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Experimental Investigation on Mechanical Behavior of E-Glass and S-Glass Fiber Reinforced with Polyester Resin

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Abstract — *Glass fiber reinforced polyester composites have played a dominant role for a long time in various applications for their high specific strength, stiffness, and modulus. An E-glass and S Glass fiber with random oriented reinforced polymer composite was developed by hand layup technique with varying fiber percentages in this research work. In this particular investigation, E Glass-Polyester (E-P) and S Glass –Polyester (S-P) composite is compared with that of a combination of E Glass and S Glass-Polyester (ES-P) composites formechanical properties. The influence of glass fiber percentage on the mechanical properties such as tensile strength, flexuralstrength, and impact strength was investigated. The hardness of composites was evaluated by using the Brinell hardness tester. The results showed remarkable improvement in the fabricated composite's mechanical properties with increased glass fiber contents. The results show the best suitable fiber resin ratio concerningstrength.*

Keywords—*E&SGlass fiber; polyester resin; hand layup technique and mechanical properties*

I. INTRODUCTION

Polymers are particularly attractive as matrix materials because they are easily processable. Their density is comparatively low compared to other materials. They exhibit excellent mechanical properties. High-temperature resins are used as composite materials to manufacture high-speed aircraft, rockets, and other related space and electronics. The reinforcements share the major load, especially when a composite consists of fiber reinforcements dispersed in a weak matrix (e.g., carbon/epoxy composite). Therefore, such composites' strength and stiffness are controlled by the strength and stiffness of constituent fiber.[1-4]. The major advantage of fiber-reinforced composites is to offer high strength and modulus Those are either comparable to or better than many traditional metallic materials. Because of their low specific gravity, the strength- weight ratio, and modulus - weight ratios, these composite materials are markedly superior to metallic materials. Besides, the fatigue strength - weight ratio and fatigue damage tolerance of many composite laminates is excellent [5, 6].Glass fibers are the most common of all reinforcing fibers for polymeric matrix composites (PMC). The principal advantages of glass fibers are low cost, high tensile strength, high chemical resistance, 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. S-glass, originally developed for aircraft components and missile casings, has the highest tensile strength among all fibers in use. However, the compositional difference and the higher manufacturing cost makeit more expensive than E-glass.

A lower-cost version of S-glass called S-2 glass is also available. Although S-2 glass is manufactured with less-stringent nonmilitary specifications, its tensile strength and modulus are similar to those S-glasses. Glass fibers are available in continuous strand roving, chopped strands, and woven roving. Woven cloth is wired using continuous twisted strands called yarns. The form of woven roving is suitable for hand layup molding. The average tensile strength of glass fiber may exceed 3.45N/mm2. The tensile strength of glass fiber may reduce due to surface damage and the presence of water. The major structural applications for the fiber-reinforced composite are in the field of automobile components and sporting goods. It is classified into three groups in automobile applications: body components, chassis components, and engine components. Exterior body components such as a hood, door panels require high stiffness and dent resistance and Class-A surface finish for appearance. The composite material used for these components is an E-glass fiber reinforced sheet molding compound composite. Other body components are roof frames, door frames, bumper beams, engine valve covers, timing chain covers, oil pan, etc. Unileaf E-glass fiber-reinforced epoxy springs have replaced multi-leaf steel springs with 80% weight reduction. Other structural chassis components such as driveshaft and road wheels have been successfully in the laboratory, and further research is going on regularize for common use. In sporting goods application, the glass fibers reinforced epoxy is prepared over wood and aluminum in pole vault poles because of its high strain energy storage capacity. A good pole must have reasonably high stiffness and high elastic limit stress so that the strain energy of the bent pole can be recovered to propel the athlete above the horizontal hardness bar.Other glass fiber sporting goods are surfboards, archery bows, and arrows.

Mechanical properties of fiber-reinforced composites depend on the constituent materials (type, quantity, fiber distribution, and orientation, void content), besides those properties, the nature of the interfacial bonds, and load mechanisms transfer at the interphase.

E-glass and S-glass random fiber reinforcement in the polyester resin matrix was produced using the hand layup technique with varying Laminates in the present paper. The tensile, flexure, Impact, and Brinell tests were carried out, and their performances were evaluated.

II. LITERATURE REVIEW

Varga, Cs., Miskolczi, N., Bartha, L., and Lipóczi, G.(2010)Was et al. l discussed Polyalkenyl-poly-maleic-anhydride-ester/amide-type new experimental additives have been developed and used to achieve the better properties of glass-fiber-reinforced polyester composites. The Thepolyalkenyl-poly-maleic-anhydride ester-type surface modifying additive has deteriorated the tensile and flexural properties of the laminates. Still, the dynamic properties have been more favorable than those of specimens with untreated glass fibers. Fibre-matrix interaction responsible for increased or decreased mechanical properties has been studied on SEM micrographs of composites' fractured faces.

Davallo, M., and Pasdar, H. (2009). Flexural properties of continuous random glass-polyester composites formed by resin transfer molding (RTM) and hand-lay up (HLU) molding have been studied to determine glass content's effects, composite thickness, reinforcement geometry, and type of fabrication on damage developed during flexure tests. Flexural parameters derived from the force-deflection data of composites containing 20 % and 30 % continuous random fiber showed mean values of flexural strength and modulus of 84 MPa and 7 GPa and 110 MPa and 10 GPa for the HLU composites (Cx20 and Cx30 test groups), respectively and similarly, the mean values of flexural strength and modulus of 96 MPa and 7.6 GPa and 120 MPa and 11 GPa for the RTM composites (Cx20 and Cx30 test groups), respectively.

González, C. and LLorca, J.(2007), et al. l discussed the mechanical behavior of polymer–matrix composites unidirectionally reinforced with carbon or glass fibers subjected to compression perpendicular to the fibers was studied using computational micromechanics. The stress-strain curve was determined by the finite element analysis of a representative volume element of the microstructure idealized as a random dispersion of parallel fibers embedded in the polymeric matrix. It was found that the composite properties under transverse compression were mainly controlled by interface strength and the matrix yield strength in uniaxial compression.

Agarwal, A., Garg, S., Rakesh, P. K., Singh, I. and Mishra a, B. K. (2010) was et al. l discussed.The effects of various environmental conditions on the tensile behavior of GFRP plate were investigated. The mechanical behavior of polymeric matrix composites, in particular, is affected by environmental conditions. The experimental results show that the tensile strength of GFRP plates is affected at different levels when subjected to selected environmental conditions

Estabraq T. Abdulla(2013) was et al. l discussed In this study, two commercial types of reinforced glass fibers were studied: chopped and 0/90 fiberglass composted with unsaturated polyester resin. The composites were prepared by hand layup method in three layers. The flexure properties were studied by using a three-point bending test. The results showed that pure unsaturated polyester UPE is fractured when they reach the maximum point. Different behavior was shown for the fiber/polyester composite depending on the type of the fiber.

Al-Mosawi, A. I. (2009) was et al. l discussed reinforcing by fibers this property will be improved greatly, where the fibers will withstand the maximum part of loads and by consequence will raise the strength of composite material. The tensile strength will be increased as the fiber percentage addition increased, where these fibers will be distributed in a large area in the resin.

Sureshkumar.P.Karthick.B, Dinakaran.S, R.Rajapradeepan(2014) was et al. l discussed In this experimental study, the glass fiber reinforced polyurethane composite is prepared, and the Tensile, Flexural, and Impact Strengths are analyzed.Currently, the glass fiber is manufactured with other resins such as epoxy, vinylester, and polypropylene; glass fiber reinforced polyurethane composite laminates were prepared by hand layup method was placed on the matched plate mold for curing. The composites were manufactured

at various ratios such as 30:70, 35:65, and 40:60 (Fiber: Resin). The fiber resin ratio 40:60 has more tensile and flexural strength than the other two ratios from the results obtained. But there is no big variation in impact strength due to a change in ratio. From this experimental study, we can conclude that by increasing the fiber content in the composite material, the
tensile and flexural strength will be increased. Still, at some point, the strength will start to decrease due to a lack of adhesion material.

M. S. EL-Wazery, M. I. EL-Elamy, and S. H. Zoalfakar(2017) were et al. l discussed E-glass fiber with random oriented reinforced polymer composite was developed by hand layup technique with varying fiber percentages (15%, 30%, 45%, and 60% by weight percentage). The influence of glass fiber percentage on the mechanical properties such as tensile strength, bending strength and impact strength were investigated. The hardness of composites was evaluated by using the Brinell hardness tester. The results showed remarkable improvement in the fabricated composite's mechanical properties with increased glass fiber contents. Tensile strength varies from 28.25 MPa to 78.83 MPa, flexural strength varies from 44.65 MPa to 119.23 MPa, and impact energy at room temperature varies from 3.50 Joules to 6.50 Joules, as a function of fiber weight fraction. The hardness value will greatly increase from 31.5 BHN to 47 BHN—thebest mechanical properties obtained at 60 wt.% of glass fiber of fabricated composites.

Various studies show that the Mechanical Behavior of E-Glass and S-Glass fiber reinforced with polyester resin is not studied yet. Our present work is I, E-glass and S-glass random fiber reinforcement in polyester resin matrix was produced by hand layup technique with varying fiber percentages (15%, 3 0%, 45%, and 60% by weight percent). The tensile, flexure, Impact, and Brinell hardness tests were carried out, and their performances were evaluated.

III.EXPERIMENTAL METHODOLOGY

A. *Material Selection*

a) Glass fibers

Glass fiber is a lightweight, extremely strong, and robust material. Although strength properties are somewhat lower than carbon fiber and less stiff, the material is typically less brittle, and the raw materials are much less expensive.The E-glass and S –glass fiber with random orientation was used as a reinforcing material in the polyester resinmatrix. The E glass fiber shown in fig 1 and Chemical composition is given table1, and S glass fiber is shown in Figure 2. Chemical composition shows in table 2This kind of glass combines C-glass characteristics with very good insulation to electricity. Properties of E-Glass fiber and unsaturated polyester resin are given in the following Table3

Table.1.Chemical Composition E-glass fiber

SiO_2	B_2O_3	Al_2O_3	Na_2O	K_2O	TiO_2	CaO	MgO
70	10	16	13	3	2	20	3

Fig 1.E-glass fiber

Fig2.S.Glass fiber

Table.2.Chemical Composition S-glass fiber

SiO_2	Al_2O_3	MgO	Na_2O	CaO	Fe_2O_3
66	23	9.5	0.15	0.2	0.1

Table.3.Mechanical Properties of glass fibers and resin

Materials	Mechanical Properties			
	Tensile Strength (Mpa)	Modulus of Elasticity (GPa)	Density (gr/cm3)	Elongation%
E Glass	3445	72.3	2.58	4.8
S Glass	4890	86.9	2.46	5.7
polyester resin	85	3.23	1.35	-

b) Polyester resin

Generally, polyester resins can be made by a dibasic organic acid and dihydric alcohol. They can

be classified as saturated polyesters, such as polyethylene terephthalate, and unsaturated polyester. To form the composite matrix network, the unsaturated group
or double bond needs to exist in a portion of 8 the dibasic acid.Unsaturated Polyester resin is a liquid that will cure into a solid when the hardener is added. It has been specially formulated to cure at room temperature. The hardener, MEKP (Methyl Ethyl Ketone Peroxide), is added to cure and also to harden the resin

B. Preparation of Composites

Glass-reinforced polymer composites were fabricated by using the hand layup (H LU) technique in different Laminates of glass fiber in polyesters such as E Glass-Polyester (E-P), S Glass –Polyester (S-P), andE Glass and S Glass-Polyester (ES-P)

The paraffin wax is applied on the lower on the open mold. The acetate sheet is placed on the wax
theapplied surface of the die plate, and again wax is applied over the acetate sheet. Fiber reinforcing fabric was placed in an open mold and then saturated with a wet (resin) by pouring it over the fabric and working it into the fabric and mold. Usually at room temperature, though heat is sometimes used to ensure a proper curing process. Figure 3 illustrates how this might be done simply by placing a woven fabric on a moldconstructed from wood or other conventional materials. The polymer resin is then rolled or squeezed into the fabric, and the resin is allowed to react chemically ("cure") to a hard matrix. The mold is then left so that the resin will cure. The prepared Laminates(E-P)(S-P)(ES-P) Glass fiber reinforced polyester composite slabs were taken out from the mold, and then specimens of suitable dimensions were prepared from the composite frame (30cm x 30cm and plate thickness 5mm for different mechanical tests according to ASTM standards. The test specimens were cut by using the cutter. Figure 4 shows that prepared laminates

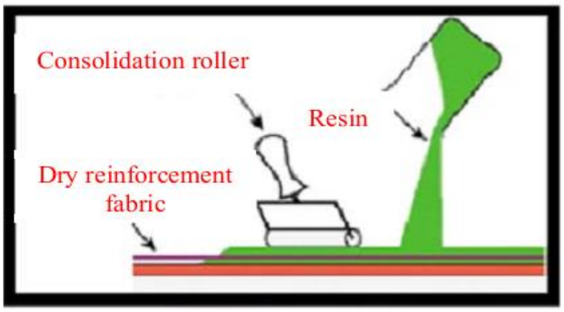

Fig.3.Experimental setup for the hand layup technique of GFRP composite production

Fig.4.Prepared laminates

C. Mechanical Testing

a) Tensile testing

The glass fiber reinforced polyester composite material fabricated was cut into the required dimension using a saw cutter. For mechanical testing, the edges of this composite are finished by using emery paper. The tensile test was carried out on a universal testing machine (UH-F1000kN) with a 5 mm/min crosshead speed as per the ASTM standards. The test specimens were prepared as Per ASTM D638 (165 x 19) mm; thickness is 5 mm, shown in Figure5. The three specimens were subjected to tensile test, and their values were recorded

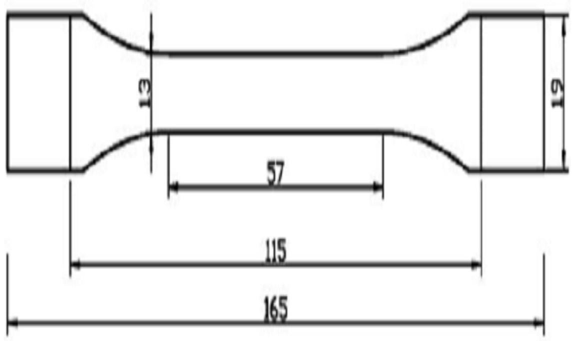

Fig.5The geometries and dimensions of the specimen

b) Flexural testing

Three-point flexural tests were conducted to assess outdoor environments' effects onthe flexural strength of GFRP composite. The specimens were tested with the exposedsurfacein compression; however, failure occurred in tension at the mid-span of specimens.Three-point Bending tests were used to study the flexural strength of the composite material specimens fabricated. It was carried out using a universal testing machine of 1000 kN full-scale load capacity with a crosshead speed of 5 mm/min according to ASTM standard D-790 (240 mm x 29 mm). The thickness is 10 mm in figure 6.

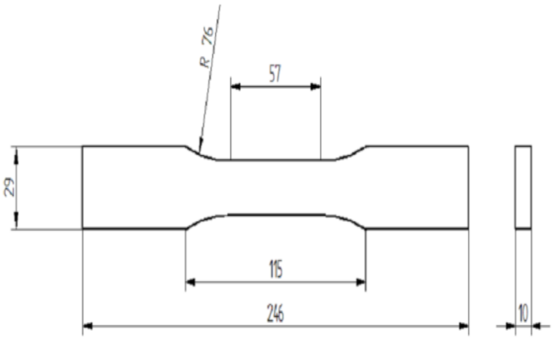

Fig.6The geometries and dimensions of the flexural specimen

c) Hardness Test

The Brinell hardness test was conducted on the specimen using a standard Brinell hardness tester. A load of 300 kg was applied on the specimen for 30 sec using a 5 mm diameter hard metal ball indenter. The indentation diameter was measured using a microscope containing an ocular, usually graduate in tenths of a millimeter, permitting estimates to the nearest 0.05 mm. The surfaces of the specimen should be smooth and free of oil and dirt. The hardness was measured at three different locations of the specimen, and the average value was calculated. The Brinell hardness testing machine as shown fig 7

Fig.7.Brinell Hardness Testing Machine

d) Impact Test

The toughness of the composite specimens was measured using the Izodimpact tester (PIT Series, U-shaped pendulum of up to 150 J) after determining the impact energy according to the slandered ASTM D-256. The composite fabricated material's impact energy was calculated by measuring the amount of energy before its fracture.The un-notched specimen is kept in a cantilever position, and the pendulum swings around to break the specimen. The impact energy (J) is calculated from the dial gauge fitted on the machine. Fig 8 shows that ready for testing laminates

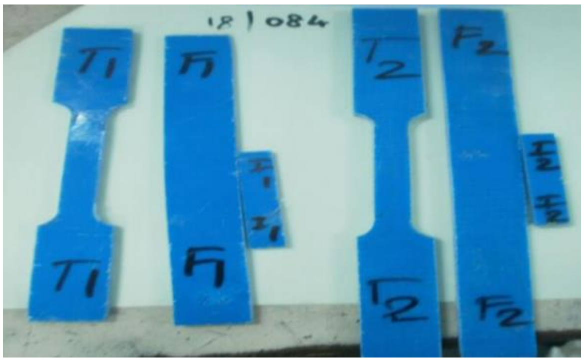

Fig.8. Before Testing Laminates

IV. RESULTS AND DISCUSSION

A. Tensile Strength

The properties of the composites depend upon the reinforcement materials. The variation in tensile strength of the fabricated laminate composites with E-P,S-P, and ES-P Laminates of glass fiber content are shown in Figure 9.

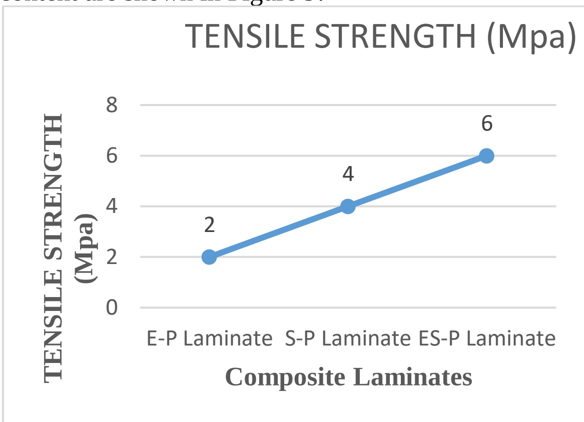

Fig.9.The variation in tensile strength with the glass fiber

The tensile strength test results with the variation in the glass fiber content of the fabricated composites are listed in Table 4.

Teble.4. Effect of glass fiber contents on tensile strength of fabricated composites

Composite Laminates	Width (mm)	Thickness (mm)	Max Load (F_{max}) N	Ultimate Tensile Strength (Mpa)
E-P	12.98	5.96	1.63	36.31
S-P	12.98	5.96	3.66	45.31
ES-P	12.98	5.96	5.72	73.99

This table shows the tensile strength of the E-P and S-P composite laminates 36.31Mpa, and 45.31Mpa respectively. The composites' tensile properties are mostly affected by the materials, method, specimencondition and preparation, andthe reinforced percentage. It was found from Figure 9,and the

tensile strength increased from 36.315 to 73.99MPa, with the maximum tensile strength beingfor the composite with E and S glass fiber percentage. The tensile strength of the fabricated. Composite depends to a large extent on the interfacial bonding strength between the matrix
reinforcement and also on the inherent properties of the composite ingredients. We show that after reinforcing the fibers, this property will be improved greatly. The fibers will withstand the maximum part of loads and, by consequence, will raise the strength of composite material. The tensile strength will be increased as the fiber percentage addition increased, where these fibers will be distributed in a large area in the resin. In the composite reinforced with random fibers, the load is concentrated at the end of short fibers Distributed in the matrix, which controls the transmission of the load from the matrix to the fibers through the interface.The region is weak. Improvement in tensile composites helps the composite to withstand more tensileforces when they are in service. Also, materials with more strain are likely to fail-safe in service.

B. Flexural Strength

In this test, glass fiber reinforced polyester composites' flexural strength behavior in different glass laminates (E-P,S-P,ES-P). The bending strength test results with the variation in the glass fiber content of the fabricated composites are listed in Table 5. It was found from Table 5, the bending strength increased from 80.907MPa to 91.698MPa with glass fiber varied from EglasstoE and S glass fiber laminates, and the maximum value of bending strength reached to 91.698MPa at the addition of E and S glass fiber. As mentioned below, the resin is brittle; therefore, its flexural strength will be low before reinforcement (80.907MPa). Strength, as shown in Figure 10.

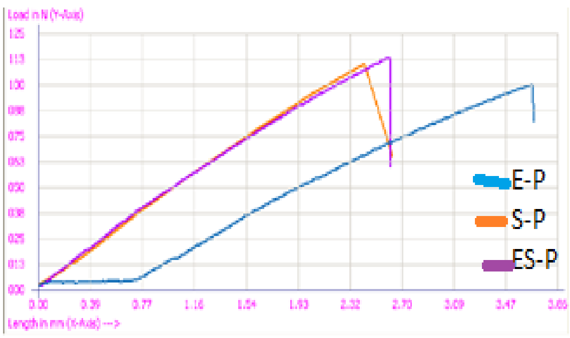

Fig.10.The variation in flexural strength with the glass fiber

Results reveal that type of reinforcements show good stiffness and bending strength, But after added the fibers to this resin, the flexural strength will be raised to the producing material because the high modulus of elasticity of these fibers will help to carry a large amount of load s and raise this

Table.5.Effect of glass fiber contents on Flexural Strength of fabricated composites

Composite Laminates	Area (mm²)	Max Load (F_{max}) N	Flexural Strength (Mpa)	Flexural Modulus (Mpa)
E-P	45.02	100.170	80.907	7207.626
S-P	45.02	110.107	88.933	7702.659
ES-P	45.02	113.531	91.698	9427.342

C. Impact Strength

The variation of impact strength with the glass fiber laminates in case of room temperature was presented in Figure 7. It was found from this figure11. The impact energyglass-Polyester laminates 2J.in addition of S glass fiber to reach impact strength 6J.The results of the Impact strength test with the variation in the glass fiber content of the fabricated composites are listed in Table 6.

Table.5.Effect of glass fiber contents on the Impact strength of fabricated composites

S.NO	Composite Laminates	Impact Strength
1	E-P	2
2	S-P	4
3	ES-P	6

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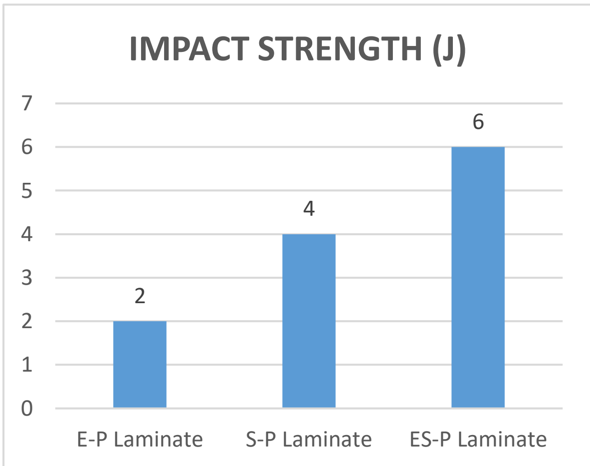

Fig11. The variation in Impact strength with the glass fiber

The impact resistance will continue to increase with increasing the glass fibers reinforcing percentage. The impact resistance is considered low to the resins due to the brittleness of these materials. After reinforcing it with glass fibers, the impact resistance will be increased because the fibers will carry the maximum part of the impact energy, which exposition on the composite material.

D. Hardness

The Brinell hardness values for random glass fiber/polyester composite are shown in Figure 12. This figure showed the composite increases' hardness from 16 BHN to 20 BHN with E and S glass fiber. The maximum BrinellHardness of 20 BHN was obtained at ES glass fiber content. The hardness is plotted with weight fiber fraction in Figure 12, and we notice that hardness increase with the additionof glass fiber content; Polymers have low hardness. Still, this hardness value will greatly increase when glass fibers reinforce the resin due to the distribution of the test load on the glass, which decreases the penetration of the test ball to the surface of fabricated composite material and, by consequence, raises the hardness of this material.Addition of glass fiber content increased the composite's modulus, leading to a corresponding increase in the composite's hardness.The results of the Hardness test with the variation in the glass fiber content of the fabricated composites are listed in Table 7

Table.7.Effect of glass fiber contents on the hardness of fabricated composites

S.NO	Composite Laminates	Max Load (N)	Hardness (BHN)
1	E-P	100	16
2	S-P	100	12
3	ES-P	100	20

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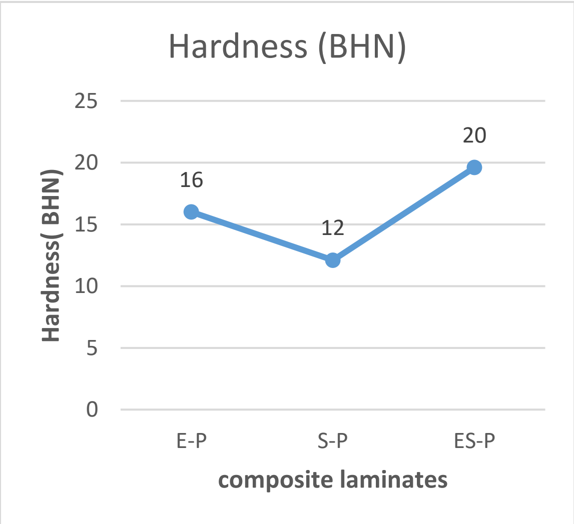

Fig12. The variation in hardness with the glass fiber

By the various mechanical testing results shows (Fig 13), .that combination E-glass and S-glass fiber reinforced polyester composites aremaximum tensile Strength, flexural Strength,Impact strength and Hardness values to be achieved by comparing to other reinforced polyester composites.

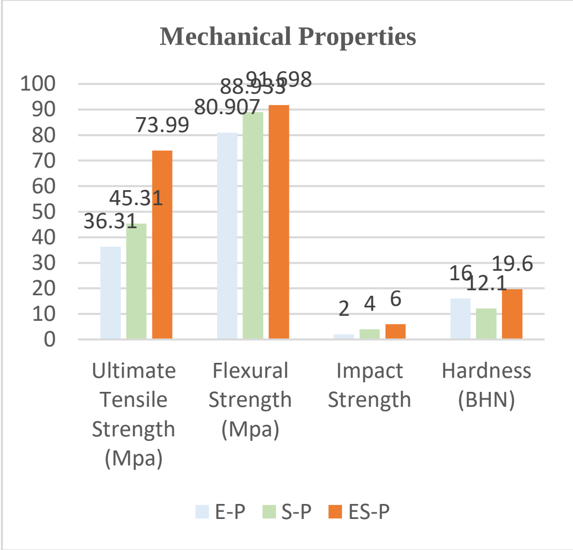

Fig13. The Mechanical Properties of glass fiber reinforced

V. CONCLUSION

This experimental investigation of the mechanical behavior of glass fiber reinforced polyester resin composites leads to the following conclusions:

This work shows that successful fabrication of glass fiber with random oriented reinforced polyester composites with different fiber contents is possible and cost-effective by simple hand layup technique. It was found that the tensile strength varies from 36.315 to 73.99M, flexural strength varies from 80.907MPa to 91.698MPaand impact energy at room temperature varies from 2 Joules to 6. Joules with the addition of E and S in glass fiber reinforced polyester composites. The hardness value will greatly increase from 16 BHN to 20 BHN when the resin reinforced by glass fibers composite laminatesto a great extent has improved the mechanical property such as tensile strength and flexural bending strength of polyester resin due to the presence of glass fiber reinforcement. Finally, we conclude the combination of E-glass and S-glass fiber-reinforced polyestercompositesiscan be Effectively and better strength.So this material suitable for windshield applications because these glasses are transparent, heat resistance, pressure and breakage resistance, and chemical resistant.

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