123.75	77.34375	
3.5	133.75	83.59375	
4	141.25	88.28125	

Table 6. Flexural Test observations for **30% GPRL**

Deflection (mm)	load(P) N	Flexural Strength(σ_f) (M.Pa)	Flexural Modulus (G.Pa)
0.5	35	21.875	5.1
1	72.5	45.3125	
1.5	98.75	61.71875	
2	118.75	74.21875	
2.5	131.25	82.03125	
3	145	90.625	

Table 7. Flexural Test observations for **40% GPRL**

Deflection (mm)	load(P) N	Flexural Strength(σ_f) (M.Pa)	Flexural Modulus (G.Pa)
0.5	41.25	25.78125	4.1
1	70	43.75	
1.5	92.5	57.8125	
2	107.5	67.1875	
2.5	121.25	75.78125	
3	135	84.375	

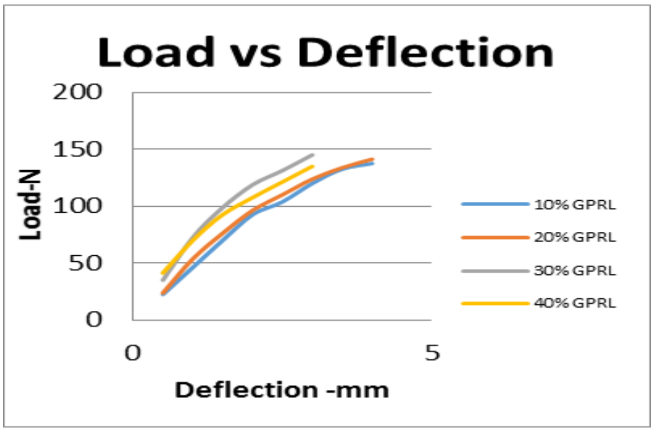

Figure:7 Load vs Deflection Curves to determine Initial slope

3.2 Tensile Test Result

The Ultimate tensile load for different laminas is shown in Figure 7. The 30% GPRL has highest Ultimate tensile load of 519.13 N. It shows that by adding glass powder load carrying capacity increases up to some extent i.e, 30% GPRL and has shown decrease in Ultimate Tensile Load for 40%GPRL

Table 8 Ultimate Tensile load of laminas

Specimen	10% GPRL	20% GPRL	30% GPRL	40% GPRL
Ultimate Tensile load (N)	**477.10**	**489.18**	**519.13**	**335.59**

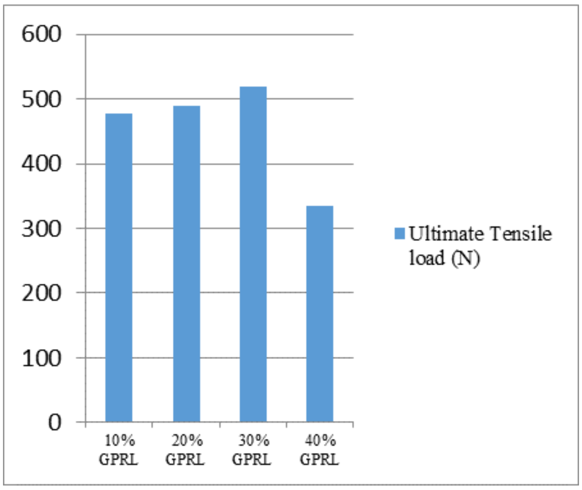

Figure:8 Ultimate Tensile Load vs GPRL's

4. Conclusion

The ., 10% , 20%, 30%, 40%GPRL prepared by hand lay up method composite specimens as per ASTM standards were subjected to mechanical characterization , the results are analyzed and compared. The results show that composite with 30 % by weight of the glass powder produces the highest Flexural strength(90.6 M.Pa) , Young's modulus(5.1 G.pa) and Ultimate Tensile Load(519.3N) comparitively; the highest deflection was achieved when the percentage by weight of glass powder is 10 % . Increase in addition of glass particles weight % from 0 to 30 % improved the observed mechanical properties relatively but found decrease in same properties for 40 % composite lamina. i.e.

The flexural strength of ., 10% , 20%, 30% and 40%GPRL composites were observed to be 85.9, 88.2, 90.6 and 84.3 M.Pa respectively. The 30% GPRL were found to have 11.6 %and 14.8% increase in the flexural strength and Flexural Modulus repectively than the clear cast (unreinforced) Isopthalic polyester resin as shown in Table[1] whereas 40% GPRL Composite show decrease in flexural strength and Flexural Modulus. The 10% and 20%GPRL composite showed more deflection before break . The 30% GPRL composites showed Maximum Ultimate Tensile Load when compared with 10% , 20%, and 40% GPRL composites.. From the above results, it revealed that the GPRL composite showed better Tensile and Flexural properties upto some weight % of Particles.

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