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EFFECT OF FIBRE GLASS ADDITION ON THE MECHANICAL PROPERTIES OF GLASS FIBRE REINFORCED POLYMER (GFRP) COMPOSITE

Mfon Udo[1*], Philip Babalola[1], Samson Ongbali[1], Solomon Banjo[1], Victoria Obasa[2], Jesutoni Adelore[1],

[1] Mechanical Engineering Department, Covenant University, Ota, Nigeria
[2]Department of Metallurgical and Materials Engineering, University of Lagos, Nigeria
Corresponding Author: E mail: mfon.udo@covenantuniversity.edu.ng

Abstract

A fibre glass reinforced polymer was developed, using epoxy resin as the matrix material and E- glass fibre as the reinforcement, by hand laying method. Different set of the composite were produced by varying the weight percentage (wt%) addition of the reinforcement to the epoxy resin as follows 10%, 20%, 30%, 40% and 50%. The polymeric composite so produced were subjected to various mechanical property tests as hardness, tensile, impact, tests. The hardness test was conducted using TQ SM1000 Universal Testing Machine, the tensile strength test was carried out on Hounsfield Tensiometer model while the impact test was carried out on Izod Impact Testing Machine. It was observed that the mechanical properties of hardness, tensile strength and impact strength were of higher values in the composites with different weight fractions of glass fibre than in unreinforced epoxy resin. It was also found out that the values of those mechanical properties increased directly proportional to the amount of weight percentage of the reinforcement in the composites with the highest of the values residing in the composite with 50 wt% of the reinforcement. The hardness value for GFRP composite with 50 wt% glass fibre reinforcement stood at 57 BHN, tensile strength at 332.7 MPa and impact energy value of 17.5 J/m^2.

Keywords: glass fibre reinforced composite, epoxy resin, mechanical properties

1. Introduction

Composite is an engineered material made from two or more constituent materials with distinctly different properties [1]. Each constituent retains its identity in the composite without dissolving or merging completely into each other although they act in concert. A composite generally has two major components known as the matrix and the reinforcement. The matrix is a relatively soft and primary phase with a continuous character which holds the reinforcement phase and shares applied load with it [2]. On the other hand, the reinforcement is the hard and second phase of the composite which mainly carries the applied load in the composite. The reinforcement phase can be in the form of whiskers, continuous or discontinuous fibres, or particulate [3, 4]. Most commonly synthetic fibres in use include glass, carbon, aramid and basalt fibres while paper, wood asbestos fibres are rarely used. Eventually the properties of the formed composite will be different from the properties of the constituent materials but will be affected by such factors as the particle size of reinforcement, the type of reinforcement, as well as the shape and distribution of reinforcement in the matrix [5]. A composite may be composed of all metals, metals with non-metals or all non-metals [6, 7]. Most frequently used non-metals include polymers, ceramics and carbon. Where polymer is the matrix materials, we have polymeric composite. Polymeric composites are very useful in many areas of life like aerospace, automobile, civil and marine construction industries, biomedicals, oil and gas industries. They are used for construction of ladders, platforms, handrails, system tanks, pipes and pump support [8,9]. They are also used in structural applications to strengthen beams, columns and slabs of buildings. Such structural members can even be strengthened using the composite after they have been damaged due to loading. They are so useful because they possess good strength to weight ratio, high durability, wear and corrosion resistance, impact and fire resistance, damping property and flexural strength [8, 10-13]. Findings from some authors have proved polymeric composites as better alternatives to many conventional materials as the former has been found to have improved mechanical, structural and tribological properties [14-16]. One of the main benefits of polymeric matrix composites is that it is light weight with elevated rigidity and strength along the reinforcement path. Other desirable characteristics are that compared to metals, it has superior resistance to corrosion and fatigue [17, 18]. In glass fibre reinforced polymer composites, the matrix is plastic which though tough is weak but is strengthened by strong and stiff reinforcement material of fibre, filament or mat. The extent of the strengthening is a function of the mechanical properties of both the reinforcement and the matrix, their volume relative to one to another as well as the fibre length and orientation within the matrix [19,20]. This research work has epoxy resin as the matrix material and glass fibre as the reinforcement and seeks to find out how the quantity of the reinforcement material in the composite will affect some mechanical properties of the entire composite.

2. Materials and Method

2.1 Materials Preparation

The materials used for this research work include glass fibre (E-glass fibre with % composition as shown in Table 1) as reinforcement agent, epoxy resin as matrix material and epoxy resin hardener. These materials were procured from local market. The samples of glass fibre reinforced polymer (GFRP) composite were produced using Hand Lay Up method. This involved first of all laying layer by layer a predetermined mass fraction of the reinforcement materials (glass fibre) in a mould well sprayed with released gel. The mould used was cylindrical shaped plastic mould and release gel was first sprayed on the inside surfaces of the mould to ease the removal of the composite from the mould after curing. The weight fractions of the reinforcement materials used were 10%, 20%, 30%, 40% and 50%. Then epoxy resin that is well mixed with the hardener was poured into the mould (which contains the glass fibre), and allowed to cure under ambient conditions.

Table 1: Chemical Composition of E-glass fiber (21)

Element	SiO_2	Al_2O_3	B2O3	CaO	MgO	ZnO	BaO	Na2O+K2O	TiO	Fe2O3	F2
% Composition	**52-56**	**12-16**	**5-10**	**16-25**	**0-5**	**-**	**-**	**0.2**		**0-0.3**	**-**

2.2 Test Procedures

Hardness test, tensile strength test, impact test were the various tests carried out on the various samples of the composites produced.

2.2.1 Brinell Hardness Test.

Hardness can be defined to be the resistance of material's surface to abrasion, scratching and/or indentation. Samples for Brinell hardness test were prepared accordance with ASTM E10 standard while the Brinell hardness test was carried out on a TQ SM1000 Universal Testing Machine with a 10 mm diameter steel ball indenter. In this test, a steel ball of 10 mm in diameter is used with an applied force of 500kg. The Brinell hardness number (BHN) was then calculated by dividing the applied force, P, by the actual surface area of the indentation. So that:

$$\text{BHN} = \frac{P}{\pi D t} = \frac{2P}{\pi D\left[D-\sqrt{D^2-d^2}\right]} \quad (1)$$

Where D is the diameter of the ball in, t is the indentation depth from the surface, while d is the diameter of the indentation at the surface.

2.2.2 Tensile Strength test

Tensile strength of a material is the maximum tensile stress that material can withstand it fails. The samples for tensile strength test were prepared according to the ASTMD732-2010 standard while the test was carried using the Universal Testing Machine (UTM) equipped with a 500kg load cell. The machine has a displacement velocity of 1.5 mm/min.

2.2.3 Impact Test

Impact strength is the measure of a material's toughness. While toughness is the material's ability to absorb energy without rupturing. The samples for this test were prepared according to the ASTM D256 standard and the test was carried out in Izod or Charpy impact testing machine.

3. Result and Discussion

3.1 Brinell Hardness, Tensile strength, Impact Strength Tests

The results of Brinell hardness test, tensile strength test, and impact test are given on Table 2.

Table 2: Results of tensile, hardness and impact tests

Reinforcement Material (Wt%)	Tensile (MPa)	Hardness (BHN)	Impact (J/m^2)
0	172	8	0
10	194.7	17	3.5

20	254.8	26	5
30	297.8	39	6.5
40	321.2	47	8.5
50	332.7	57	17.5

The relationship between the values of tensile strength and the weight % of reinforcement material in the composite is shown in the graph in Figure 1, the relationship between hardness values and the weight % of reinforcement material in the composite is shown the graph in Figure 2 while Figure 3 shows graphically the relationship between impact strength values and weight % of reinforcement material in the composite.

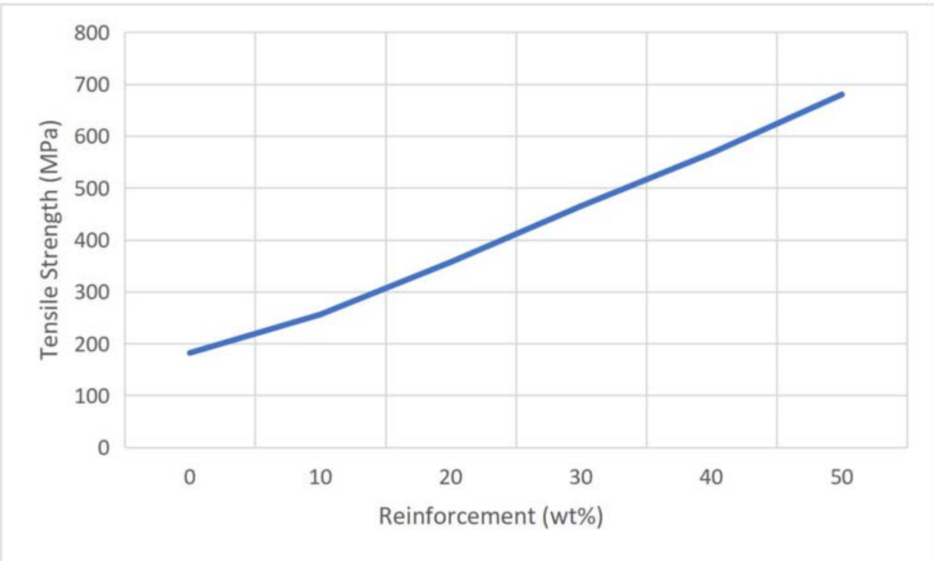

Figure 1: Graph of Ultimate Tensile Strength values against samples

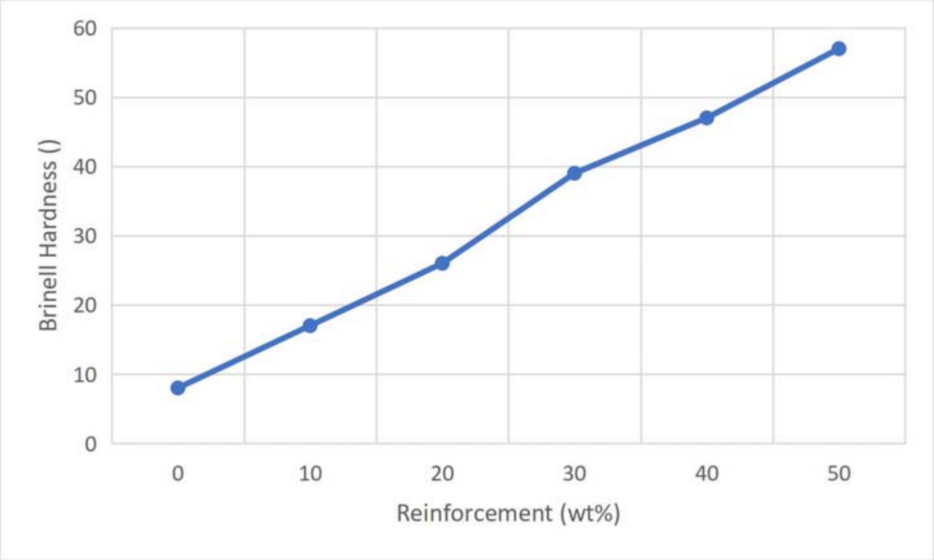

Figure 2: Graph of Brinell Hardness Number against samples

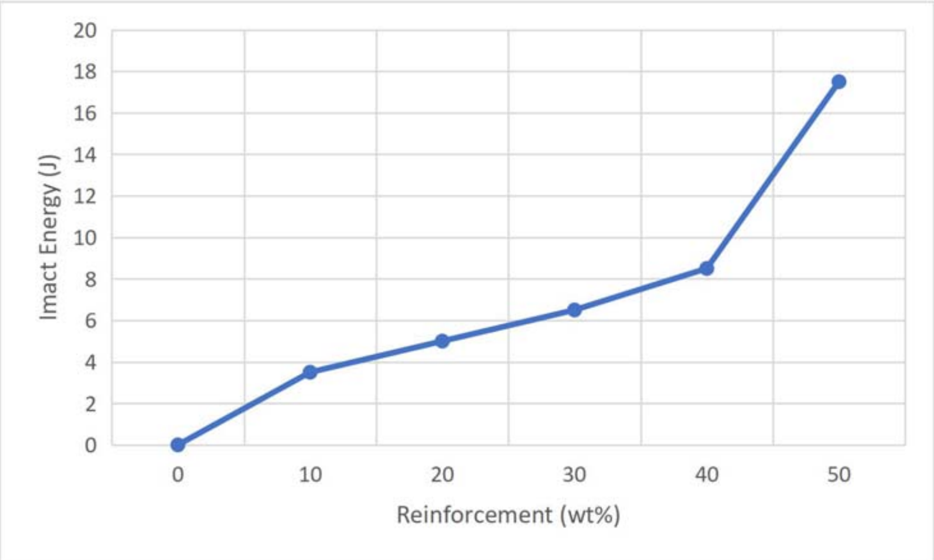

Figure 3: Graph of Compact Strength values against samples

The result of tensile strength test as shown in Figure 1 shows that the tensile strength value increases as the % weight of reinforcement increases in the composite. The lowest tensile strength value is recorded by the sample that does not have the reinforcement at all while the highest value of 680 MPa was recorded by the composite that contained 50 wt% of the reinforcement. This shows that the reinforcement material – glass fibre - increases the tensile strength of the composite far above what the matrix material possesses and that the more the glass fibre reinforcement in the composite the higher its tensile strength.

The Brinell hardness values shown on Figure 2 follows the trend of the tensile strength values. The value also increases as the wt % of the reinforcement increases, from 8 BHN in sample that does not have reinforcement to 57 BHN in the sample that contains 50 wt % of glass fibre. The hardness of the glass fibre has influenced that of the composite causing it to have a good hardness value.

The impact strength also followed the trend of other mechanical properties examined earlier. As the wt % of fibre glass increased the impact strength value also increased (Figure 3). It was found that the impact strength of the matrix material without the reinforcement was found as zero. It was also found that when some wt % of the reinforcement material was added impact strength value was recorded but the slope of the curve of impact strength against the wt % was not just a uniform straight line. The curve can be divided into three parts when considering the slopes of the curve. The first part of the curve between 0 and 10 wt% of reinforcement content has a slope steeper than the one from 10 to 40 wt% of reinforcement content. Between 40 and 50 wt% has the steepest of all the slopes, indicating that the impact strength has a rapid increase within that limit of wt% of the reinforcement material in the composite.

Conclusion

The effect of weight percentage of glass fibre – a reinforcement material in GFRP composite with epoxy resin as matrix material on the mechanical properties of the composite was studied. The weight percentages of the reinforcement material added to the matrix were 10%, 20%, 30%, 40% and 50%. The following conclusion can be drawn from the study

- The mechanical properties of hardness, tensile strength and impart strength of epoxy resin can be enhanced with addition of glass fibre as a reinforcement material to it.
- The mechanical properties of the composite increase as the weight percentage of the reinforcement material increases within the limits of reinforcement addition in this work
- The highest values of hardness, tensile strength and impact strength (for this work) of 57, 332.7MPa and 17.5 J/m^2 respectively in the composite were attained in the composite with 50 wt% of glass fibre – reinforcement material.
- The impact strength of epoxy resin which read zero can be highly enhanced in glass fibre reinforced composite of epoxy resin.

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