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Mechanical Investigation of S-Glass/Carbon Fibers Reinforced Epoxy Polymer Matrix Composites

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Abstract: ***Fiber-based hybrid composite materials are used for variety of industrial purposes going on from automotive to many engineering fields such as structural, aerospace because of unique properties compared over conventional materials. Fiber based hybrid composites have greatly long-drawn-out o varying applications in today's automotive industry reason behind is due their light weight, high strength, stiffness and ease of repair. This work aims to create a novel type of hybrid composite made by reinforcing S-glass (satin type) & carbon (twill form) in an epoxy matrix. Pure and hybrid composites are made by manual laying with 0° orientation of each fiber layer and the action has been tested with different combinations of each layer of S-glass and carbon and finally with a hybrid subjected to different mechanical stresses. The fiber matrix for the hybrid is created in a 50:50 ratio. Pure samples of fiberglass and carbon fiber-epoxy composites were compared to hybrid samples. The results showed that the hybrid samples outperformed the pure forms of the composite in mechanical tests, due to the presence of carbon fiber on the end faces of the sample, which offers the hybrid form's superior mechanical properties.***

Key words: Carbon, S-glass, Epoxy, Hybrid, Hand Layup.

I. INTRODUCTION

FRP composites are materials composed of a polymer matrix of epoxy resin reinforced with fibers. Fibers are made from a variety of materials such as glass, carbon, or aramid. Fibers role in composite material is to provide strength and stiffness, while the epoxy resin provides the composite material with its characteristic toughness and chemical resistance. The combination of these two materials creates a composite material that is strong and stiff, but also possesses excellent chemical and environmental resistance. The use of FRP composites in the modern age has skyrocketed, due to the materials' unique combination of characteristics.

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For instance, fiber reinforced epoxy matrix composites are often used in the many industries because of high strength-to-weight ratio, and their ability to withstand the extreme temperatures and pressures encountered during flight. The chemical and environmental resistance of these materials also makes them a great choice for use in the marine and automotive industries, where they are often used to fabricate parts that are exposed to harsh environmental conditions [1,3]. In addition to their use in the industrial sector, FRP composites are also gradually being used even in the medical field. Due to their excellent strength and stiffness, these materials are perfect for the fabrication of medical implants and prosthetics. The excellent chemical and environmental resistance of these materials also makes them an ideal choice for medical devices that are exposed to bodily fluids, as well as devices that are used in harsh environments. Overall, fiber reinforced epoxy matrix composites have become an indispensable material in a variety of industries due to their unique combination of characteristics. Their high strength-to-weight ratio, excellent chemical & environmental opposition, and the ability to withstand extreme temperatures and pressures make them a great choice for diversified applications. As technology advances, FRP composites are sure to become even more important as more applications are discovered. FRP composites are a type of material that is widely used in many industries due to its strength and durability. They are made up of a combination of epoxy resin, a thermoset plastic, and fiberglass, carbon fiber, or aramid fibers. This combination creates a strong and lightweight material that is resistant to corrosion, fatigue, and impact. The most significant benefit of FRP composites is their high strength-to-weight ratio. This ability of the material makes them to have reduced weight is a prime priority, such as aerospace and automotive components. They are also used for strength based system as a priority, such as sporting goods and medical equipment [1,3].

In addition to their strength and light weight, FRP composites are highly resistant to environmental degradation. They have better resistant to chemicals, moisture and UV radiation, making them ideal for use in outdoor applications. They also have excellent vibration and sound damping properties, making them suitable in soundproofing and vibration-dampening applications. Fiber reinforced epoxy matrix composites also have excellent electrical insulation properties. This makes them ideal for use in electrical components, such as wiring harnesses, circuit boards, and connectors. They can also be used in applications that require electromagnetic shielding, such as telecommunications equipment.

Overall, FRP composites are an excellent choice for many applications due to their light weight, strength, electrical insulation and durable properties. They are used in a wide variety of industries, from aerospace and automotive to medical and telecommunications. Their versatility makes them a great choice for many applications. Fiber reinforced epoxy matrix composites are a revolutionary new type of material used in a wide range of applications, from aerospace engineering to nanotechnology. These materials are made up of a matrix of polymers, such as epoxy, reinforced with fibers such as glass, carbon, or basalt [2].

The combination of these materials creates a unique material with a wide range of properties, making them ideal for use in many different applications. The most significant property of fiber reinforced epoxy matrix composites is their strength. The addition of fibers to the matrix increases the strength and stiffness of the composite material, making it much more durable and reliable than traditional materials. Additionally, the fibers can be tailored to the specific application, allowing for the creation of composites with properties such as increased corrosion resistance or a higher specific strength. This makes fiber reinforced epoxy matrix composites ideal for use in demanding applications, such as aerospace engineering, where high strength and reliability are paramount [3,4]. Another major advantage of fiber reinforced epoxy matrix composites is their low weight compared to traditional materials. The addition of fibers to the matrix reduces the weight of the composite material, making it much lighter than other materials of similar strength. This ability of material system is considered, where weight is a major factor, such as in nanotechnology or in the aerospace industry. Finally, fiber reinforced epoxy matrix composites also have excellent fatigue resistance, meaning they can be used in applications where they will be subjected to repeated stress. This makes them an ideal choice for use in applications such as automotive engineering, where components are subjected to high levels of stress over long periods of time. Overall, fiber reinforced epoxy matrix composites are a revolutionary new material with a wide range of properties that make them ideal for use in a variety of applications.

Whether used in aerospace engineering or nanotechnology, these composites offer a unique combination of strength, low weight, and excellent fatigue resistance. As such, they are quickly becoming the material of choice for many applications [3,4]. The study of microstructure and thermo-mechanical properties of composites reinforced with different weaves of glass and carbon fabrics is a growing area of research. In this paper, we investigate the effect of hybridization on these properties. We used a combination of glass and carbon fabrics to form hybridized woven composites. We then conducted a series of tests to measure the microstructure, mechanical properties, and thermal properties of the composites. The results showed that hybridization had a positive effect on the microstructure of the composites, resulting in improved mechanical and thermal properties. The tests also revealed that the glass-carbon hybridized composites exhibited better thermal and mechanical properties than the glass-only and carbon-only composites. The hybridization led to a higher degree of fiber entanglement and an improved fiber-matrix interface, which contributed to the enhanced properties. Overall, our results demonstrate that hybridization is an effective method to improve the microstructure and thermo-mechanical properties of composites reinforced with different weaves of glass and carbon fabrics. The findings of this study could be useful for optimizing the design of composite materials for use in high-performance applications [5].

The mechanical properties of hybrid polymer composites comprising of glass and carbon fibers in different configurations were studied for the first time at different in-situ temperatures. The objective of the research was to understand the behavior of the hybrid composites under varying temperatures and to determine their optimal thermal performance. The results of the study showed that the stiffness of the composites increased with increasing temperature. This was attributed to an improved bonding between the glass and carbon fibers as the temperature increased. The flexural modulus of the composites was also found to increase with increasing temperature, up to a certain point, after which it decreased. The impact strength of the composites was found to be higher at higher temperatures compared to lower temperatures, possibly due to a more flexible matrix structure at higher temperatures. The shear strength of the composites was also found to increase with increasing temperature. The results of this study showed that the mechanical properties of hybrid polymer composites including glass and carbon fiber components can be improved with increasing temperature, up to a certain point.

This suggests that the optimal temperature for the performance of such composites can be determined by analyzing their mechanical properties [6].

The study used varying concentrations of carbon fiber and glass fiber to reinforce epoxy composites. The specimens were then subjected to standard tests to measure the tensile strength, flexural strength, and impact strength through dynamic mechanical analysis. The results were compared to examine the performance of the composites. The results of the study showed that the tensile strength of the carbon fiber reinforced epoxy composites was significantly higher compared to the glass fiber reinforced epoxy composites. The flexural strength and impact strength of the carbon fiber reinforced epoxy composites were also significantly higher than the glass fiber reinforced epoxy composites. Overall, the results of the study showed that reinforcing epoxy composites with carbon fiber significantly enhanced the thermo-mechanical properties of the composites in comparison to the glass fiber reinforced epoxy composites. The carbon fiber reinforced epoxy composites showed higher tensile strength, flexural strength, and impact strength. This makes it an ideal choice for applications in the automotive, aerospace and defense industries [7].

This study aimed to compare the mechanical properties of carbon and glass fiber-reinforced epoxy, polyester and vinyl ester-based composites. The results of this study concluded that the glass-fiber reinforced composites had a higher tensile strength and higher modulus of elasticity, while the carbon-fiber reinforced epoxy composites had a higher compressive strength.

The vinyl ester-based composites had the highest impact strength, while the polyester-based composites had the lowest impact strength. Overall, the study found that the mechanical properties of carbon and glass fiber-reinforced composites were affected by the type of resin used, and the type of reinforcement used. Based on the study, it can be concluded that the carbon and glass fiber-reinforced epoxy, polyester and vinyl ester-based composites are suitable for a variety of applications, depending on the properties desired. The carbon-fiber reinforced epoxy composites are most suitable for applications where a high compressive strength is needed, while the glass-fiber reinforced composites are most suitable for applications requiring high tensile strength and modulus of elasticity. The vinyl ester-based composites are most suitable for applications where a high impact strength is desired, while the polyester-based composites are least suitable for applications requiring high impact strength. Overall, this study provides valuable insights into the mechanical properties of carbon and glass fiber-reinforced epoxy, polyester and vinyl ester-based composites [8]. Glass Carbon/Epoxy based Hybrid Composites are a type of advanced composite material with exceptional mechanical and thermal properties. This type of composite material combines the properties of both glass and carbon fibers with the epoxy resin, offering superior strength and stiffness compared to traditional composite materials. It also has excellent vibration damping capabilities and can withstand extreme temperatures. The mechanical and thermal properties of this type of composite are largely determined by the type and amount of fibers used, as well as the type of epoxy resin. The mechanical properties like tensile strength, flexural strength, and impact resistance are typically better than those of glass and carbon fibers alone, due to the improved adhesion between the fibers and resin. Similarly, the thermal properties of hybrid composites are better because of improved heat transfer between the fibers and resin, which helps to dissipate heat quickly. In conclusion, Glass Carbon/Epoxy based Hybrid Composites are an advanced composite material with superior mechanical and thermal properties compared to traditional composite materials. The combination of glass and carbon fibers with the epoxy resin offers superior strength and stiffness, as well as improved vibration damping and heat transfer capabilities. As such, this type of composite material is often used in applications that require high-performance mechanical and thermal properties [9]. Hybrid glass/carbon fiber reinforced epoxy composites are a type of composite materials that combines the properties of glass and carbon fibers to create a stronger and more lightweight material. This material has a wide range of applications, from automotive components to structural components in airplanes. The main advantage of this material is its high strength-to-weight ratio and its good fatigue resistance. This material has an excellent stiffness, which means it can withstand large loads with minimal deformation. The combination of glass and carbon fibers also provides good moldability, as it can be easily shaped and formed into complex shapes. The material also has excellent resistance to corrosion and moisture. In terms of mechanical properties, hybrid glass/carbon fiber reinforced epoxy composites have excellent tensile strength and compressive strength. The tensile strength of this material is up to five times higher than traditional steel materials, while the compressive strength is up to three times higher.

The material also has good impact resistance, which means it can absorb impacts without cracking or shattering. Overall, hybrid glass/carbon fiber reinforced epoxy composites are an excellent material for many applications due to their combination of lightweight strength, stiffness, and corrosion resistance. They offer excellent durability, strength, and moldability, making them a great choice for automotive, aerospace, and other industrial applications [10].

Hybrid glass/carbon fibre composites are a type of material that is used widely in the aerospace and automotive industries due to its exceptionally strong properties. The combination of glass and carbon fibres creates a material that has high tensile strength, excellent fatigue resistance, and excellent corrosion resistance. Additionally, this composite material is also lightweight and provides excellent stiffness. In terms of its strength, hybrid glass/carbon fibre composites are renowned for their strength-to-weight ratio, which is significantly higher than that of other materials. This is primarily due to the combination of glass and carbon fibres, which give the material its unique properties. The addition of glass fibres makes the material more resistant to cracking, while the inclusion of carbon fibres increases its stiffness and tensile strength. Furthermore, the strength of hybrid glass/carbon fibre composites is also due to the fact that the two materials are combined in such a way that the strength and stiffness of each material are retained, while the weaknesses of each material are negated. This is achieved by using a process known as ‘fiber-matrix bonding’, which ensures that each fibre is securely bonded to the matrix. In conclusion, hybrid glass/carbon fibre composites are an excellent choice for aerospace and automotive applications due to their exceptional strength, stiffness, fatigue resistance, and corrosion resistance. Furthermore, the combination of glass and carbon fibres provides a material that has a higher strength-to-weight ratio than other materials, while the fiber-matrix bonding process ensures that these properties are retained [11].

Glass/carbon fiber reinforced epoxy hybrid polymer composites are a material developed for use in a variety of applications, from aerospace components to automotive parts. These composites offer a wide range of advantages, including high strength-to-weight ratios, superior corrosion resistance, and excellent environmental durability. When compared to other composite materials, glass/carbon fiber reinforced epoxy hybrid polymers offer enhanced strength and stiffness, thanks to their fiber content.

The fiber content also helps to increase the thermal and electrical insulation properties of the composite, as well as making it more resistant to temperature fluctuations. Furthermore, the use of epoxy resin as a binding agent helps to increase the overall rigidity of the composite and makes it more resistant to chemical attack. These materials are also highly resistant to fatigue, meaning that they are well-suited for use in applications where parts are subject to regular, repeated impacts or vibrations.

In addition, glass/carbon reinforced epoxy hybrid polymers have been found to perform well in environments subject to extreme temperatures, standing up to temperatures as high as 250ºC and as low as -50ºC. Despite these advantages, one of the main drawbacks of glass/carbon fiber reinforced epoxy hybrid polymers is their cost. The high cost of the materials, combined with the labor involved in the production process, means that they may not be the best choice for applications that require low-cost materials. Overall, glass/carbon fiber reinforced epoxy hybrid polymers are an excellent choice for a wide range of applications, offering an ideal combination of performance, strength, stiffness, and durability. While the materials may be more expensive than other composites, the cost can be justified in terms of performance and the long-term savings that can be made through reduced maintenance and repair costs [12]. Nano-indentation is used to measure the mechanical properties of the carbon/glass hybrid composites. Nano-indentation is a powerful tool to measure the hardness, modulus and work of adhesion of materials at the nanoscale. By combining the nano-indentation results with in-situ scanning electron microscopy, in the work it was able to correlate the mechanical properties to the microstructure of the composites. They also performed finite element analysis to simulate the nano-indentation process and compare the experimental results. It was found that the mechanical properties of the carbon/glass hybrid composites are strongly dependent on the graphene content. The increase in graphene content led to an increase in both the hardness and modulus of the composites. It was also observed that the work of adhesion increased with the graphene content. Overall, the article provides an in-depth study of the interfacial properties of carbon/glass hybrid composites via the nano-indentation technique. The work provided a comprehensive overview of the nano-indentation experiment, the results obtained, and the finite element analysis performed. The results of the study will be useful for further research into the development of hybrid composites [13]. In light of the above studies, an organized procedure for experimenting with composites of S-glass and carbon fiber reinforced epoxy thermoset polymer composites in pure and hybrid laminates using the manual laying technique has been prepared. The samples were cut as per ASTM standards for mechanical testing and an attempt to study their mechanical abilities under different loading conditions.

II. MATERIALS & METHODS

2.1 Materials

S-type glass fiber (satin type 195 g/m²) and carbon fiber (twill type 195 g/m²) were used as reinforcing materials are shown in figure 1. A thermosetting polymer matrix material called Epoxy Grade Lapox L-12 with hardener k-6 in a ratio of 100:10 was used to prepare three different laminates. Table 1 shows the developed configurations of the composite materials.

Table 1. Composite Material Configurations

Sl. No	Materials	Material Configurations
1	S-Glass Epoxy Composite	S-E
2	Carbon Epoxy Composite	C-E
3	Hybrid Composite	C-S-E

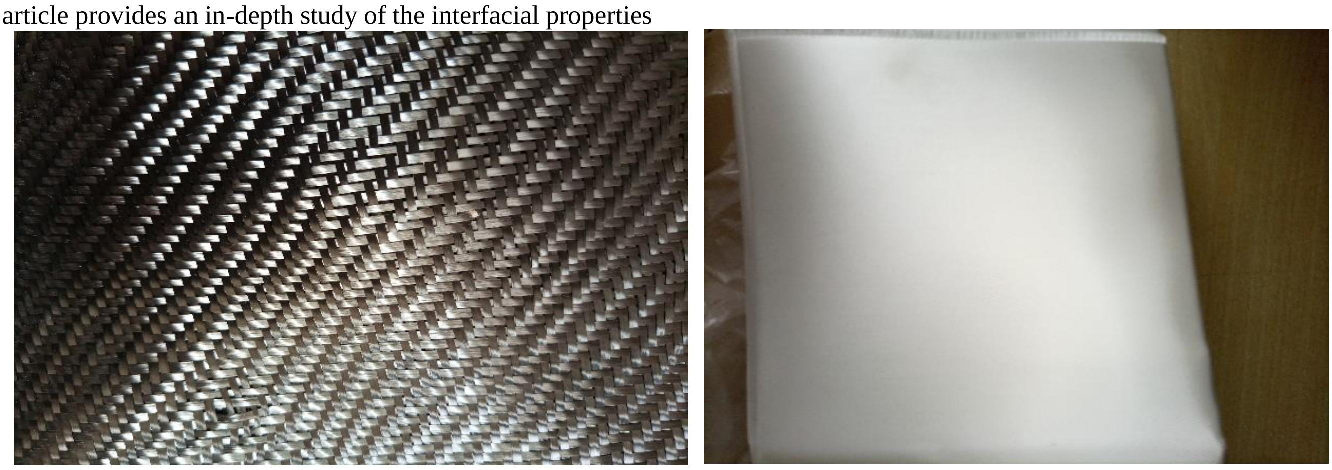

Fig. 1 Carbon & S-glass Fibers

Fig. 2 Lapox L-12 & K-6 Hardener

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2.2 Fabrication Method

The manual laying technique was used in three different combinations as defined in Table 1. Figure 1 shows the fabrication of composite laminates by the hand lay-up technique in line with compression molding using reinforcement materials: s-glass and carbon fiber are shown in figure 1, as it is used as structural reinforcement and a thermoset Lapox L Class -12 polymer matrix with 100:10 hardener with k-6 grade are indicated in figure 2. Samples were cut according to ASTM standards from laminates prepared by water jet grit machining method, and then the samples were dried in an oven as shown in figure 3. Five samples were considered for testing to provide an average value for the test.

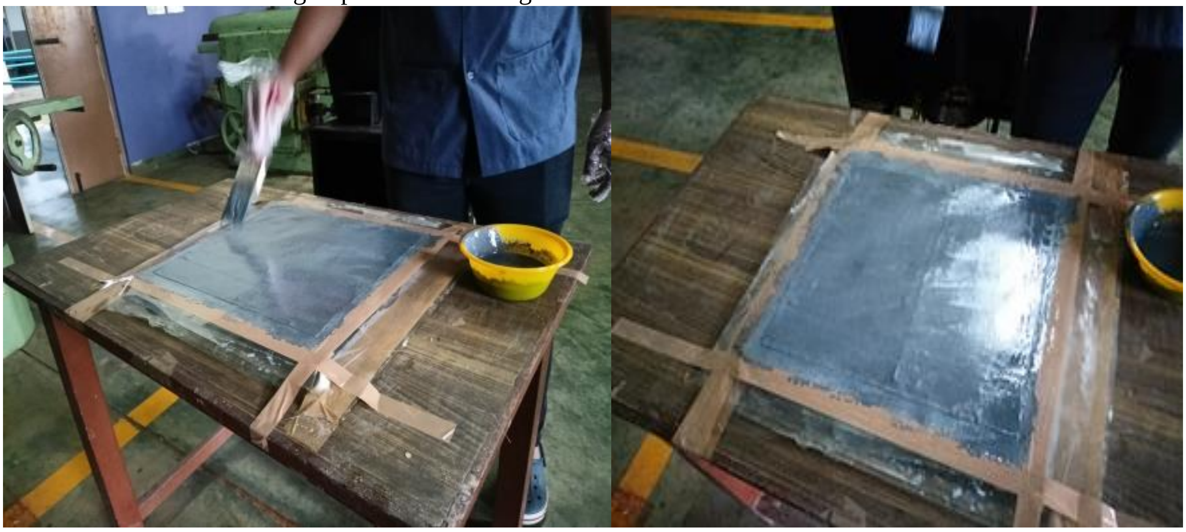

Fig 3. Hand Layup Technique

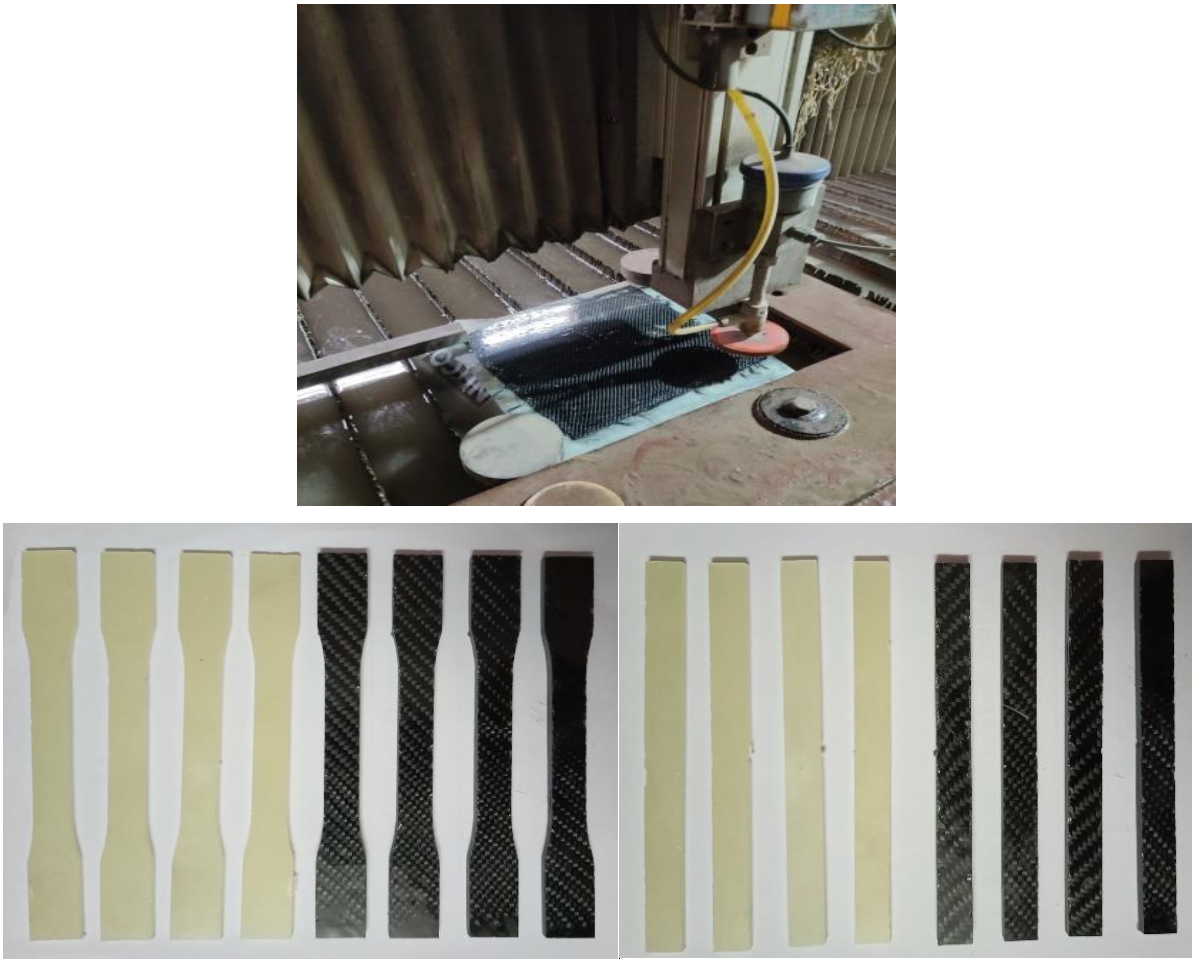

Fig 4. Abrasive Water Jet Machining & Cut Specimens

III. MECHANICAL CHARACTERIZATION

The samples were subjected to different mechanical loads to understand its mechanical behavior as per ASTM standards is shown in the table 2 [14].

Table 2. Mechanical Tests as per ASTM Standards

Sl. No	Test	ASTM Standard	References
1	Density	ASTM D792	[15]
2	Tensile	ASTM D638	[16]
3	Flexural	ASTM D790	[17]
4	ILSS	ASTM D2344	[18]
5	Charpy Impact	ASTM D6110	[19]
6	Izod Impact	ASTM D256	[20]
7	Shore D Hardness	ASTM D2240	[21]
8	Barcol Hardness	ASTM D2583	[22]

IV. RESULTS & DISCUSSION

The test results of the samples that were manufactured by hand layup- compression molding method under various mechanical loads are shown in the table 3. figure 4 indicates the comparison graph of the mechanical characteristics of the composites determines after the tests.

Table 3. Mechanical Properties of Composites

Material Code	Density	Ultimate Tensile Strength (MPa)	Tensile Modulus (GPa)	Maximum Flexural Strength (MPa)	Flexural Modulus (GPa)	Interlaminar Shear Strength (MPa)	Izod Impact Strength (J/m)	Charpy Impact Strength (J/m)	Barcol Hardness Value	Shore-D Hardness Value
S-E	1.30	163.89	10.63	223.66	13.67	14.33	422.10	216.50	29.83	80
C-E	1.23	185.57	12.51	310.45	19.32	16.49	386.70	226.45	30.83	84
C-S-E	1.25	283.30	15.45	374.33	23.21	18.37	428.20	250.90	42.50	86

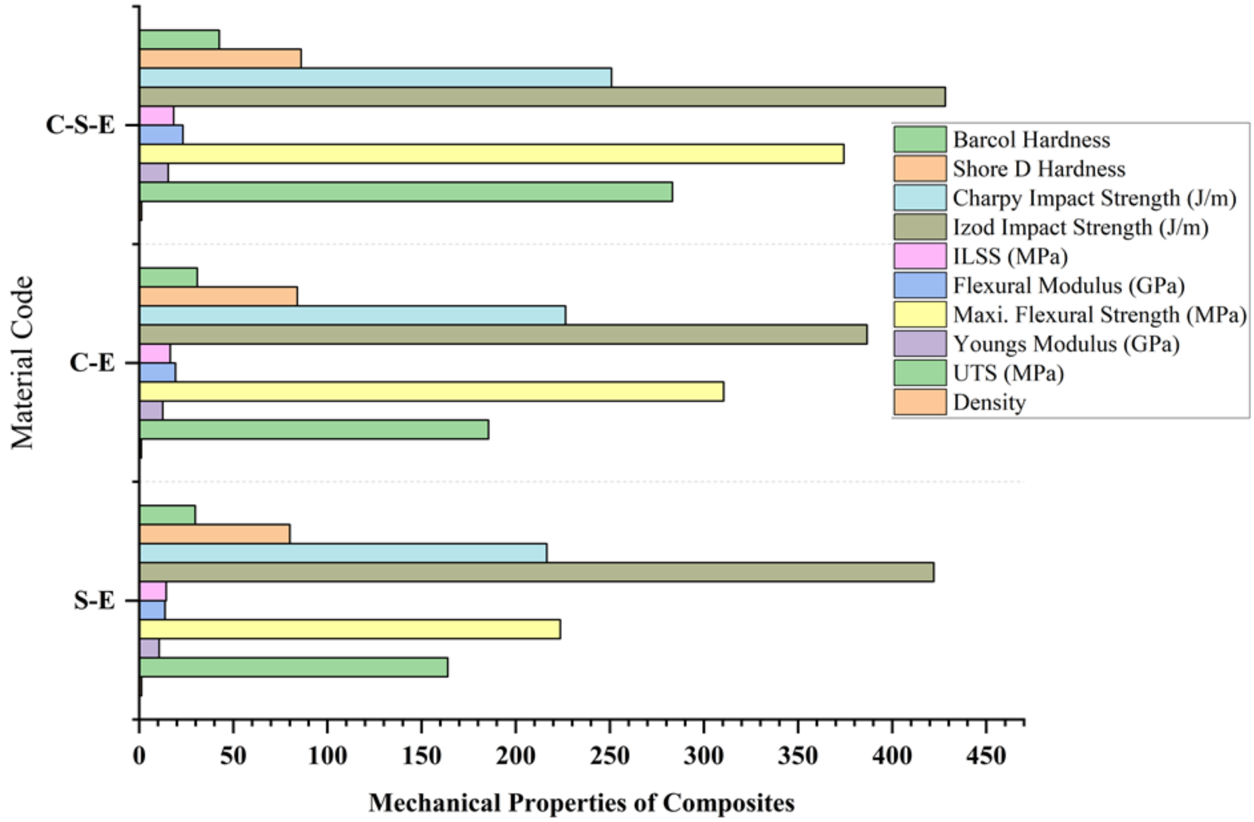

Fig. 5 Comparison of Mechanical Properties of Composites

4.1 Density

Densities of the composites were determined at room temperature as per - ASTM D792 [15] standard method based on Archimedes' law, using density tester & specimens used are as shown in the figure 5. The results obtained showed that the glass-epoxy composites were characterized by a density greater than 1.30 compared to the other composites as shown in the table 3. The density of fiberglass reinforced epoxy composite is higher because s-glass fibers are denser than other fiber types. The higher density of the glass fibers gives the composite a higher density.

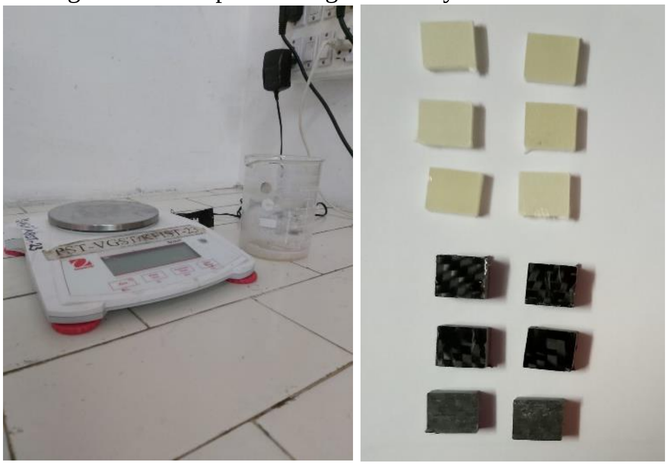

Fig. 6 Density Tester & Specimens

4.2 Tensile Properties

Tensile test was performed, ASTM D 638 [16], maintaining a lateral loading rate at 5 mm/min on specimens with a span of 57 mm using a 100 KN computerized universal testing machine (Kalpak brand) as shown in the figure 5. From the test results shown in Table 3, it is clear that the hybrid composite has superior tensile strength and modulus of 283.30 MPa and 15.45 GPa. The tensile properties of the carbon fiber reinforced S-glass-epoxy hybrid composite results from the combination of two different fiber kinds. Carbon fibers have a high strength-to-weight ratio, while s-glass fibers have high stiffness and modulus of elasticity. From the figure 5, the specimen failure are depicted, these picture shows that the samples under tensile loading conditions failed away from the necking region and also fiber failures are also appearing.

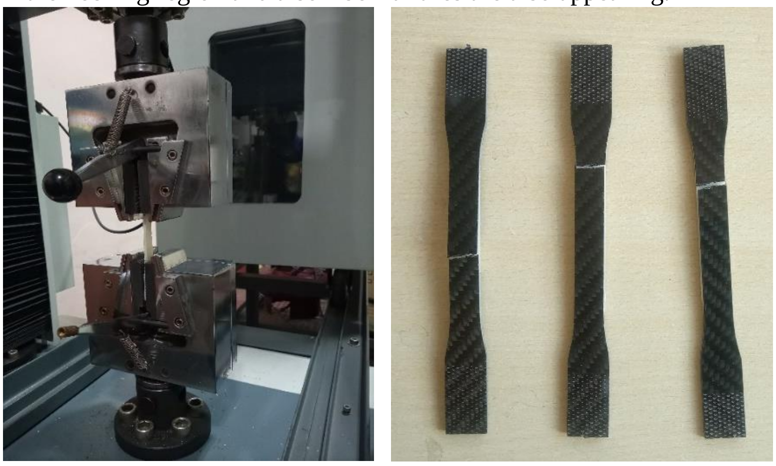

Fig. 7. Specimen under Tensile Test & Failed Specimens

4.3 Flexural Properties

Flexural abilities were evaluated on specimens prepared according to ASTM D790 [17] having a span of 60 mm and subjected to three-point bending with a transverse load of 5 mm/min using a 100 kN universal computerized testing machine (Kalpak Make) is indicated in the figure 6. Table 3 shows that the maximum flexural strength of the hybrid is 374.33 MPa and the flexural modulus is 23.21 GPa. Carbon fiber/s-glass reinforced epoxy composites have higher flexural strength and flexural modulus due to the high strength and stiffness of the fibers used in the assembly of materials in their construction. The fibers used in these composites are much stiffer than traditional glass or plastic fibers, allowing them to withstand a three-point bending load when applied. Figure 6 also shows the failure of the samples and has better resistance to the load.

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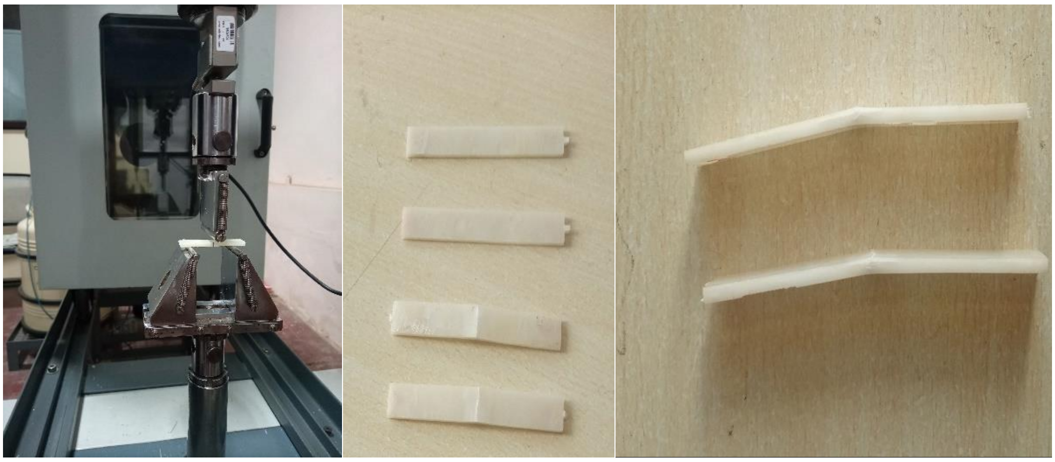

Fig. 8. Specimen under Flexural Test & Failed Specimens

4.4 Interlaminar Shear Strength Property

Interlayer shear strength is an important property of fiber reinforced epoxy composites as per ASTM D2344 [18]. It is a measure of the strength of the bond between the layers and determines the overall strength of the composite. The interlayer shear strength of the hybrid composite obtained after the test was 18.37 MPa (table 3), higher than that of the other composites tested. The interlayer shear strength property of S-glass carbon reinforced epoxy composites is higher because carbon fiber offers a higher level of stiffness and strength than S-glass. Carbon fiber also has a higher modulus (stiffness) than glass fiber.

4.5 Impact Response

Impact strength of composites were tested in impact tester as shown in the figure 6, it is significant because it determines the amount of force the composite can withstand without cracking or failing. Impact resistance is an important property of all materials used in engineering applications as it affects a part's structural integrity and its ability to withstand dynamic loads. The impact test was performed according to two different standards, according to ASTM D256 [20] and ASTM D6110 [19], which correspond to the conditions of the Izod impact test and the Charpy impact test. Table 3 shows the Izod impact strength and the resistance to Charpy impacts of the hybrid composite with impact values of 428.20 J/m and 250.90 J/m is higher than other composites. The Izod and Charpy impact strengths of S-glass carbon fiber reinforced hybrid epoxy composites are higher because the fibers act as a reinforcing agent and add additional strength to the composite. The fibers are directional, providing extra strength in specific directions. From the figure 6, it is shown that fibers also act as a barrier to crack propagation, increasing the impact strength of the composite. In addition, glass fibers have a higher modulus of elasticity than carbon fibers, which means more energy is absorbed on impact.

Fig. 9. Specimen under Impact Test & Failed Specimens

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4.6 Hardness Property

Hardness testing of composites is conducted to evaluate the mechanical abilities of the material ability towards wear, abrasion and impact resistance using shore d and barcol tester as shown in the figure 7. Hardness testing can also help determine a composite's relative strength and suitability for specific applications. Hardness testing is a quick and easy way to assess the quality of a composite and can provide engineers with valuable information when designing components that require a high level of performance. The Barcol hardness rating of the hybrid is 42.50 (Table 3). The Barcol hardness according to ASTM D2583 [21] value of S-glass carbon fiber reinforced epoxy hybrid composite is high due to the grouping of the high strength and stiffness of carbon fiber and the good strength of S-glass fiber. The combination of these two materials results in a strong, stiff and tough composite, resulting in high Barcol hardness. The Shore D value of 86 for the hybrid composite (Table 3) is slightly higher than for the other samples. The Shore D hardness test as per ASTM D2240 [22] , is meant for testing the hardness of a plastic/or other material by measuring the depth of an indentation made with a diamond indenter, thus the hardness value of S glass-carbon fiber reinforced epoxy hybrid composite is high because of the presence of hard carbon fibers. Carbon fiber has a much higher modulus of elasticity than S-Glass, meaning it can withstand greater forces before deforming. This makes it ideal for use in composites as it offers increased stiffness and strength without sacrificing weight. The combination of these two fibers creates a material with excellent mechanical properties and high Shore D hardness.

Fig. 10 Shore-D & Barcol Hardness Testers

V. CONCLUSION

Composites with different material configurations were developed using the traditional technique of manual placement in a die to ensure even load distribution on the laminates, eliminating air pockets or air bubbles created during manufacturing, leaving the laminates with a constant thickness throughout when measured the surface. Samples were machined to ASTM standards to ensure mechanical testing was performed according to test conditions. The results of different mechanical tests were collected and analyzed from which the following conclusions were drawn.

1. The density of s-glass-epoxy composites was higher than other composites due to the denser glass fibers used in the composite.
2. The hybrid composite exhibited excellent tensile strength and modulus due to the amalgamation of two different fiber types.
3. The flexural properties of the carbon fiber reinforced S-glass-epoxy hybrid composite were superior mainly by the high strength and stiffness of the fibers used in its construction.
4. The ILSS of carbon-reinforced S-glass-epoxy composites has been improved, with carbon fibers offering higher levels of stiffness and strength than S-glass.
5. The hybrid composite's Izod and Charpy impact strengths were higher than other composites because the fibers act as reinforcing agents and provide additional strength to the composite.
6. The Barcol hardness and Shore D value of the hybrid composite with S- type in line with Carbon were high by the presence of hard carbon fibers and the combination of two different fibers creating a material with excellent mechanical properties.

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Availability of Data and Material/ Data Access Statement	Not relevant.
Authors Contributions	All authors have equal participation in this article.

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