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Assessment of Mechanical Properties of Glass Fiber Polymer Composites

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***Abstract* - In this research work, an E-glass fiber with random oriented reinforced unsaturated polyester resin composite was developed by hand lay-up technique with four different fiber loadings (10, 20, 30 and 40 wt. %). The tensile strength, flexural strength and impact strength of the composites were determined as per ASTM standards. The results clearly indicated an improvement in tensile strength, flexural strength and impact strength of the composites with the increase in fibre loadings.**

Keywords: Glass fiber, unsaturated polyester, fiber loading, glass fiber polymer composite, mechanical properties.

I. INTRODUCTION

A composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone. The major constituents are reinforcement fiber and a matrix. Nowadays fiber reinforced polymer matrix composite materials are commonly used in various applications such as aerospace, automotive, chemical industrial, sporting industries, construction and building industry etc. These composites are used because of high specific stiffness, high specific strength, low density, low thermal expansion, good fatigue resistance, stability for production of complex shape.

The composites are usually made using natural and artificial fibers. Natural fibers can be classified according to their origin into three categories. They are plant fibers, animal fibers and mineral fibers. The plants, which produce cellulose fibers can be classified into bast or stem fibers (flax, hemp, isora, jute, kenaf, kudzu, mesta, nettle, okra, ramie, rattan, roselle, urena and wisteria), seed fibers (cotton, kapok, loofah and milkweed), leaf fibers (abaca, agave, banana, cantala, caroa, curaua, date palm, fique, henequen, istle, piassava, pineapple, raphia and sisal), fruit fibers(coir, oil palm and tamarind), stalk fibers(barley, maize, oat, rice, rye and wheat), grass and reed fibers (bagasse, bamboo, canary, corn, esparto, rape and sabai) and wood(soft wood and hard wood). Artificial fibers are glass, carbon, and aramid. Glass fibers are the most common of all reinforcing fibers for polymeric matrix composites. The principal advantages of glass fibers are low cost, high tensile strength, high chemical resistance, flexibility and excellent insulating properties. The two types of glass fibers commonly used in the fiber-reinforced plastics industry are E-glass and S-glass. Another type known as C-glass is used in chemical applications requiring greater corrosion resistance to acids than is provided by E-glass. E-glass has the lowest cost of all commercially available reinforcing fibers, which is why it is widely used in the FRP industry.

The polymers are divided into two groups depending on how it reacts to heat. Those are thermoplastics and thermosettings. Thermoplastics can be repeatedly softened by heating and hardened by cooling. Thermosetting plastics, however, harden permanently after being heated once. The most commonly used thermoplastics are polyamide (PA), polycarbonate (PC), polyethylene (PE), poly methyl methacrylate (PMMA), polypropylene (PP), polystyrene (PS), poly vinyl chloride (PVC), while epoxy, phenolic resin, polyester, polyurethane resin, polyvinyl ester, unsaturated polyester and urea formaldehyde are the commonly used thermo settings. Unsaturated polyester resins can be utilized in a wide range of manufacturing processes such as compression moulding, filament winding, hand lay-up process, injection moulding, pultrusion and resin transfer moulding. The advantages of unsaturated polyester are its dimensional stability, low cost, good range of mechanical properties, corrosion resistance and low density.

II. LITERATURE REVIEW

H. Abdullah [1] investigated the effects of weathering on the mechanical properties of glass fiber reinforced plastics (GRP) materials. It was observed that the humidity, temperature, ultraviolet radiation, and pollutant increase the mechanical properties of GRP materials decrease.

M. R. Sanjay et al [2] investigated on the mechanical properties of banana/E-glass fabrics reinforced polyester hybrid composites. The mechanical properties evaluated are tensile strength, flexural strength, impact strength and hardness. From the results of the testing process, it is found that the maximum tensile strength, maximum flexural strength, maximum impact strength and maximum hardness is observed in pure glass fabric laminate and minimum in pure banana fabric laminate.

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Mechanical properties of ukam, banana, sisal, coconut, hemp and E-glass fibre reinforced laminates were investigated by Olusegun David Samuel et al [3]. Samples were fabricated by the hand lay-up process (30:70 fibre and matrix ratio by weight). The mechanical properties were tested and showed that glass laminate has the maximum tensile strength and bending strength.

R. Velmurugan et al [4] investigated on the mechanical properties of palmyra/glass fiber hybrid composites. Composite plates are prepared for different palmyra/glass fiber weight ratio. Tensile, impact, shear and bending properties are studied. The experimental study showed that the mechanical properties of the composites are improved due to the addition of glass fiber along with palmyra fiber in the matrix.

Aramide F. O et al [5] conducted experimental study on mechanical properties of a polyester fibre glass composite. Fiber glass polyester composite samples were fabricated with different fiber glass volume fractions. The ultimate tensile strength, young's modulus and impact strength of the materials were determined through standard tests on standard test samples. It was observed that the ultimate tensile strength and young's modulus of the fiber glass polyester composite increases with increase in the fiber glass volume fraction. Also the impact strength of the samples decreases with increase in fiber glass volume fraction.

LW H Leonard et al [6] investigated the effects of chopped strand mats glass fibre content on the mechanical properties of polyester composites. Tensile and fracture toughness tests were performed on neat polyester and GFRP composites with fiber volume percentages that ranged from 12 to 60% vf, with an interval of 12% vf. Results concluded that tensile strength, yield strength, young's modulus and fracture toughness increase with increasing fiber content.

Manjunatha G et al [7] investigated the effect of polypropylene/glass fiber on the mechanical properties of polymer composites. The samples with 25 and 50 wt. % glass fibers loading were compounded using a single screw extruder before undergoing injection molding process. The results show that the tensile strength decreased with the increasing of glass fiber loadings. Also the impact strength increased with increasing of glass fiber loadings.

N M Kusaseh et al [8] studied the flexure and impact properties of glass fiber reinforced nylon 6-polypropylene composites. The glass fiber (GF) reinforced nylon 6 (PA6)-polypropylene (PP) composite specimens were prepared successfully using injection molding process. Test specimens of five different compositions such as, 70%PA6+30%PP, 65%PA6+30%PP+5%GF, 60%PA6+30%PP+10%GF, 55%PA6+30%PP+15%GF and 50%PA6+30%PP+20%GF were prepared. Results showed that flexural strength is low for pure polymer blend and flexural strength of GF reinforced composite increases gradually with the increase in glass fiber content. Test results also revealed that the impact strength of 70%PA6+30%PP is the highest and 55%PA6+30%PP+15%GF composite shows moderate impact strength. On the other hand, 50%PA6+30%PP+20%GF composite shows low toughness or reduced impact strength.

The mechanical properties of short random glass fibers polymer composite has been studied by Ismail Ibrahim Marhoon [9]. Epoxy matrix composites reinforced with short random glass fibers and TiO2 particles with different weight fractions (3, 6, and 9 %wt.) were prepared and then the mechanical testing was measured by tensile, impact, and hardness. The results showed that the mechanical properties improve with increasing weight fraction. Also the mechanical properties of hybrid composite is better than compared with the composite reinforced with glass fiber alone at same weight fractions.

III. MATERIALS AND METHODS

Materials

The materials selected for preparation of polymer composites are unsaturated polyester resin as the matrix and E-glass fiber as reinforcement.

The unsaturated polyester resin has been chosen as the matrix material because its dimensional stability, low cost, ease of handling, easy of processing, lower shrinkage etc. The most frequently catalyst used is Methyl Ethyl Ketone Peroxide (MEKP) with the amount varies from 1-2%. The catalyst is mixed directly in to the polyester resin. Accelerator is mixed with the polyester in combination with the catalyst. The name of the accelerator used is cobalt naphthalene. The catalyst does not take part in the chemical reaction but simply activates the process for curing process. The function of the accelerator is to make the process faster. The most common types of glass fiber used in fiberglass is E-glass, which is alumino-borosilicate glass with less than 1% w/w alkali oxides, mainly used for glass-reinforced plastics.

Fabrication of Composites

E-Glass reinforced polymer composites were fabricated by using the hand lay-up technique in different weight percentages of glass fiber in polyester such as 10%, 20%, 30% and 40%. Hand lay-up technique is the simplest method of composite processing. The infrastructural requirement for this method is also minimal. A steel mold is used for preparing the test specimen and having dimension of 300mm x 300mm x 5mm. The wax was coated on the mould for easy removing

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and good surface finishing of the laminates. Thin plastic sheets are used at the top and bottom of the mold plate to get good surface finish of the composite. The unsaturated polyester resin is taken along with 1% each of catalyst-Methyl Ethyl Ketone Peroxide (MEKP) and accelerator- cobalt naphthenate. First the catalyst is added with resin and then the accelerator. Initial layer of the mould was filled with unsaturated polyester resin mixture and then glass fibers were spread over the resin mixture and rolled with hand roller. Again, resin mixture is poured on the glass fibers and then pressed heavily for 7 hours before removal. Then, the top plastic sheet was removed from the mould and cured at ambient temperature for one day.

IV. RESULTS AND DISCUSSIONS

Mechanical Testing

After fabrication the test specimens were subjected to various mechanical tests as per ASTM standards. The mechanical properties of the composites with different fiber loading under this investigation are presented in Table -1.

Table 1: Mechanical properties of the composites

Glass fiber (% wt)	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (KJ/m^2)
10	28.86	42.58	66.67
20	34.03	57.16	74.50
30	48.14	79.63	86.27
40	53.46	86.12	92.15

Tensile strength

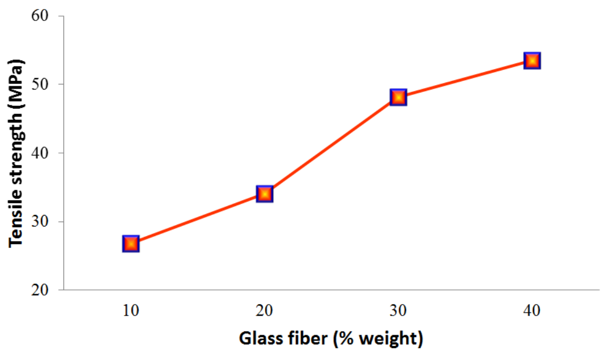

Figure 1: Tensile strength of composites

The tensile strength of all the four composites is presented in figure-1. It can be seen that the tensile strength of glass fiber reinforced unsaturated polyester composites is increasing gradually with the fiber content. With the increase in fiber loading from 10wt% to 40wt% the tensile strength is found to have increased from 28.86MPa to 53.46MPa. The increase of tensile strength may be due to the good compatibility of glass fiber and unsaturated polyester resin. Suhas Yeshwant Nayak et al [10] conducted experimental study on tensile and flexural properties of chopped strand E-glass fibre mat reinforced CNSL epoxy composites. Glass fibre in the form of chopped strand mat (CSM) with different weight fractions such as 15%, 30%, and 45% were used as reinforcement in CNSL-epoxy resin composites. The results clearly indicated an improvement in tensile strength with the increase in fibre content. Edcleide M. Araújo et al [11] investigated the mechanical properties of glass fiber polyester composites. Composites with 20, 30, 40, 50 and 60 wt. (%) of recycled fiberglass were prepared by compression molding and compared with polyester/ virgin glass fiber composites. The results showed that a increase in tensile strength when the fiber content increases up to 40% for both virgin fibers and fiber wastes.

Flexural Strength

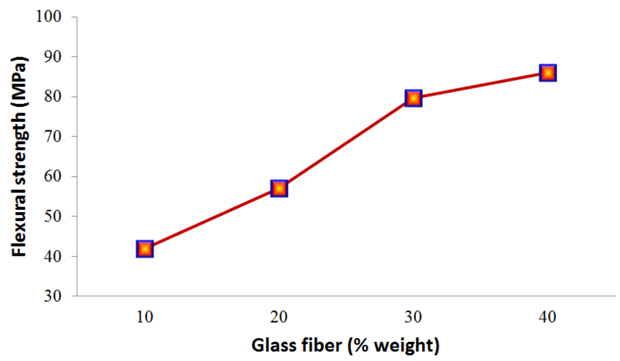

Figure 2: Flexural strength of composites

Figure-2 presents the effect of fiber loading on flexural strength of different composites. From the figure it is observed that flexural strength of glass fiber reinforced unsaturated polyester composites are increasing gradually with the increase of fiber loading. This is an indication of good dispersion of fibers in the unsaturated polyester matrix. Highest flexural strength was obtained for composites with fibre content of 40% which is about 2 times more than the strength of 10% fiber composite. For composites with fibre content of 20% and 30%, the flexural strength obtained was 57.16MPa and 79.63MPa respectively. Mustafa Faisal Zaidan et al [12] investigated the effect of percentage for chopped fiber glass reinforcement thermoplastic sheet on the flexural strength. Hot compression method used to fabricate thermoplastic reinforced by fiber glass at different percentage (10,20,30,40) wt.%, the flexural strength test done by using three-point bending test. The experimental study showed that increase in fibre content improves the flexural strength of the composites. J.L. Thomason [13] investigated the mechanical

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performance of long glass fibre reinforced polypropylene composite. The results of this study indicated that increase in flexural strength when the fiber content increases up to 40%.

Impact strength

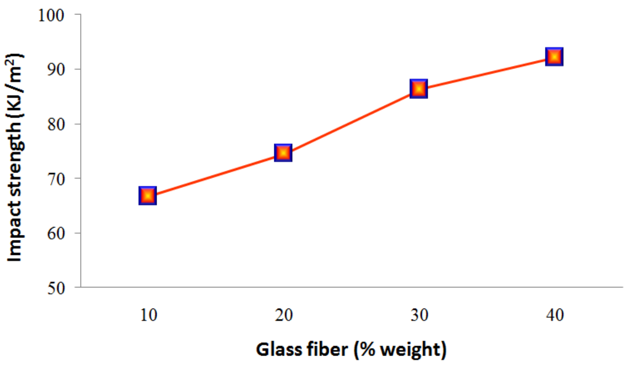

Figure 3: Impact strength of composites

Effect of fiber loading on impact strength of different composites is shown in figure-3. From the figure it is observed that resistance to impact loading of glass fiber reinforced unsaturated composites is increasing gradually with the increase of fiber loading. M. B. Kulkarni et al [14] investigated the thermal and mechanical properties of glass fiber-reinforced unsaturated polyester/benzoxazine composites with different fiber loading like 0, 10, 20, 30 and 40%. The results of this study indicated that the impact strength increased with increasing of glass fiber loadings. The mechanical properties of polyester/fiberglass composites were investigated by Edcleide M. Araújo et al [11]. The results showed that a increase in impact strength when the fiber content increases up to 50% for both virgin fibers and fiber wastes.

V. CONCLUSION

The effects of glass fiber content on mechanical properties of the composites were investigated. The main conclusions are:

- This research study has proved that glass fiber unsaturated polyester resin composites could be manufactured by hand lay-up technique at different fiber loading.
- The tensile strength, flexural strength and impact strength of the fiber glass polymer composite increases with increase in the fiber glass loading

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