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Influence of Carbon & Glass Fiber Reinforcements on Flexural Strength of Epoxy Matrix Polymer Hybrid Composites

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ABSTRACT
Hybrid composite materials are more attracted by the engineers because of their properties like stiffness and high specific strength which leads to the potential application in the area of aerospace, marine and automobile sectors. In the present investigation, the flexural strength and flexural modulus of carbon and glass fibers reinforced epoxy hybrid composites were studied. The vacuum bagging technique was adopted for the fabrication of polymer hybrid composite materials. The hardness, flexural strength and flexural modulus of the hybrid composites were determined as per ASTM standards. The hardness, flexural strength and flexural modulus were improved as the fiber reinforcement contents increased in the epoxy matrix material.
***Keywords* –** Micro Hardness, Epoxy, Hybrid, Flexural Strength, Vacuum Bagging Technique

I. INTRODUCTION
Hybrid composite materials have successfully substituted the traditional materials in several lightweight and high strength applications. The development of composite materials improves their performance based on the reinforcement of two or more fibers in a single polymeric matrix which leads to the advanced material system called hybrid composite with a great diversity of material properties. Thus, there is a need to investigate the mechanical properties like hardness, tensile strength, compression strength and flexural strength. The flexural strength is most commonly determined through a three-point bend test, in which a loading nose deflects a specimen at a set span and loading rate until fracture. When the load is applied, the test specimen deflects such that the lower side of the test specimen will be under tension whilst the upper side will be subjected to compression. Shear stress is also present along the mid-plane of the specimen. Due to the anisotropic nature of the specimen being tested in this analysis, the bending failure may be caused by tensile, compressive, shear or a combination of these stresses. Hybrid composites are being investigated throughout the globe because they have enhanced properties than their mother composites which are relatively cost effective. The mechanical properties like bending, fatigue, stiffness and strength of carbon-glass/epoxy hybrid laminates were reported by the researchers [1-2]. An optimal design for the flexural behavior of glass and carbon fiber reinforced polymer hybrid composites was reported by Chensong Dong et al., [3]. The effect of hybrid composite specimen subjected to in-plane tensile and compressive loading was studied and found that the hybrid laminated specimen with higher percentage of steel sustains greater loads irrespective of fiber orientation [4]. Unlike metallic materials, the flexural strength and the stiffness of polymeric composite increases and decreases frequently with applied cyclic load. Marginal reduction in bending property has been observed with increase in the applied cyclic load. The possibility of defect annihilation can be reason for the observed marginal changes [5-7]. Influence of carbon nano tubes on tensile, flexural and impact properties of short fiber reinforced composites were studied and reported by Rahmanian et al., [8]. Fibers and flakes were used as reinforcements to enhance the mechanical properties in the hybrid composites [9]. Jawaid et al., [10] conducted experiment on effect of jute fiber loading on tensile and dynamic mechanical properties of oil palm composites. They have identified that the tensile properties of jute oil palm fiber hybrid composites are increased substantially with increasing the content of jute fibers as compared to oil palm epoxy composites. Reinforcing the glass fiber into the sisal polypropylene composites enhances the tensile and flexural properties without any effect on tensile and flexural module [11]. The present work is to study the influence of glass fiber and carbon fiber reinforced in epoxy polymer matrix on the flexural behavior of the hybrid composites. The hybrid composites were developed by varying the reinforcements from 15%, 30%, 45% and 60% of glass and carbon fibers in 40% epoxy matrix under vacuum bag process. The hardness and flexural properties were studied as per the ASTM standards. The flexural ability of the hybrid composite material has been studied using three point bend method

II. EXPERIMENTAL DETAILS

2.1 MATERIAL SELECTION

The glass fibers and carbon fibers are selected as reinforcements and epoxy as matrix material. The epoxy resin and hardener Tri Ethylene Tetra Amine (TETA) were provided by Atul Ltd. Polymers division, Valsad, Gujarat, India. The glass fiber of bi-directional woven mat with 200 gsm and the density of 2.5 gm/cc are used. The carbon fiber of bi-directional woven mat with 200 gsm and the density of 1.78 gm/cc are used. The glass fiber and carbon fiber used in the fabrication of hybrid fiber reinforced composites are shown in figure 1.

Figure 1: The glass fiber and carbon fiber

2.2 FABRICATION OF COMPOSITES

The glass fiber and carbon fiber reinforced in epoxy polymer matrix hybrid composites were developed using vacuum bag process by varying the reinforcements in terms of weight percentage of 15%, 30%, 45% and 60% in 40% of epoxy matrix. The weight fraction of fibers and epoxy matrix materials were determined by considering the density, specific gravity and mass. Initially, the fabrication of the composite was done at room temperature by hand lay-up technique. The required ingredients of resin and hardener were mixed thoroughly in a basin and the mixture is subsequently stirred constantly. The required sizes of fiber mats were prepared and the glass fiber was positioned manually in the open mold and the mold surface must be smooth enough to prevent bonding to the laminate. The mixture so made is brushed uniformly over the glass and carbon plies alternatively. The entrapped air is removed manually with rollers to complete the laminates structure. Then the vacuum bagging is applied to the mold with a vacuum pressure of 0.1mbar for uniform distribution of resin and also to remove the entrapped air. The composite is cured at room temperature and the post curing was done at 50^{o}C for 30 min, 65^{o}C for 45 min and 75^{o}C for 1 hour. The fiber reinforced polymer matrix composites are mainly used due to easy availability of glass fibers and economic processing technique adopted for producing the fiber reinforced polymer matrix composites. The vacuum bagging process adopted for the development of hybrid composite is shown in figure 2.

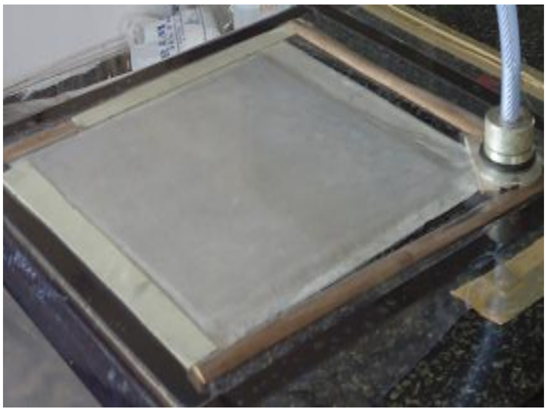

Figure 2: Vacuum bag process

2.3 SPECIMEN PREPARATION

The glass and carbon fibers reinforced epoxy composite slabs were taken out from the mold and then the specimens of suitable dimensions were prepared from the composite slabs for conducting tests according to the ASTM standards. The test specimens were prepared using diamond tipped cutter and different tools in the work shop. Micro hardness test specimens were prepared according to ASTM standard. The flexural ability of the hybrid composite materials in the present investigation has been studied using three point bend method. The specimen size is 3 mm x 12.7 mm x 64 mm prepared according to ASTM D790.

2.4 TESTING OF FRP COMPOSITES

The specimens were prepared from the developed composites and edges of the specimens are finished by using file and emery paper. Micro hardness test was conducted as per ASTM standard on the specimen using a Vickers micro hardness tester. The hardness was measured at three different locations of the specimen and the average value was calculated. Flexural modulus indicates a material's stiffness when flexed. The specimen lie on a support span and load is applied at the center by the loading nose producing bending at a specified rate. The parameters for this test are the support span, loading speed and maximum deflection for the test. Testing variables are based on the specimen thickness which is defined differently by ASTM D790. Flexural strength at specified strain levels and flexural modulus were calculated. The test was repeated thrice and the average value was taken. By using the equations (1) and (2), the flexural strength and flexural modulus have been calculated. [7]

$$\text{Flexural strength} = \frac{3P_{max}\,L}{2bh^2} \qquad \text{……….} (1)$$

$$\text{Flexural modulus } E_F = \frac{mL^3}{4bh^3} \qquad \text{………} (2)$$

Where,

P_{max} - Maximum load at failure in Newton
L - Distance between centers of support in meter
b- Width of the specimen in meter
h- Thickness of the specimen in meter
m- Initial slope of the load-deflection curve

III. RESULTS AND DISCUSSIONS

3.1 HARDNESS

The variations of micro hardness of the composite materials are shown in the figure 3. This graph explains the effect of glass fiber and carbon fiber reinforcements on the micro hardness of the hybrid composites. The carbon fiber reinforced epoxy composite exhibits higher micro hardness as compared to the other two composites. The 60% carbon fiber reinforced composite shows 14.29% increase in the micro hardness as compared to 60% glass fiber reinforced composite and 23% increase in the micro hardness with that of 30% glass fiber and 30% carbon fiber reinforced hybrid composite. The increase in the hardness in the composites is the indication of the good bonding between the matrix and the reinforcement materials.

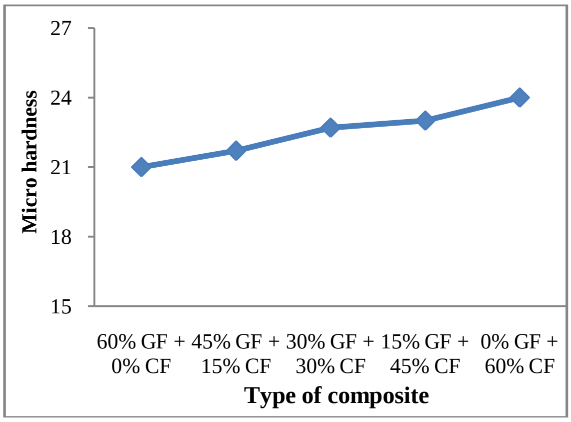

Figure 3: Effect of reinforcements on micro hardness of the fibers reinforced composites

3.2 FLEXURAL STRENGTH

The variations of flexural strength of fiber reinforced composites are shown in figure 4. The 60% carbon fiber reinforced composite shows 64.9% increase in the flexural strength as compared to 60% glass fiber reinforced composite and 29.23% increase in the flexural strength with that of 30% glass fiber and 30% carbon reinforced hybrid composite. It is observed that the overall strength of the hybrid composites under this investigation have been reasonably good. The hybrid composites have lower strength than that of carbon fiber reinforced composite and it is much better than that of glass fiber reinforced composite. Hence, the inclusion of carbon fiber mat has played a significant role to enhance the flexural strength of the laminates [11, 12]. It was observed that the damage of fibers on the top layer subjected to compression and bottom layer subjected to tensile failure which was in accordance with the bending theory of beams. The flexural strength represents the highest stress experienced within the material at its moment of rupture.

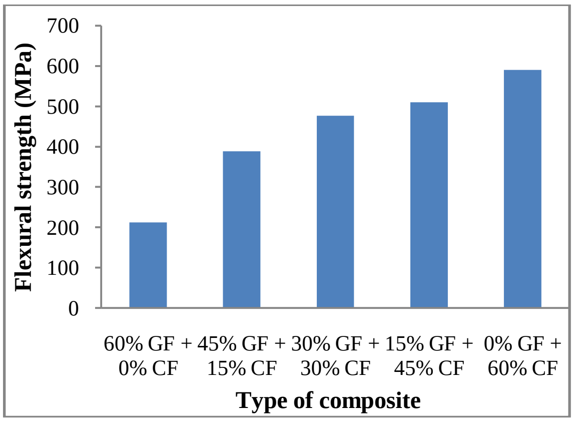

Figure 4: Effect of reinforcements on flexural strength of the fiber reinforced composites

Flexural modulus is a measure of how a certain material will strain and potentially even deform when force is applied to it. This is an important calculation in engineering, since it indicates the designers to know the maximum force that the different materials can bear. The variations of flexural modulus of fiber reinforced composites are shown in figure 5. The flexural modulus of the glass fiber reinforced composite is lower than the hybrid composites and the flexural modulus of the carbon fiber reinforced composite is higher than the other type of hybrid composites. The 60% carbon fiber reinforced composite shows 64.4% increase in the flexural modulus as compared to 60% glass fiber reinforced composite and 26.85% increase in the flexural modulus with that of 30% glass fiber and 30% carbon reinforced hybrid composite. The result indicates the good bonding between the fibers and matrix.

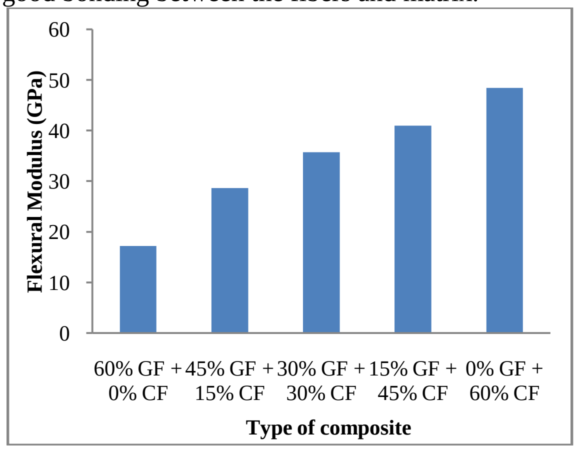

Figure 5: Effect of reinforcements on flexural modulus of the fiber reinforced composites

Figure 6 shows the load v/s displacement curve of 15% carbon - 45% glass fibers reinforced with 40% epoxy resin polymer hybrid composite. The graph indicates that, the load applied during the experimentation is uniformly distributed between fiber and matrix. The load applied is successfully transferred to the fibers by the matrix which is the indication of linearity in the graph till the maximum load that can resisted by the hybrid composite. This indicates the quality of the composites developed by vacuum bag technique which is the indication that the developed composites are free from porosity.

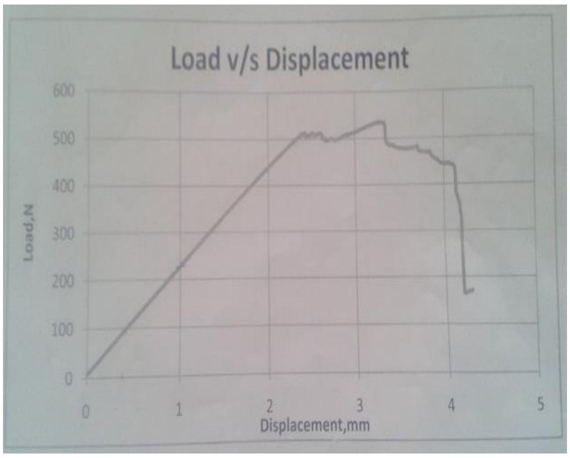

Figure 6: Load v/s displacement curve of 15%carbon / 45% glass fibers in 40% epoxy hybrid composite.

IV. CONCLUSIONS

The carbon fiber and glass fiber reinforced hybrid composites have been fabricated by vacuum bag method. The good bonding between the fibers and matrix has been observed. Experimental evaluation of micro hardness and flexural strength of hybrid composites as per ASTM standards have been successfully completed. The micro hardness of carbon fiber reinforced composite is higher than the other type of hybrid composites. The carbon fiber reinforced composite have more flexural strength and flexural modulus than that of the glass and carbon fibers reinforced hybrid composites.

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