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Evaluation of Mechanical Characteristics for FRP Material Using Glass, Carbon and Basalt Fibres

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Abstract:

Fibre Reinforced Polymer (FRP) composites have been implemented in the field of automobile industries to replace existing metal components due to significant characteristics of strength to weight ratio, better stiffness, ease of manufacturing and corrosion free nature. FRP composites consist of polymer fibres as reinforcement and adhesive resin as matrix to form hybrid material. Currently, the synthetic fibres of glass, aramid, carbon, basalt, polyethylene are used to make composite in manufacturing industry with matrix as epoxy resin. Due to the difficulties raised while manufacturing the automobile components in terms of strength-weight factor, the alternate matrix materiel vinyl ester resin has been proposed to enrich the strength of hybrid composites. This paper describes about the mechanical behaviour of hybrid composites by comprising the glass fibre, carbon fibre and basalt fibre is reinforced with epoxy resin and vinyl ester resin. The results of tensile strength, compressive strength, flexural strength, impact energy and material hardness have been compared and evaluated for different combination of carbon, glass and basalt fibres.

Keywords: *Fibre Reinforced Polymer (FRP) Composite, Epoxy Resin, Vinyl Ester Resin, Mechanical Characteristics and Matrix.*

I.INTRODUCTION

In recent years, FRP materials have seen a tremendous increase in their use in the automotive industry. Although the advantages of employing FRP materials include lightweight, cheap cost, greater corrosion resistance, and ease of maintenance, the design of fibre-reinforced materials is often not as well-known as that of metallic equivalents **(1).**David Plappert et al **(2)** described the baseline material characteristics of a high-performance basalt composite made up of unidirectional plies of endless fibres in an epoxy matrix. A hand-layup investigation of 0^0 and 90^0 fibre orientation lay-up samples of a similar material system. The various basalt performs are combined with Polypropylene and Glass to create a hybrid framework. Shiza Parmar and Hireni Mankodi**(3)** explored the application of basalt fibre mixed with various types of fibres and architectures. The mechanical characteristics of the matrix material improved as the reinforcing content of the fibre increased. Mithilesh and Mahesh **(4)** discussed the mechanical characteristics of a hybrid composite made up of Basalt fibres and Glass fibres that was created by hand lay-up procedures. The results revealed that carbon black reinforcement of woven Basalt and Glass fibre hybrid composite has a substantial impact on the composite mechanical characteristics. The physical and mechanical properties of Basalt Fibre Reinforced Polymer bars and its comparison with Glass FRP (GFRP) bars has been studied by Mohamed Abdel-Hamid et al **(5)**. The types of fibres (basalt and glass), bar diameter (10 mm and 12 mm), and fibre volume fraction were all explored in this study (50 % and 65 %). The test findings showed that basalt fibre bars with the same fibre volume % as GFRP bars had much better mechanical characteristics (approximately 1.28 times those of GFRP bars).

Vacuum Assist Resin Transfer Moulding (VARTM) was used to fabricate three different sandwich composites with H130 PVC foam as the core material and reinforcing of E-glass/Epoxy, S glass/Epoxy, or a hybrid of basalt/S-glass/Epoxy and evaluated with flat wise tensile, shear tension, flexural, and torsion tests **(6).**The orthogonal series of diverse tests are done utilising the applicable Taguchi approach, centred inside in the various layers of Jute / Basalt and material orientation**(7).**Experimental research on the mechanical characteristics of epoxy-based composites was carried out by Thirumalai et al **(8).** For the fabrication of the hybrid composite, epoxy resin was employed as the matrix material, while jute and basalt fibres were used as reinforcing materials. The tests were carried out in accordance with ASTM guidelines.Due to the possible inexpensive cost of this material combined with its strong mechanical performance, particularly at high temperatures, new possibilities on basalt fibre uses have been emerged. Results demonstrate that the basalt fibre outperformed the glass fibre in terms of mechanical properties**(9).**Tensile and three-point bending tests were used to study the mechanical behaviour of the BFRP composites by Konstantinos Karvanis et al **(10).**Results indicates that as the frequency is increased, the expansion Tg of the BFRP composites increases significantly, but the storage modulus curve has a less steep decline in the middle transition zone. Jute fibres with a fibre length of 5-6 mm were used to make the fibre-reinforced composites. Polyester and epoxy resins were utilised in this experiment by Ajith Gopinath et al **(11).** The composites were made using a fibre-to-resin weight ratio of 18:82. The mechanical characteristics of the composites, such as tensile strength, flexural strength, impact strength and hardness, were evaluated on the produced composites. Results suggest that the jute reinforced epoxy composite outperformed the Jute-polyester composite in terms of mechanical qualities. Tamilarasan and Inbanaathan (12) illustrated the potential of jute and banana fibre composites in combination with carbon fibre, focusing on both physical and mechanical qualities. It also highlights the differences in mechanical characteristics of natural fibre composites when non-natural fibres, such as carbon fibre, are added in an equivalent ratio. Woven fabric reinforced vinyl ester composite has been investigated on the impact of hollow polymeric microspheres (PHMS) on particular mechanical and thermal characteristics of glass, basalt, and carbon **(13)**. With the addition of PHMS, the composites' specific flexural and specific impact strengths were somewhat raised; however, the specific flexural modulus was lowered. The goal of this research is to determine the material stability particularly on the synthetic fibres of carbon, glass and basalt fibre by comparing vinyl ester and epoxy resin.

II. MATERIALS AND METHODOLOGY

Materials

Many of the researchers have selected the woven fabric of synthetic fibres to investigate the hybrid composites. In the present investigation, the synthetic fibres carbon fibre, glass fibre and basalt fibre are chosen as raw materials (Figure 1).Generally, the strength and stiffness of fibre materials are much higher than that of the matrix material, making them a load-bearing element in the composite structure. The characteristics of selected fibres possesses high stiffness and thermal conductivity which is applicable to manufacture automobile components. The different combination of FRP material has been prepared by using two different adhesives (matrix phase).Matrix is important in the binding of FRP reinforcing materials. The matrix's principal function is to bond and shield fibres from the elements. Matrix and fibres must be thermally and chemically compatible. In this study, the matrix material of epoxy resin and vinyl ester resin has selected to make composite which referred in Figure2.Chemical resistance and thermal stability are the two advantages of these materials. Vinyl esters, can withstand alkalis and harsh chemicals. Vinyl esters, as opposed to polyesters, are more resistant to moisture absorption and shrinking. The standard physical and mechanical properties of chosen fibres and matrix are mentioned in Table I.

Table I Properties of Synthetic Fibre& Resin

Material Property	Carbon	Glass	Basalt	Epoxy Resin	Vinyl Ester
Density (kg/m^3)	1750	2550	2670	1100	1160
Youngs modulus (GPa)	183	72	92	85	80
Poisson's ratio	0.23	0.21	0.26	0.33	0.3 – 0.33
Thermal conductivity (W/mK)	0.1	1.3	0.03	0.2	0.35
Melting Point (^{0}C)	3697	1360	1500	140	160

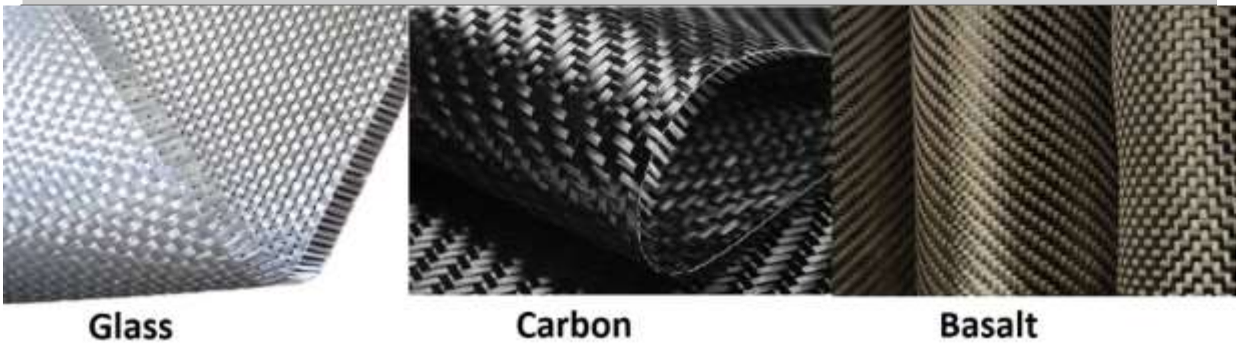

Figure 1. Selected Synthetic Fibre (Reinforcement)

Figure 2. Selected Resin (Matrix)

Specimen Preparation

The FRP composite would be manufactured by different methods such as hand lay-up technique, vacuum assisted moulding and compression moulding. In this research, the composite specimens have prepared by hand layup method which is simpler and more convenient among others. Firstly, the mould structure of required specimen shape gets rinsed with glue/grease or covered by polyethylene sheet. It helps to demould specimen easily and avoid resin stick with mould cavity. After preparing mould, the matrix phase of resin (gel) applied over the mould surface. The mat structured woven fabric has layered in mould as reinforcement of required shape and size. Then the mould gets compressed with hydraulic press machine for 48 hours. By this process, the various combination of FRP material using carbon, basalt and glass fibre is tabulated below (Table II). The specimens are moulded for the size of 300 × 300 mm and achieve thickness of 3 – 5 mm.

Table II Various Combination of Composite Specimen

Specimen Designate	***Combination***	
	Fibres	***Resin Ratio***
Epoxy 1 (E1)	Glass + Carbon	1:1
Epoxy 2 (E2)	Glass + Carbon	1:2
Epoxy 3 (E3)	Glass + Basalt	1:1
Epoxy 4 (E4)	Carbon + Basalt	1:1
Epoxy 5(E5)	Carbon + Basalt	1:2
Epoxy 6 (E6)	Glass + Basalt	1:2
Vinyl 1 (V1)	Carbon + Glass	1:1
Vinyl 2 (V2)	Basalt + Glass	1:1
Vinyl 3 (V3)	Basalt + Carbon	1:1

III. EXPERIMENT RESULT AND DISCUSSION

Experiments on the mechanical properties of tensile, compression, flexural, hardness and impact tests have been conducted for the prepared composite. Each specimen is examined for the material flaws, with the results indicating the type or severity of the flaw. The below figure 3 and figure 4 shows the tested samples of both resins respectively.

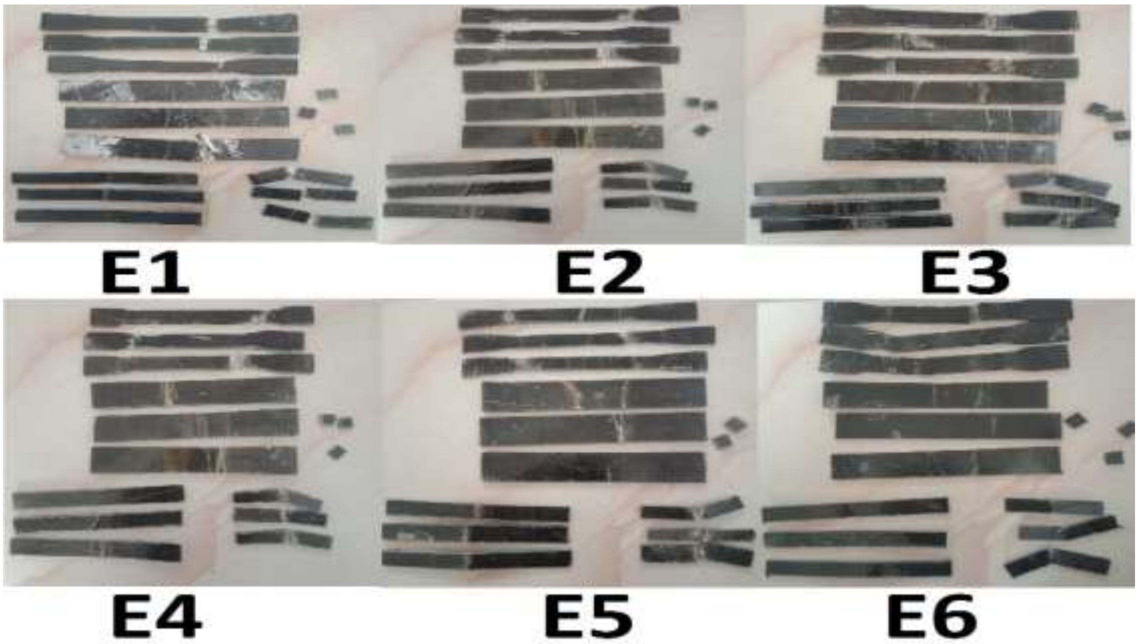

Figure 3. Epoxy Resin Tested Samples

Figure 4. Vinyl Ester Resin Tested Samples

Tensile Test

The specimens were tensile tested in accordance with standard of ASTM D638 for both epoxy and vinyl ester resin. Specimens measuring of 165 mm x 13 mm x 3mm were examined with a gauge length of 57mm (figure 5). It was observed that the maximum tensile strength 159.87 MPa at the peak load of 7.194 kN for sample E4(carbon & basalt fibre with epoxy resin 1:1 ratio).The least tensile strength 72.633 MPa attained for carbon & basalt fibre with epoxy resin 1:2 ratio at the load of 3.268 kN. Similarly, the maximum tensile strength 213.96 MPa for sample V2 (basalt + glass) at the peak load of 10.27 kN whereas the least tensile strength 100.611 MPa at 4.8 kN for sample V3 (basalt + carbon). Figure 6a,b represents the graphical comparison of epoxy and vinyl ester resin samples.

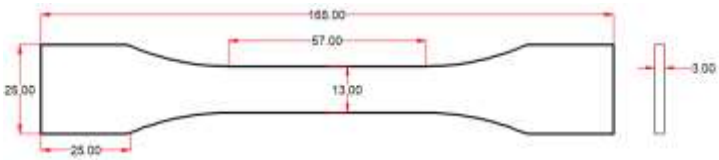

Figure 5. Tensile Test Size (ASTM D638)

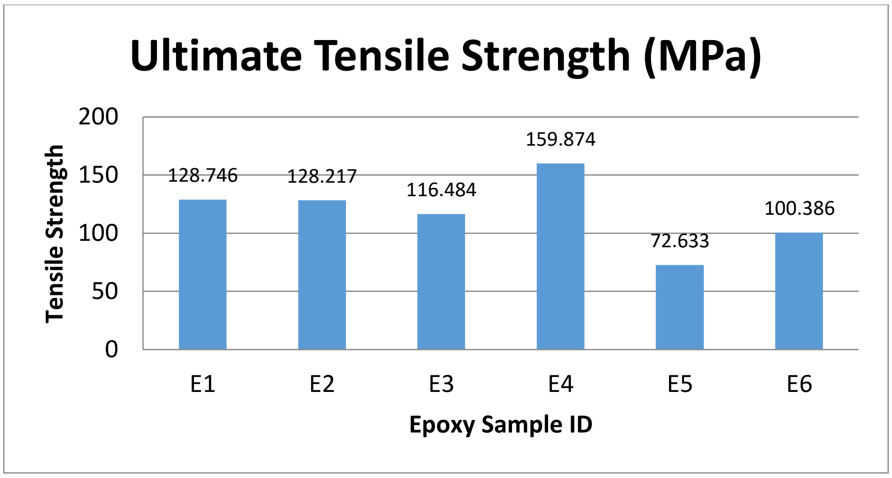

Figure 6a. Ultimate Tensile Strength for epoxy Samples

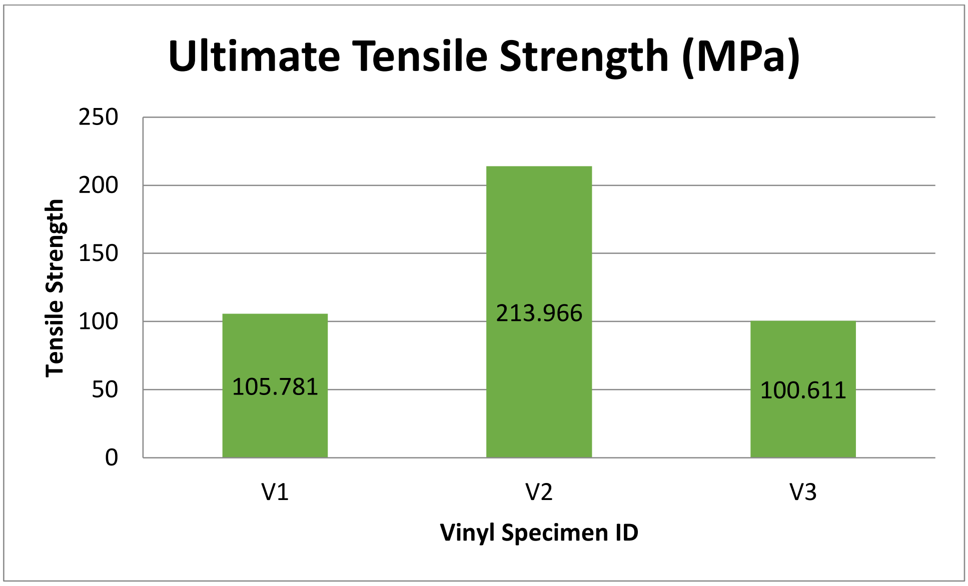

Figure 6b Ultimate Tensile Strength for Vinyl Samples

Compression Test

The UTM Machine was used to conduct compression tests on all compositions (epoxy and vinyl ester) that met the ASTM D3410 (figure 7) specimen requirement. The acquired mechanical property data, such as ultimate breaking load displacement at maximum force, are shown in graphs. Comparatively, the highest compressive strength 69.36 MPa acquired at the peak load of 5.2 kN for the sample E2 (carbon + glass with epoxy resin 1:2). The least compressive strength 27.16 MPa obtained at load of 2.073 kN for sample E1 (glass + carbon with epoxy resin 1:1). The same compression test carried for vinyl ester specimen respectively where the results graphically mentioned in figure 8a,b. In vinyl ester combinations, the maximum compressive strength 33.354 MPa acquired at the peak load of 2.5 kN for sample V2 (basalt + glass) whereas minimum strength 16.88 MPa for sample V1 (carbon + glass) at load of 1.26 kN.

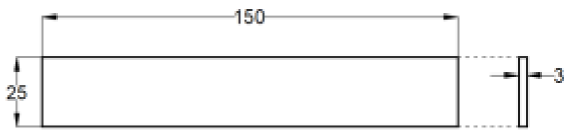

Figure 7. Compression Test Size (ASTM D3410)

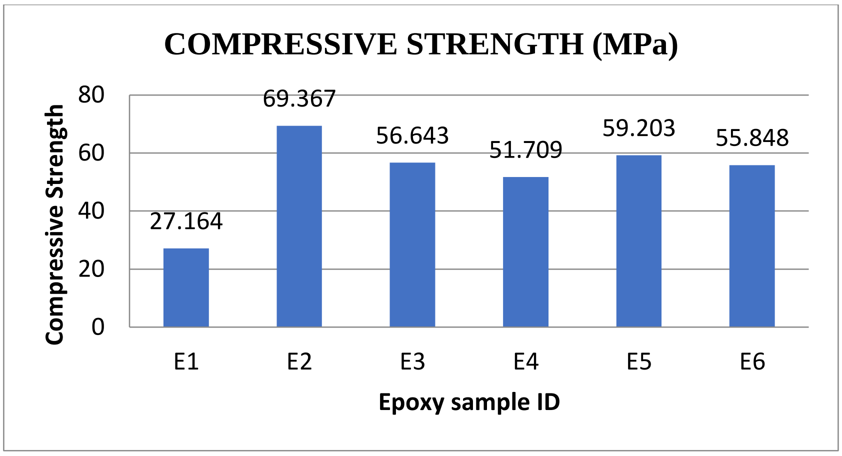

Figure 8a Compressive Strength for Epoxy Samples

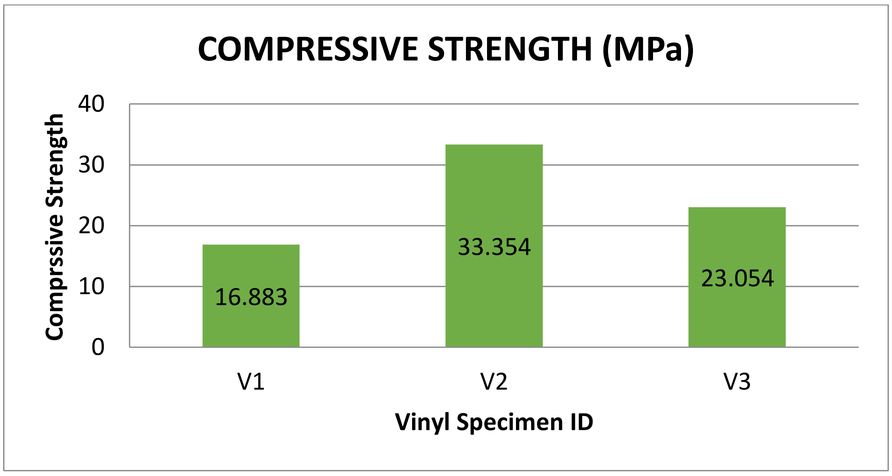

Figure 8b Compressive Strength for Vinyl Samples

Flexural or Bending Test

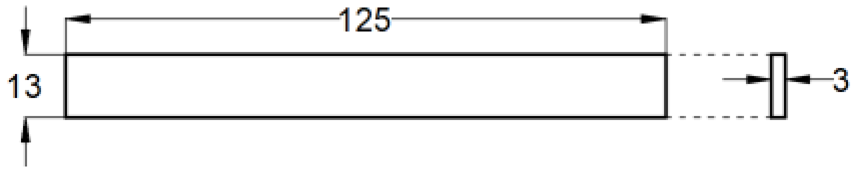

Figure 9. Flexural Test Size (ASTM D790)

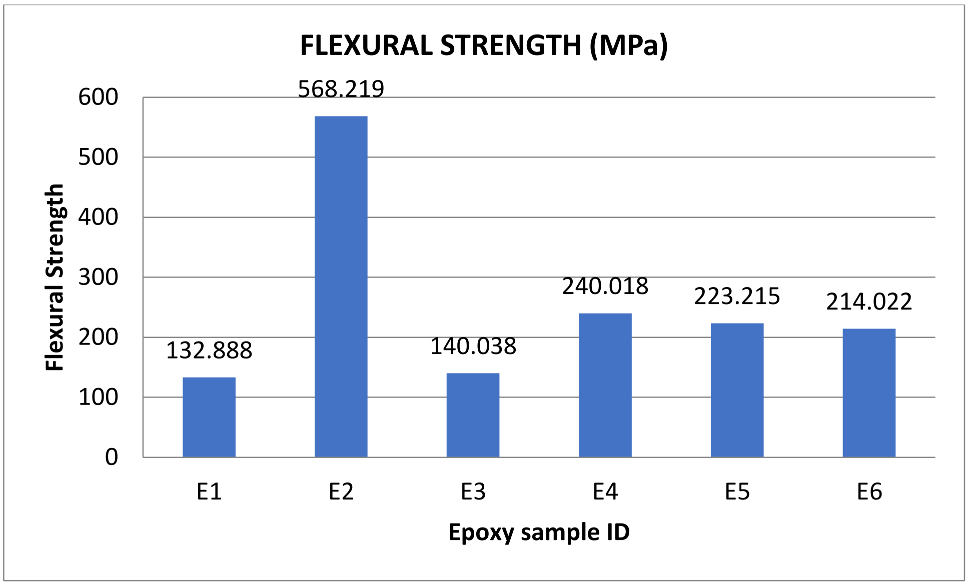

Figure 10a Flexural Strength for Epoxy Samples

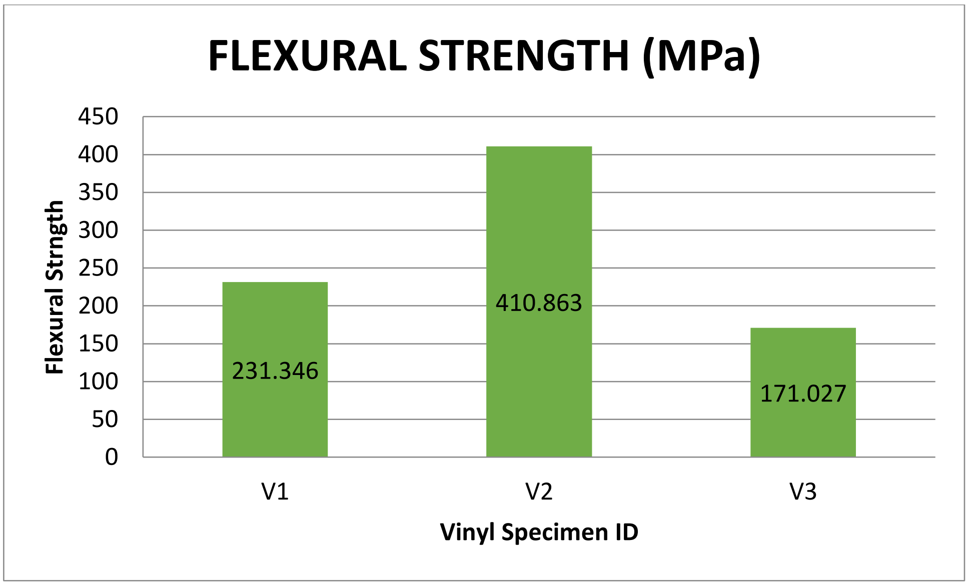

Figure 10b Flexural Strength for Vinyl Samples

The three-point bending test was used to measure the specimen flexural strengths according to ASTM-D790. A span length of 50 mm was used to examine specimens that were 125 mm x 13mm x 3mm in size (figure 9). Figure 10 shows that the comparison of flexural strength results acquired for the epoxy resin and vinyl ester samples. The maximum flexural strength was 568.219 MPa achieved for the sample E2 at the peak load of 0.886 kN and the flexural modulus was 20763.711 GPa. Sample E2 is combination of glass fibre and carbon fibre with epoxy resin 1:2 ratio. Similarly, the maximum flexural strength of vinyl ester was 410.863 MPa and flexural modulus 15938.479 GPa at the load of 0.64 kN obtained for the sample V2 (glass + basalt). The least flexural strength of vinyl ester was 171.027 MPa and flexural modulus 5376.644 GPa for sample V3 (carbon + basalt) as shown in 10a,b.

Impact Test

Impact test carried out for the present study by Charpy impact test machine where the ASTM D256 standard specimen size of 65 × 13 × 3 mm (figure 11).The better impact energy 5.1 J was observed for sample E2 and low for E6 which graphically indicated through indicated in figure 12a,b. For vinyl ester impact results, the better impact energy 5.7 J observed for V2 and minimum for V1 sample.

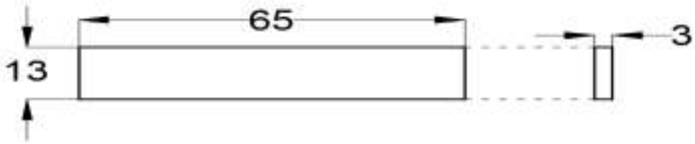

Figure 11. Impact Test Size (ASTM D256)

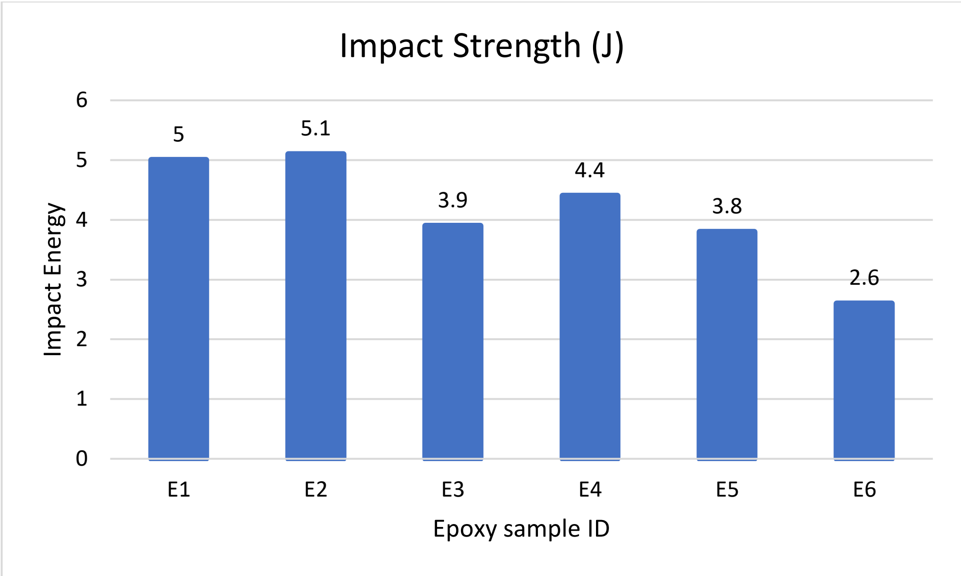

Figure 12a Impact Energy for epoxy Samples

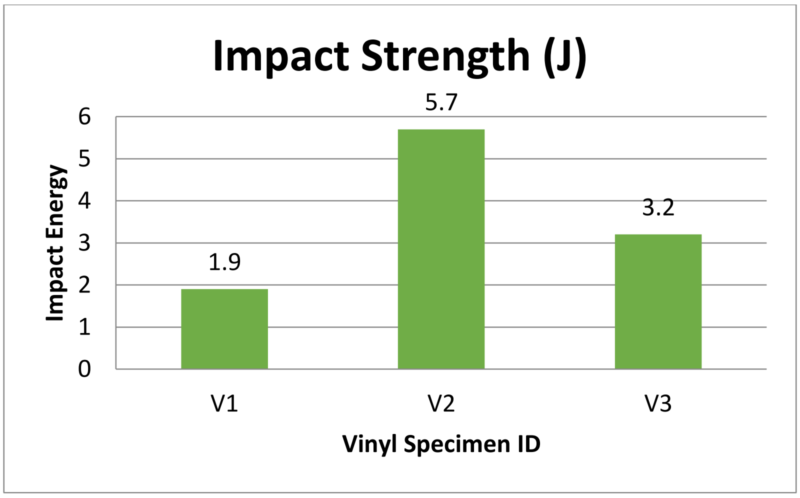

Figure 12b. Impact Energy for Vinyl Samples

Hardness Test

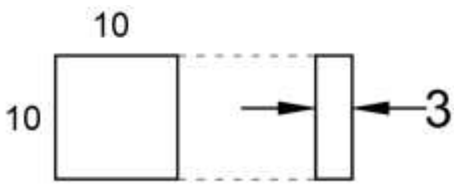

Figure 13. Vickers Hardness Test Size

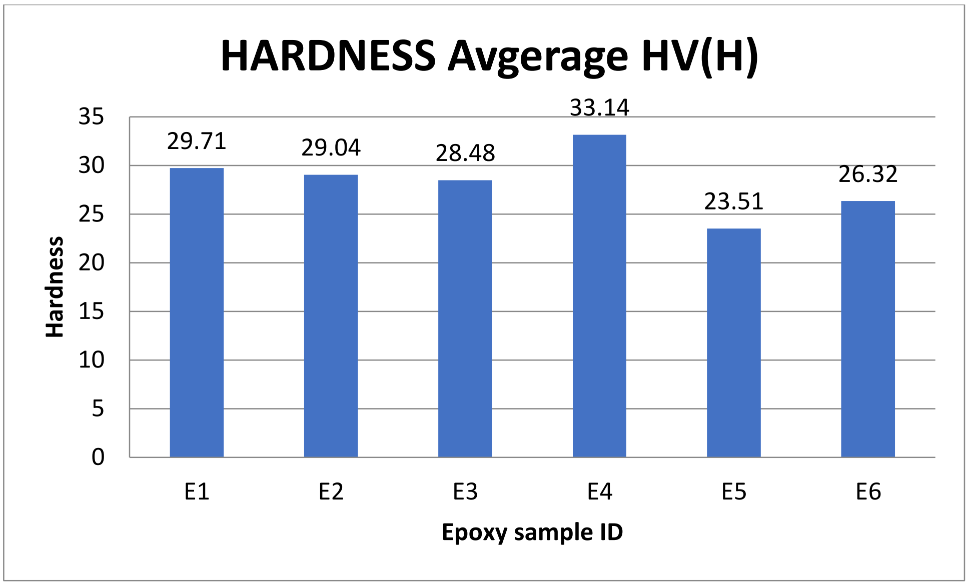

Figure 14a Hardness Value for Epoxy Samples

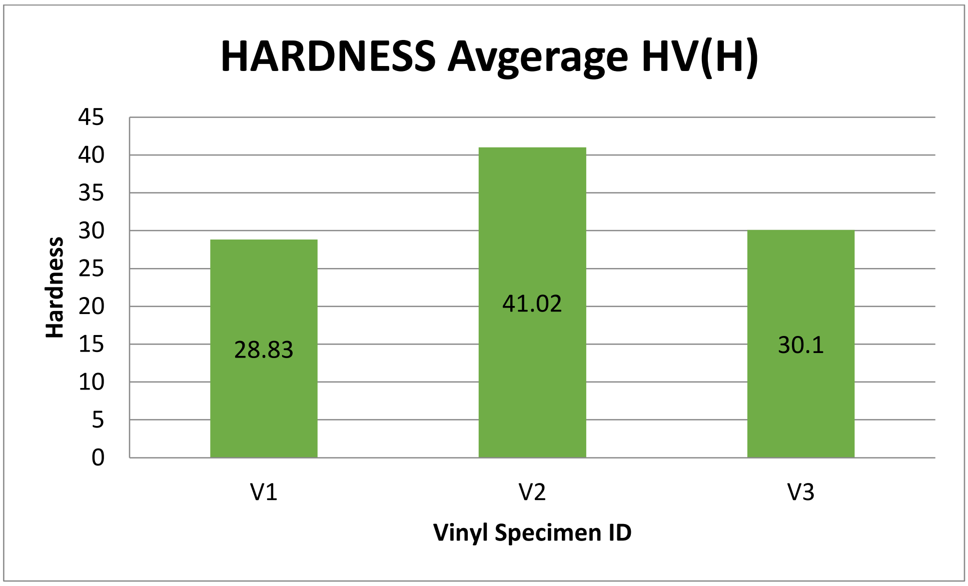

Figure 14b Hardness Value for Vinyl Samples

Hardness is a material attribute, not a basic physical property. It is defined as indentation resistance and is assessed by measuring the permanent depth of the indentation. Simply said, when a constant force (load) is applied to a specific indenter, the smaller the indentation, the harder the material. The Vickers hardness test method was referred in this study that the ASTM standard size of 10 × 10 × 3 mm (figure 13). The better hardness 33.14 HV was observed for sample E4 and minimum hardness value 23.51 for sample E5 (figure 14a,b). For vinyl ester, the better hardness 41.02 HV acquired for sample V2 and low value 28.83 HV for sample V1.

IV.CONCLUSION

This research describes about the hybrid composite of Fibre Reinforced Polymer material where it proposed to manufacture automobile components. The experiment test of material strength has been processed for different combination of synthetic fibres carbon, basalt and glass. Additionally, the two different matrix material of epoxy resin and vinyl ester resin was used to made FRP composite and processed in this study. The mechanical characteristics of tensile strength, compressive strength, flexural strength, impact strength and material hardness were found experimentally in accordance of ASTM standard. the sample E2 achieved better mechanical properties than others for epoxy combinations. In vinyl ester combination, the sample V2 achieved better property than others. By observation of both results of epoxy resin and vinyl ester resin, the FRP material made by vinyl ester resin was stronger and heavier than epoxy resin material. The obtained better results of mechanical properties have summarized below:

- The maximum tensile strength of 159.874 MPa acquired for epoxy resin and 213.966 MPa for vinyl ester resin.
- Compressive strength of 69.367 MPa for Epoxy resin and 33.354 MPa for vinyl ester.
- The better flexural strength 568.216 MPa for epoxy and 410.863 MPa for vinyl ester resin.
- The impact energy of 5.1 joules attained for epoxy material and 5.7 joules of impact energy for vinyl ester material.
- The maximum hardness acquired for epoxy is 33.14 and for vinyl ester material is 41.02.

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