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Review on Development of Glass Fiber/Epoxy Composite Material and its Characterizations

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Abstract— The present study is an attempt to take an overview of the work done in the area of characterization of Glass Fiber/Epoxy composite material. Different manufacturing processes are used for making Glass Fiber/Epoxy composite. Based on comprehensive literature review of various aspects in developing Glass Fiber/epoxy composite material, it is observed that extensive work has been done related to manufacturing and mechanical characterization of current material, whereas limited studies carried out to analyses tensile, shear and flexural strength by varying volume fraction of Glass Fiber and epoxy materials. The behavior under tensile, shear and flexural loading and different manufacturing processes of laminated Glass Fiber/Epoxy composite are the main areas of interest of researchers.

***Index Terms*— Glass Fiber, Resin, Composite Material, Tensile, shear, flexural strength**

I. INTRODUCTION

Polymeric based composites materials are being used in many applications such as automotive, sporting goods, marine, electrical, industrial, construction, household appliances, etc. [4] Composite material is a macroscopic combination of two or more distinct materials, having a recognizable interface between them. Composite laminate is a combination of fiber and resin mixed in proper form. One of the unique properties of composite laminate is that it has high specific strength. Composites are being utilized as viable alternatives to metallic materials in structures where weight is a major consideration, e.g., aerospace structures, high speed boats and trains. Fiberglass is a composite material consisting of glass fibers in a matrix of epoxy. The glass fibers as purchased are woven into cloth, which is categorized by weight per square yard, type of weave, and type of glass. There are several types of epoxy available. The mechanical properties of the fiberglass depend on the volume ratio of the two components as well as on the properties of the glass fiber component and
the epoxy component individually. [2] Therefore, in this study, the manufacturing processes and mechanical behavior of glass fiber rein-forced epoxy composites by varying parameters such as Fiber orientation, thickness, and volume fraction has been studied.

II. EXPRIMENTATION

In this research there are many requirement were needed.

1- Two types of fiber were taken, continuous fiber Fig. (1) and discontinuous or random fiber Fig. (2) E glass type.

Fig. 1 Continuous [2]

Fig. 2 Discontinuous [2]

2. Wood plate and glass plate for composite fabricate. With many keys for fixture the continuous fiber.
3. Epoxy will be taken with hardener to make the matrix by using suitable smooth brush
4. Many measures and gauges devices are require such balance ,ruler , flask for volume gauge , oil as an isolation for prevent adhere between the resin and the pattern after harder .
5. Sharp cuter to cut specimens for testing in different angles according to load apply.
6. Measurements were taken to specimens according to tests requirements.
7. Hardness, impact, tensile tester devices are used. [2]

In the present study the composite laminate specimens are prepared using the hand layup technique and the specimen are subjected to the investigation is carried out as per the ASTM standards. The simplest manufacturing technique adopted involved laying down bidirectional type fibers over a polished mould surface previously treated with a releasing agent: after this, a liquid thermosetting resin is worked into the reinforcement by hand with a brush or roller. The process is repeated a number of times equal to the number of layers required for the final composite. Resin and curing agents are pre-mixed and normally designed to cross-link and harden at room temperature. The major advantage of this manufacturing process is its great flexibility, meaning that it suits most common mould sizes and complex shapes. It can be re-used for several runs and the actual cost of the raw materials make this process economically feasible. [4]

Fig.3 Preparation of Laminated Specimens. [4]

The E-glass/Epoxy based composite slabs filled with varying concentrations of (0%, 10% and 15% volume) fly ash, aluminum oxide (Al_2O_3), magnesium hydroxide ($Mg(OH)_2$), and hematite powder were prepared. The volume fraction of fiber, epoxy and filler materials were determined by considering the density, specific gravity and mass. Fabrication of the composites is done at room temperature by hand lay-up techniques. The required ingredients of resin, hardener, and fillers are mixed thoroughly in a basin and the mixture is subsequently stirred constantly. The glass fiber positioned manually in the open mold. Mixture so made is brushed uniformly, over the glass plies. Entrapped air is removed manually with squeezes or rollers to complete the laminates structure and the composite is cured at room temperature. [5]

The Bi-directional Woven E-glass fiber was used with polyester in this study. The weight of the Bi-directional Woven E-glass fiber is 230gm in all orientations of the composite plate and weight of the matrix is varied as a 345gm, 403gm, and 460gm according to the fiber: matrix ratios. The Composite laminates are fabricated (300mm X 300mm) using bi-directional woven E-glass fiber/polyester Resin
with different orientations of fiber as (0° / 90° / 0° / 90°), (0° / 30° / 60° / 90°) and (0° / +45° / 90° / -45°) with different weight ratios of fiber: matrix (1: 1.5, 1: 1.75 and 1:2) in each orientation using Hand lay-up method.At the end of the manufacturing process, the final thickness of plate was measured as about 4.00mm, 4.1mm, and 4.2 mm for the fiber: matrix ratios of 1:1.5,1:1.75, and 1:2.The fabricated laminate is shown in fig [6]

Fig.4 Production of Composite Laminate [6]

The process of fabrication is carried out by using Diglycidyl Ether of BisphenolA (DGEBA) / Tri-ethylene Tetra Amine (TETA) as the epoxy matrix, chemically belonging to the „epoxide‟ family is used as the matrix material in the ratio 10:1. The composite specimen is fabricated as per the standard procedure. Unidirectional fabric of E-glass with density 220 gsm is used to reinforce the polymer matrix. The surfaces will be thoroughly cleaned in order to ensure that they were free from oil, dirt etc., before bonding at room temperature and pressure. The laminate will be allowed to cure for about 24 hours.

Fig. 5 Manufacture of Glass fibre laminate using Vacuum hand lay – up technique [9]

Vacuum hand lay – up technique fig. 5 was used to make the laminates. Vacuum bag moulding uses a flexible film to enclose the part and seal it from outside air. A vacuum is then drawn on the vacuum bag and atmospheric pressure compresses the part during the cure. Vacuum bag material is available in a tube shape or a sheet of material. Vacuum level (500 mm of Mercury for 2 hours) was monitored so as to avoid surface undulations and also avoid air pockets at the interface. Vacuum hand lay – up process offers many benefits when compared to conventional hand lay-up techniques. As it is a closed moulding process, it virtually eliminates potentially harmful volatile organic compound (VOC) emissions. The vacuum system also facilitates good resin distribution and consolidation of the laminate. As a result, the mechanical properties of the laminates are likely to be higher than the case with hand laminating. [9]

For the development of the composite material was used for filament winding or filament winding technique using an angle of 90 ° (hoop). For this, it has built a device consisting of a rotating drum PVC with a metal base, which was used, for the winding of the layers. The roving was wound throughout the cylinder with the aid of a handle attached thereto, where each coil will produce a layer or unidirectional fiberglass blade. Composite materials by this method. The process consists of applying resin layers in the liquid state and suitable viscosity over a defined mold (which must be previously applied a release) so that successive applications of resin layers and interspersed fibers are made until it reaches the desired thickness for the material.

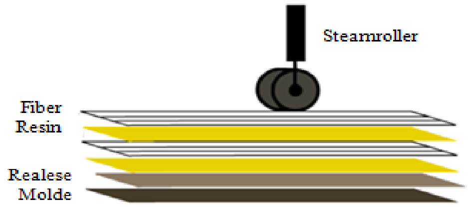

Fig. 6 Scheme of the manufacturing process by manual lamination. [11]

After the addition of each fiber layer, a compression is performed with the aid of a roller or spatula in order to have a material with a uniform thickness and to minimize the presence of voids. After curing the resin, the fabricated piece is removed from the mold and, if appropriate, procedures are carried out to improve its finish. For the production of laminates all were used five layers of unidirectional fibers, thus obtaining a composite plate with about 3.0 mm final thickness. [11]

Laminates composed of a single ply of glass fabric with epoxy resin were fabricated, with a thickness of nearly 0.52 mm, after curing 24 h at room temperature. Due to the laminate heterogeneity, the specimens should be large enough to have mechanical properties representative of the material. Considering the limitation of grip, specimens were cut along the fiber direction from the laminate with a dimension of 105 mm × 22 mm (L × W). Two aluminium sheets of 40 mm long, 22 mm wide and 0.3 mm thick were glued on the end of specimens to avoid stress concentration. When the epoxy was fully cured, the typical test specimens were shown in Figure 2b. The gauge lengths of specimen are 25.0 mm, and there are 8 glass fiber yarns in the width with a volume fraction of 34.3%. [13]

III. Mechanical characterization

For hardness test it shows that the values of hardness for the four types of specimen there is no significant effect on hardness of the materials having different orientations of fiber and it is maximum in discontinuous fiber specimen , with orientation 90° , with orientation 0°, then with orientation 45° respectively. The impact test shows that the difference in the orientation had significant effect on the impact strength of the composite material, it is concluded that the impact strength is minimum in orientation 90°and above of that in parallel orientation and still constant in specimen of angle 45 °. The tensile test shows that the load increased to the maximum value and then dropped suddenly as a brittle fracture at angle of 0° and 90°, while the shear response quite nonlinear for angle of 45°. It has been observed that the crack propagates in a direction perpendicular to the direction of the external load action glass fibers/epoxy composite specimens of 90° fiber orientation angle, while for 0° fiber orientation angle of glass fibers/epoxy specimens, failure was irregular and cracks propagate in different directions.[2]

The mechanical behavior of glass fibre and carbon fibre reinforced vinyl ester composites was studied. From the results it is observed that the carbon fibre & resin of vinyl ester with mixture of Promoter, accelerator, catalyst showed better Mechanical properties. It is concluded that shortest fibers have good adhesion with the vinyl ester resin for tensile properties. Tensile strength & compression strength is more in carbon fibre and less in glass fibre. Flexural strength is more in glass fibre and less in carbon fibre. Extension is minimum in case of carbon fibre compared to glass fibre. Deformation is maximum in glass fibre and minimum in carbon fibre. Carbon fibre shows more in young's modulus and less in glass fibre. Maximum load at high yield point shows in carbon fibre and minimum in glass fibre [4]

Based upon the test results obtained from the various tests carried out, it was observed that com- posite filled by 10% volume of Mg (OH) 2 exhibited maxi- mum ultimate strength of 375.36 MPa when compared with other filled composites. Composites filled by Al2O3 exhibited better ultimate strength compared with com- posites filled by fly ash and hematite. Increase in addition of Mg (OH) 2, Al2O3 and fly ash to composites leads to decrease in ultimate tensile strength. Experimental results show that composites were filled by 10% volume of fly ash having high impact strength when compared with other filled composites. Composites filled by 10% volume Al2O3 and Mg(OH)2 exhibited good impact strength but increase in addition of Al2O3 and Mg(OH)2 leads to decrease in impact strength. Test re- sults indicated that impact strength increases with adding more hematite powder to composites. The experimental results indicated that composite filled by Mg (OH) 2 exhibited maximum hardness number 88.69 BHN when compared with other filled composites. From the results, it is observed that increase in addition of Al2O3 and hematite to composites increases the hardness of the composites. Increase in addition of fly ash to composites leads to decrease in hardness number. [5]

In this study, the effects of stacking sequences with different weight ratios of fiber matrix of glass/epoxy laminated composite plates were investigated. The effects of the fiber orientation **0° / 30° / 60° / 90°** with fiber matrix proportion **1 : 2** is effective which absorbs more impact energy when compared to other fiber orientations and other fiber matrix proportions. The effects of the fiber orientation 0°/ 90°/0°/90° with fiber matrix proportion 1:1.75 which shows better tensile strength when compared. Fiber orientations and other fiber matrix proportions. The effects of the fiber orientation **0°/** 90°/0°/90° with fiber matrix proportion 1:2 which shows better flexural strength when compared to other fiber orientations and other fiber matrix proportions. [6]

The prepared glass/epoxy laminate exhibits various strength and stiffness values at different fibre orientations. Both stiffness and strength are found to be highest in the longitudinal direction and will be least in the transverse direction. Also, the specific strength and specific stiffness are found to be high in the longitudinal direction as compared to the other tested directions. This is because of the dominant properties of the fibres in the longitudinal direction. As fibre orientation changes from 0° to 90°, the properties of the fibres decline and the properties of the matrix dominate. At 45° orientation of fibres, both the fibres and the matrix play a major role in determining the properties of the composite. [9]

In determining the density and volumetric fraction of fiber show that the density values are inversely proportional to the fiber concentration in the composite, being higher for samples 0°, after the sample 45°, then the samples 90°, with orientation 0° respectively. The modulus of elasticity, tenacity and tensile strength shows that the difference in orientation had a significant effect on the elasticity, tenacity and tensile strength of the composite material, in samples 45° and 90° in relation to the 0° sample. It follows that the elasticity and tenacity is at least above 45° orientation than the 0° orientation in parallel angle samples. The maximum tensile loads for glass/epoxy composites in case of $\theta = 0°$ are higher than that for $\theta = 90°$. The tensile test for $\theta = 45°$ for composite materials show nonlinear behavior up to fracture. [13]

The mechanical properties of glass yarn and GFRP are also dependent on the temperature. For glass yarn, tensile strength and toughness decrease nearly 25.3% and 31.1% when temperature increases from 25 to 75 ^{0}C. However, when heated to 100 ^{0}C, tensile strength and toughness of glass yarn rebound due to the augment of frictional force between fibers. For GFRP, tensile strength shows almost no change (within 3%) when temperature increases from 25 to 50 ^{0}C, but decreases sharply (about 18.9%) over the temperature range of 50-100 ^{0}C because of the softening of the resin matrix when Tg of epoxy resin is reached.[15]

IV. Conclusion

The manufacturing methods and mechanical properties of Glass Fiber/Epoxy composites have been discussed. The important application of these composites has highlighted. The various preparation technologies were used for preparing the GRP composites with various environmental conditions. Ultimate tensile strength and flexural strength of the fiber glass polyester composite increased with increase in the fiber glass Volume fraction of fiber weight fractions. The Young's modulus of elasticity of the composite increased with the fiber glass Volume fraction. The Young's modulus of elasticity of the composite increased with the fiber glass Volume fraction.

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