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***Research Article***

# Mechanical Specification Review of Composite Materials and its Applications

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**Abstract**
Composite material have become popular in aviation ,automobile ,marine, and civil structures due to their balanced mechanical properties within the fabric plane and great formability .the mechanical static tensile strength, flexural strength ,hardness and impact strength are required to get variant mechanical properties substantial for design of composite mechanical parts according to the corresponding application .In this work, a review of these mechanical tests is introduced with support of references, test standards and methodology.

## 1. Introduction

Polymeric materials are now widely used in a wide range of applications. It has unique qualities and can be customized to meet our daily technological requirements. Long chains and enormous molecular weights make up polymers [1] Polymers have a skeletal structure that varies from one to the next, and they are linear in nature. Polymers A chain with two ends is included. Cyclic polymers lack chain ends and have characteristics that differ from their linear counterparts. Side chains are present in branched polymers, which can be identified by the number and size of branches. Three-dimensional network polymers have a three-dimensional structure. When compared to linear polymers with comparable chemical compositions, cross-linked polymers appear to have radically distinct properties [2]. The polymer is chosen based on the type of application and mechanical qualities necessary in everyday life. Many external forces, such as pressure, tension, vibration, and other external variables, may affect it. The chemical makeup of the polymer, as well as its molecular weight, molecular weight distribution, degree of branching, and degree of crosslinking, all influence its mechanical qualities. The capacity of the polymer to crystallize, as well as the size

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and distribution of the crystals in the bulk of the polymer, have an impact on its mechanical properties[3]. Researchers have discovered that by copolymerizing different monomers into the polymer chain, it is possible to modify the mechanical properties of the polymer chain. For economic reasons or to increase mechanical qualities, it is now usual to add fibers or solid particles to polymers[4]. The mechanical properties are also affected by the test techniques and factors, such as the applied forces, which can be tension, compression, biaxial, or shear [5]. Nanotechnology is used to improve the mechanical properties of polymers.

## 2. Polymer Composite Material

Since weight is a concern, the weight of composites must be reduced in applications and in all industries to reduce reliance on heavy traditional materials and achieve improved efficiency. Polymer composites outperform traditional materials like metals and alloys in terms of strength, heat resistance, toughness, and abrasion resistance while also being lighter. In terms of design and manufacture, they are also more adaptable. Plastic and composite materials are increasingly being used in the automotive industry for nonstructural purposes. Composite components that are light in weight can be useful.

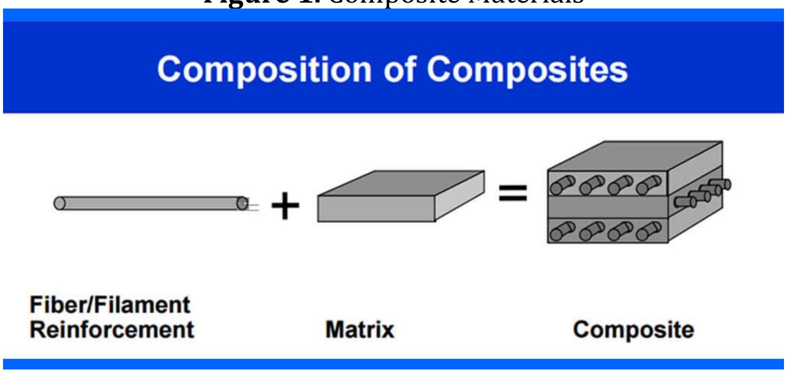
Automobiles will have better fuel efficiency and cheaper costs as a result of this research[6][7].

The volume/weight percentage of reinforcement, the L/D ratio of fibers, orientation angles, and other parameters all affect the strength of a composite[8]

Composites with glass, carbon, and aramid fibers, hybrid composites – Fiber Metal Laminates, and laminates with metal and ceramic matrix are the most often utilized materials. They are predicted to perform admirably not only mechanically, but also thermally, as high-speed movement necessitates[9].

Increasingly turning to high-performance polymer composite materials for tough-to-work-with applications. To ensure safety and economic efficiency, the materials must have distinctive mechanical and tribological qualities, as well as a low specific weight and great resistance to degradation[10].

**Figure 1.** Composite Materials



## 2.1. Epoxy

Epoxy resin is a type of thermosetting resin that has been reformed after solidification due to the creation of long polymeric chains that are entangled with one another. Cross-linking occurs when two or more groups of (crosslinking) are present in an epoxy resin.[11]

Epoxy resin is chemically resistant and has a high hardness. Furthermore, this resin has a high adhesive strength due to its chemical composition, which includes ethers, hydroxyl groups, and polar groups, which provide high adhesion strength as well as materials hardness and strength, making it ideal for high-functioning applications. During processing, these resins react with the hardeners, causing a small volume shrinkage (less than 2%), and the resin gains exceptional strength and mechanical qualities. Furthermore, because to the spacing between synapses and the presence of integrated elephant chains, the cured epoxy resins have a high endurance.[12].

## 2.2. Fiber

The fundamental benefit of fibre-reinforced composites is that they provide materials with high strength and modulus that are comparable to or better than many conventional metallic materials. Because of their reduced specific gravity, strength-to-weight ratio, and modulus-to-weight ratios, these composites outperform metallic materials. In addition, many composite chips have good fatigue ratios, weight, and the ability to endure fatigue damage.[13][14].

### 2.2.1. Glass fiber

Since the 1940s, fiberglass-reinforced polymers have been in use. Glass fibers are one of the most frequent reinforcing fibers in polymeric matrix composites (PMCs).

Glass fiber is a widely utilized material in a wide range of applications, including car bodywork, thermal and electrical insulation, sports equipment, household items, and a number of industrial applications. [15]

Fiberglass is less expensive than carbon fiber in terms of production costs.

Blending other fibers with glass fibers to generate a hybrid compound with unique properties that may be employed in a range of applications is important to keep the cost of fiber-reinforced materials in industrial applications low. Furthermore, because fiberglass is a robust and durable material, hybridizing it will result in cost savings as well as increased physical strength.[16][17]

**Figure 2.** Glass fiber

## 2.2.2. Carbon fiber

In commercial manufacturing, carbon fiber (CF) reinforcements for polymer matrix composites are used. For a wide range of potential applications, CF is the material of choice, notably in the mechanical engineering, aerospace, and automotive industries. It is perfect for usage in composite materials due to its excellent characteristics.

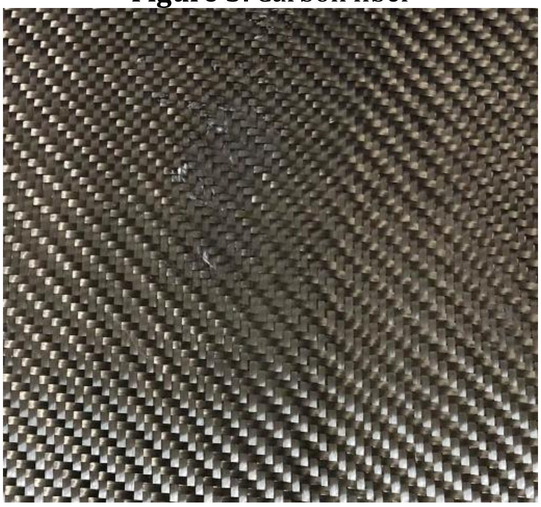
In addition to outstanding specific strength and stiffness, high thermal stability, conductivity, and wear resistance, the performance-to-weight ratio[18], [19]

CF-reinforced polymer compounds are used. Turbine applications in automotive and space fuel cell power systems, offshore - deep sea drilling rigs, turbochargers, and efficiencies

Storage and transit of compressed and antistatic gases, machinery and materials for electromagnetic protection [21].

Although regulating the characteristics of the fiber/matrix interface remains a critical difficulty, changes in the CF structure have greatly enhanced the mechanical properties of high-performance polymer composites.[22].

**Figure 3.** Carbon fiber



## 4. Hybrid Material

Better stiffness and strength can be achieved by combining two or more types of fibers into a single polymeric matrix (also known as a hybrid composite). In hybrids, certain types of fiber are typically employed. Fiberglass and Kevlar, for example, have a low modulus and/or cost, whereas others have a high modulus and/or cost. For example, boron and carbon fibres have a high modulus and/or a high cost.

Hybridization can provide a composite with high hardness and strength while also improving impact and fatigue resistance, increasing fracture toughness, and lowering overall weight and cost.[37] [38].

Reactive knitting (where layers of one fiber are sewn with another type of fiber) are all examples of hybrids.[39].

### 4.1. Hybrid composite for structural application.

The majority of composite structures and parts utilized in difficult applications are fiber reinforced composites. Hybrid composite materials have been developed and used in a greater range of applications in the building and engineering industries over the last decade. This is because hybrid vehicles meet the demand for cheaper operating, maintenance, and construction costs while still meeting performance standards in terms of scope, power, payload, and stability, according to researchers. Because of their outstanding qualities, composite materials are frequently used in new technology industries. Hybrid vehicles have shown to be a success in the aerospace business due to their high hardness, strength, chemical resistance, and corrosion resistance efficiency for the money. Acceptance of its capacity to meet the demand for high stiffness in applications like aviation composite structural parts has grown. Composite stiffness can be calculated using material characteristics values obtained from standard material properties tests.[40].

## 5. Mechanical Properties

The general and engineering uses of composite materials rely on to a significant level their mechanical and physical properties such as resistance to the tensile strength, flexibility, elongation of the material, its resistance to heat and environmental conditions such as moisture, sunlight, etc.

Other application features. All of these properties depend very much on the molecular structure and molecular weight of the resin and the intermolecular forces [41] These properties also depend to a large extent on the stiffeners and on additives such as fillers and plasticizer Among the properties that have been studied are:

### 5.1. Tensile strength

Tensile strength is a measure of a material's ability to resist static forces trying to pull and break the material. Material consist a fibrous composite of strong, brittle fibers immersed in the more ductile substrate[13].

### 5.2. Impact resistance

Impact resistance expresses the ability of a material to resist breakage under the influence of a sudden load. It is also considered a measure of a material's durability.

The most durable are the ones with the highest shock resistance[12]

### 5.3. Flexural Strength

This characteristic is a measure of the flexural strength, and can be defined as the maximum static load that can be applied to a model, The test before it undergoes or breaks and is measured in units (MPa) [42].

### 5.4. Hardness

He defined hardness as the resistance of a material to scratching or penetration, and there are several different international standards to determine the hardness of materials. The most common plasticizes are Brinell hardness and Rockwell hardness[43].

## 6. Mechanical Testing

### 6.1. Tensile Examination

This *Examination* was used to determine the properties of a load on a composite material .Composite samples were machined following the (ASTM D3039) standard[29] with dimension( 250 *25*4)$mm^3$ .

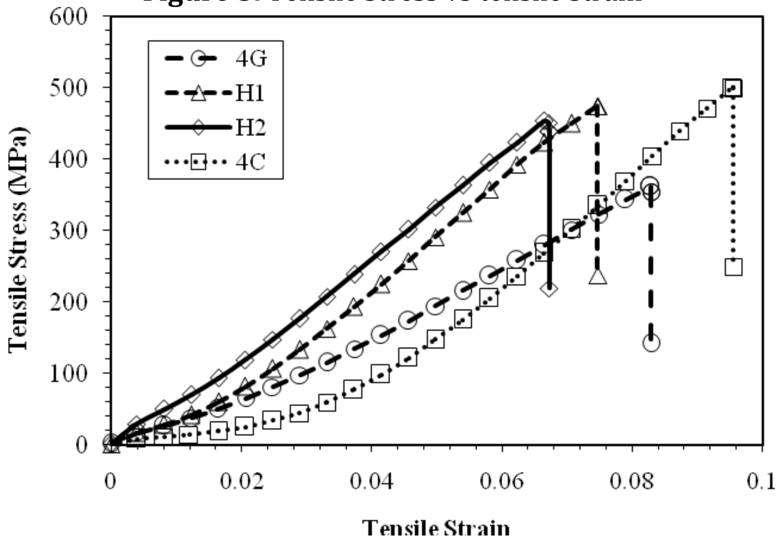
The test was performed at lab temperature 24 C using a tensile testing equipment (WDW- 200 KN) as illustrated in Figure (4). The stress was applied continuously at a constant rate of (2mm/min) until the specimens failed. The computer software that came with this machine was used to determine the tensile stress-strain relationships, as well as the tensile modulus and strength of composite materials. Each type of model was subjected to three tests, with the average value taken into account.

**Figure 4.** Tensile testing instrument

(Murugan,et.al 2014)[46] Investigated mechanical properties of static composite material in the Figure 2 depicts the stress-strain curves of woven fabric composites with four different layer sequences.

The dedicated carbon laminate configuration, 4C, has the highest stress. As expected, there is a significant tensile strength difference between dedicated 4G glass and dedicated 4C carbon beams [47][48]. This is owing to the great tensile resistance provided by high modulus carbon fiber. The tensile modulus of hybrid laminates varies, as indicated in Table 2. The slight difference in tensile strength was produced by the change in strain between the glass and carbon layers, despite the fact that all four layers of the hybrid laminate were equally loaded. Kedar et al [49] have found that a hybrid laminate with a glass layer on the outside and a carbon layer on the inside has a better strength.

**Figure 5.** Tensile stress vs tensile strain




(Al-Mosawi 2009)[11] When it comes to fiber reinforcing, this property will be much improved, as the fibers will bear the majority of the loads. , as a result, the composite material's strength will be greatly increased. The tensile strength of the resin will rise as the proportion of fiber added increases, because the fibers will be spread over a vast area in the resin.

## 6.2. Test of Flexural Strength

The three-point test method was used to determine flexural strength. A multi-purpose hydraulic press is used for this. The test form is in the middle. The flexural properties of the composite specimens were determined using a three-point bending test. . All composite specimens were machined in accordance with ASTM D790.[15] The composite specimen dimension was 128 x 12.7 x 3.5 mm3. The device of test is shown in Figure (6). The span length should be 32 times the sample thickness, according to ASTM D790. The shear deformation impact can be decreased or even removed by increasing the specimen's span to depth ratio, while the bending moment is the sole cause of the outer surface loss. As a result, it is possible to determine the elastic modulus values with greater precision. Using a flexural testing head and a tensile test machine, the load was applied at a constant rate of (5mm/min) until the specimens failed. The final results of flexural strength and flexural modulus were taken from the average of three replications. When the span-to-depth ratio of the specimen surpasses 16, considerable end forces and broad deflection are produced. To account for the relatively significant deflection, the flexural stress calculation includes an approximate correction factor. Equation can be used to calculate flexural strength.[15]

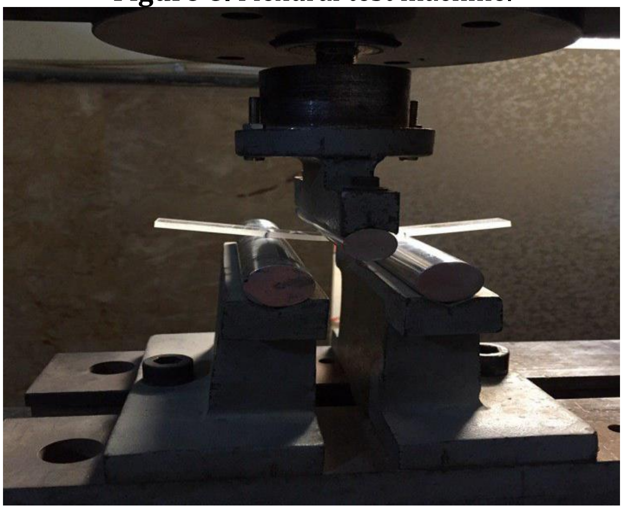
$$\text{Flexural strength} = 3FL / (2bh^2)$$

The flexural modulus can be calculated from the load-deflection curve as per equation equation [15]

$$\text{Flexural modulus} = (L^3 m) / (4bh^3)$$

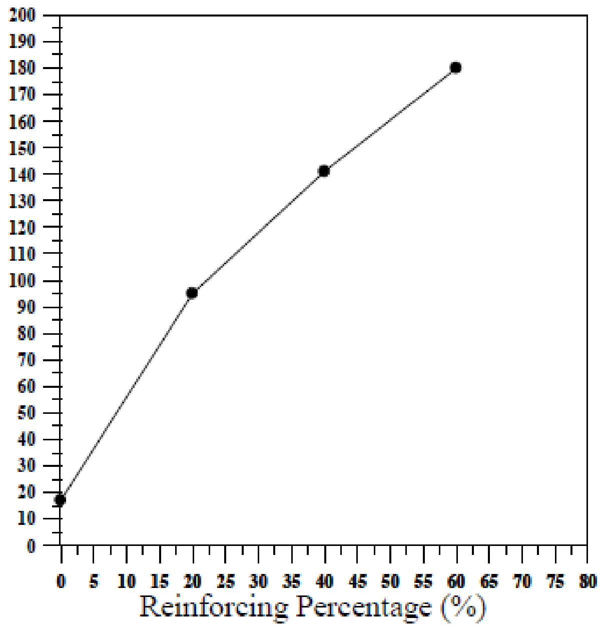
Here, F is the maximum load (N), L is the width of the support span (mm), b is the width (mm) of the specimen, h is the height (mm) of the specimen,(m) the slope of the tangent to the initial straight-line portion of the load-deflection.

**Figure 6.** Flexural test machine.



Al-Mosawi (2009)[11] investigated the mechanical properties of polymer matrix find the resin is fragile, its flexural strength before reinforcing will be minimal. However, after adding the fibers to this resin, the flexural strength of the generating material will be increased because the high modulus of elasticity of these fibers will assist in carrying a huge amount of loads while also increasing the strength.

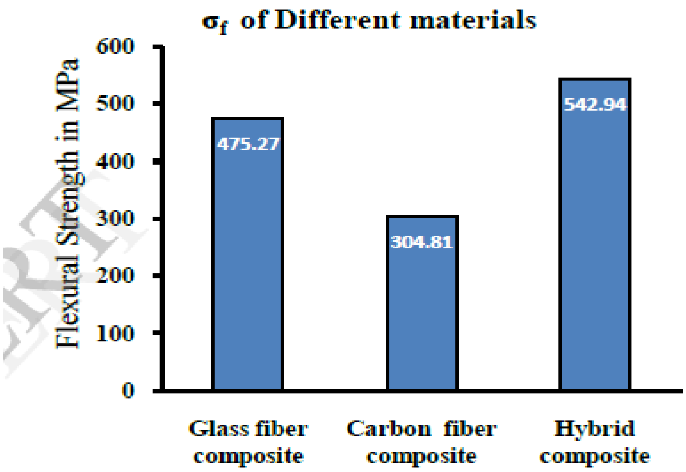
**Figure 7.** Flexural strength versus Carbon – Kevlar reinforcing percentage




Pérez -Bustamante et al. (2014) [50] According to the experimental results, the percentage difference in flexural strength for 0-90° and -45+45° orientation fiber f mm thick sample is 16.36, and for 6 mm thick sample is 32. As a result, we can deduce that fiber does have an impact.

Turla et al (2014) [51] The filament winding approach was used to successfully Three different composite materials are processed: glass and carbon fiber reinforced epoxy matrix hybrid composite, glass fiber reinforced epoxy matrix composite, and glass fiber reinforced epoxy matrix composite. , and carbon fiber reinforced epoxy matrix composite. In comparison to the other two materials, hybrid composite has a much higher flexural strength. As a result, the glass and carbon fibers had a significant impact on the composite. This feature of hybrid composite makes it obvious that it is appropriate for structural applications such as aircraft. Glass fiber reinforced composite has a much better flexural strength than carbon fiber reinforced composite. This is owing to carbon fibers' brittleness, despite their strength. Maximum tensile strength with high values.

**Figure 8.** Different types of composite material




## 6.3. Hardness test

The hardness test models are manufactured as circular discs with a diameter (25 mm ) thick (10 mm).

The Brinell method was used Calculation of the hardness of a composite material, where a steel ball is used The specimen is prepared according to the ASTM E10 To calculate the hardness of the composite material, (Brinell Hardness) will be used, where a steel ball of 5 mm diameter, with applied load 10 kg, for 15 sec. then removing the load and calculating the diameter of the effect on the surface of the sample. The hardness values can be extracted from the following relationship:

$$HB = \frac{P}{\left(\frac{\pi \times D}{2}\right)\left(D - \sqrt{D^2 - d^2}\right)}$$

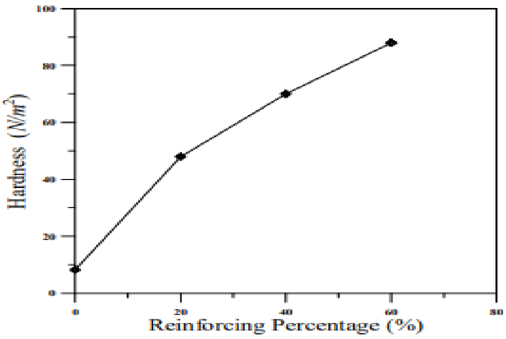
*HB= Brinell hardness (*Kg/mm$^2$ )

P= dominant force (kg)

D= Test ball diameter (mm)

d= The resulting impact drips onto the surface (mm)

Ali- Mosawi (2009) [11] Hardness: Plastic materials have a low hardness in general, with the lowest value for araldite resin before reinforcing shown in figure(6). However, the value of hardness will be substantially raised.



Fig(6): Hardness

Swapnil et al. (2017) [52]Mechanical characteristics of glass fiber/epoxy composite materials were examined with different fiber volume fractions in the composites. In the entire composition, the volume proportion of fiber is maintained at around 40%, 50%, and 60%. Experimental testing is used to determine mechanical qualities like as hardness determined. The relationship between these qualities and the volume fraction is investigated. The results reveal that with 50% of the volume fraction, the mechanical qualities are improved; nevertheless, increasing the volume fraction further improves the mechanical properties.

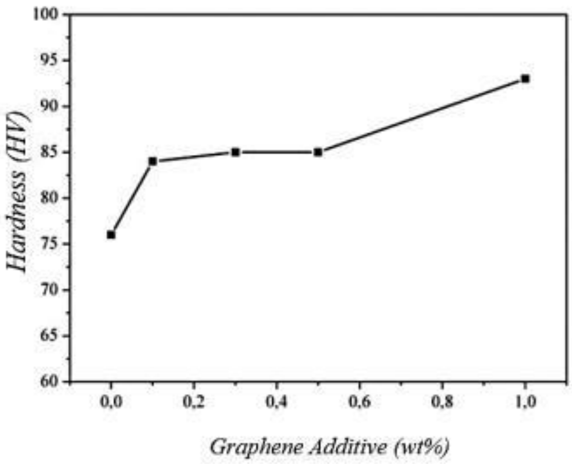
Although increased fiber content improves mechanical qualities, composites begin to delaminate. As a result, we were able to get the material with a 50:50 split in the end.

Babanli et al. (2021) [53] In these studies that the use of graphene in the composite structure improves the mechanical properties of the composite. It was discovered that the amount of graphene reinforcement employed in the composite structure ranges between 0.1-3 percent by weight, and that after 0.5 percent by weight, the composite structure becomes unstable.

Graphene has a tendency to cluster, resulting in undesired secondary phases.

Al4C3 is one example [54] [55] while the hardness increases with the increasing amount of GNT. It was determined that by using 1% GNT by weight, the hardness value increased up to about 94

However, after 0.5%, the probability of formation of the Al4C3 phase increased depending on the increasing amount of graphene. Therefore, the composition most studied in the literature are 0.3% and 0.5% by weight graphene reinforced aluminum composites.




### 6.4. Impact test

The impact tests were carried out using a Charpy impact tester (Gunt Hamburg Co. /WP400) as indicated in Figure (10). The ISO 179 2010 standard [56] was used to process all of the samples. Figure 1 shows the dimensions of the composite sample, which were 55 x 10 x 3.5 mm3 without a notch. A hammer with a weight of 2.05 kg was attached to the pendulum, and the sample was supported on each side of the Charpy impact tester. When the pendulum is released, its potential energy is converted to kinetic energy, and it hits the middle of the sample with a velocity of 3.8 meters per second. The sample is broken with some of this kinetic energy. The energy meter, on the other hand, measures the amount of energy that has been absorbed.

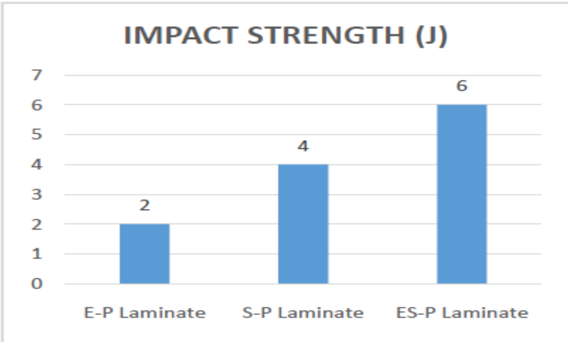
Impact strength can be calculated from the following relationship [57]

**Figure 9.** Impact test machine (Grunt WP-400 testing machine).

$$G_c = \frac{U_c}{A}$$

Avanya et al. (2013) [58] The impact resistance will continue to improve as the percentage of glass fiber reinforcing is increased. Due to the brittleness of these materials, impact resistance is deemed low for resins, although The impact resistance will be strengthened once it is reinforced with glass fibers since the fibers will transport the majority of the impact energy that is emitted on the composite material.

**Figure 10.** The variation in Impact strength with the glass fiber

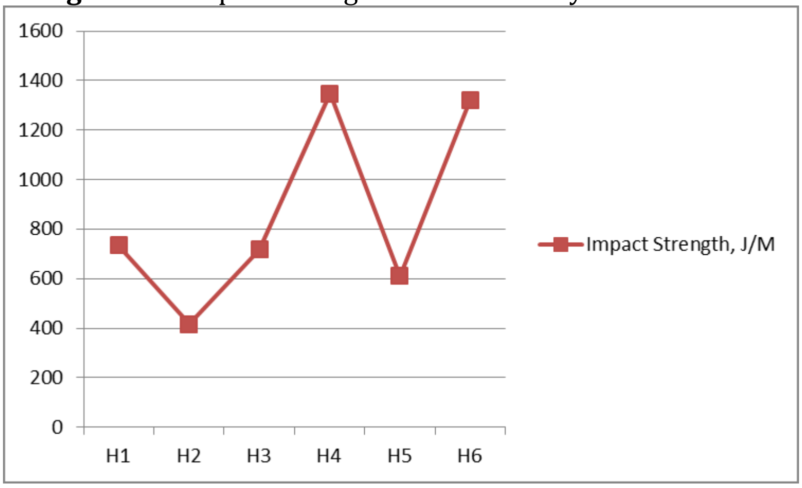



Vinay et al. (2018) [59] The following conclusions can be formed based on the evaluation of experimental results and discoveries: This work shows how a multilayer hybrid composite (with vinylester as the lattice, carbonfiber, glass fiber, and kevlar fiber as the support material) can be produced using a hand lay-up process, with laminates made up of twelve layers of fibres. On hybrid composites, static and dynamic mechanical behavior was studied. H4 Except for inter laminar shear strength, hybrid fibre has higher impact strengths than other hybrid fibre.

Table1.Sample and Orientation of Hybrid Fiber Laminates

| Name of the Sample | Orientation of Fibers 0° | 90° |
|---|---|---|
| Hybrid 1(H1) | Glass | Carbon |
| Hybrid 2(H2) | Carbon | Glass |
| Hybrid 3(H3) | Kevlar | Carbon |
| Hybrid 4(H4) | Carbon | Kevlar |
| Hybrid 5(H5) | Kevlar & Carbon | Glass & Carbon |
| Hybrid 6(H6) | Glass & Carbon | Kevlar & Carbon |

**Figure 11.** Impact strength for different Hybrid materials




## 7. Conclusion

In light of their common quality about weight ratio and superior hardness, FRP composites perform much better than many common metals.

The tensile failure stress, bending strength, impact strength, and damping ratio of epoxy matrix reinforced with glass fibers are higher, while those reinforced with carbon fibers have higher tensile strength, modulus of elasticity, and flexural modulus, the mechanical properties values increase with the increase of the volume fraction of fibers as well as the orientation of the fibers has an effect Big on those characteristics.

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