Mechanical Characteristics of FRP Composites Using Natural Fibres (Pineapple)

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Abstract - As a sustainable replacement for synthetic materials like glass, aramid, and carbon, researchers are looking more and more into using natural cellulose fibres in polymer composites. In addition to being inexpensive and lightweight, these composites are biodegradable and renewable. Nevertheless, they encounter difficulties such as inadequate wettability, moisture absorption, and inadequate adhesion between the fibre and matrix. To address these issues, a study focuses on developing a fibre reinforced polymer (FRP) composite using pineapple fibre and glass fibre as reinforcement materials and epoxy resin as adhesive. The mechanical characteristics of this composite will be tested by optimizing the material combination. The composites have potential applications in various industries, including automobiles, structural and construction and household components. This current research studied about the FRP composite which developed using combination of natural and synthetic fibre and experimented its mechanical behaviour. Synthetic E-glass fibre and natural pineapple fibre have chosen as reinforcement and epoxy resin as matrix for proposed FRP. Experiments of tensile, impact and flexural tests to be carried for different material combination. According to the tests, specimen 2 can withstand 188.055 MPa and 1787.109 GPa at a peak load of 521.539 N. In contrast, specimen 1 has a higher ultimate tensile strength and grater elongation of 57.094 N/mm2 & 2.79% respectively at a peak load of 4453.083 N making it the perfect choice for applications requiring high impact strength.

Keywords: FRP Composites, Natural Fibre, Synthetic Fibre, Mechanical Characteristics, Experiment.

I. INTRODUCTION

Engineers nowadays are looking for less expensive structural materials with low density, high strength, stiffness, resistance to abrasion and impact, low thermal expansion, and resistance to corrosion. Composite materials are created by mixing two or more distinct materials in order to meet the aforementioned parameters. Because they are inexpensive and environmentally beneficial, natural fiber composite materials find extensive usage in a variety of technical domains. In this paper we could form a new composite material with the natural fibers as Palm fruit & Sisal fiber. A composite material is one that has bulk characteristics that are substantially different from those of any of its elements and is made up of two or more separate phases, such as a matrix phase and a reinforcing phase. Despite having a small number of dispersed phases in their structures, many common materials (metals, alloys, doped ceramics, and polymers mixed with additives) are not regarded as composite materials because their properties are similar to those of their constituents (for example, the physical properties of steel are similar to those of pure iron). High strength and stiffness, low density, high temperature stability, high electrical and thermal conductivity, tunable coefficient of thermal expansion, resistance to corrosion, enhanced wear resistance, and other favorable qualities are characteristics of composite materials.

In 2020, Megahed et al. investigated the mechanical properties of low-cost hybrid fiber metal laminates (FMLs) made of aluminum 1050 alloy and jute/glass fiber reinforced epoxy composites. It looks at the effects of fiber amounts and stacking order. The findings demonstrate that jute fabric-based FMLs can have better tensile and flexural characteristics through reinforcement hybridization. Replacing partial laminas from jute/epoxy laminate with glass/epoxy laminas improves the flexural strength.

Deeban et al (2023) Conducted an experimental 10 study in which they hybridized two plant fibers derived from leaves, and the composites were created using a manual lay-up technique. The composite's mechanical strength was enhanced by 3.59 kN as a result of the hybridization of sisal and pineapple leaf fiber (PALF), with a decrease in flexural strength and an increase in compressive strength.

Babu et al (2023) Striving to making of pineapple leaf fiber epoxy reinforced in three different orientations unidirectional, bidirectional, and 45° inclined is the main goal of this paper. Every orientation of e-glass fiber is added in order to track any changes in strength. The composites are created using the Hand Layup technique. The composites are put through the Tensile Test and the Flexural Test. When E-glass is combined with composites, unidirectional fibber's tensile strength increases. The unidirectional pineapple fiber composite made of E-glass exhibits the maximum tensile strength. Ramakrishnan Muthuraja et al. (2022), Pineapple and glass fibre reinforced vinyl ester hybrid composites were made by hand lay-up processes, and their mechanical characteristics were investigated. Glass fibre addition changed the properties; hybrid composites containing 19 weight percent glass fiber and 21 weight percent pineapple fiber showed the highest degree of mechanical properties. When it came to performance, skin core type composites outperformed scattered type composites.

As a sustainable and environmentally beneficial substitute for conventional natural fibres, Mahmud et al. (2022) investigate the usage of pineapple leaf fibre combined with a viscose composite. Epoxy resin reinforcement provides stability to the composite, which has a 1/1 plain wave pattern. Tensile strength, Young's modulus, and elasticity tests were performed on the composite. In 2020, Jagadish et al. conducted an analysis focusing on the northeastern area of India, analysing the mechanical properties of short fibre reinforced polymer composites manufactured using pineapple leaves.

Praveena et al. (2022) concentrates on employing silane treatment to enhance the characteristics of polyester composites produced from pineapple leaf fibre (PALF). The objective of this study is to examine how natural fibre composites (NFC) function when exposed to silane-treated PALF with different fibre lengths. The impact, flexural, tensile, and wear rate of the composites were all examined. The mechanical characteristics of thermoset composites reinforced with pineapple leaf fibre as a substitute for above-knee glass fibre reinforced prosthetic sockets are examined by Odusote et al. (2016). The composites are mixed with epoxy and polyester at different fibre loadings after being treated with sodium hydroxide and acetic acid. Glass fibre polyester composite (GFPC) and pineapple leaf fibre polyester composites (PLPC) and pineapple leaf epoxy composites (PLEC) were tested for mechanical qualities.

Rafiquzzaman et al (2017) conducted a study on the fabrication and mechanical performance of a pineapple-glass fiber-based polymer composite. In this formulation of the composite, the matrix consisted of epoxy resin (ADR 246 TX) with glass and pineapple fibers serving as reinforcement. Bangladeshi consumers can get pineapple leaf fiber extract. By employing manual layup procedures, the composite is fabricated. The composite is constructed using varying fiber volumes (0%, 5%, 10%, 15%, and 20%). In this 2019 study, Santosh et al. investigate the mechanical characteristics of polyamide film (PALF) and the variables that affect such characteristics, such as fibre length, variety, orientation, matrix type, voids, and porosity content.

II. OBJECTIVE

Composite materials are becoming more and more necessary because of its many qualities, which include low density, excellent wear resistance, high tensile strength, and smooth surfaces. A new FRP composite is being developed using pineapple and glass fibers as reinforcement and epoxy resin as adhesive. The composites are designed for various applications, including automobiles, structural and construction, and household components. The composite will be prepared using sand casting and analysed for its mechanical properties. The composite's potential applications include side panel lining, roof lining, dashboards, and rear walls. The material's mechanical properties will be optimized through experimentation.

III. MATERIAL

Pineapples are a tasty and widely consumed fruit. Grown for its fruit, it is a perennial crop. After the fruit is harvested, the pineapple plant is useless. These pineapple leaves produce a significant amount of wasted agricultural material. Various strategies are used to handle these organic wastes. The West Indies, Brazil, and South America are the original home of the pineapple, a naturally occurring tropical plant. These days, pineapple plants come in a variety of forms that are used in various nations to make textiles, handicrafts, cotton for industrial use, and culinary and medicinal ingredients. Rich in specific strength, stiffness, flexural and high torsional rigidity, good chemical composition, and greater mechanical strength than jute fibre, PALF is reasonably priced. In several sectors, PALF is utilized as a raw material to create composite matrices that are reinforcing. The table 4.1 represents the mechanical properties of PALF.

Fig. 1. PALF Fibre

Fig. 2. Glass Fibre

E-glass fibre, widely used since 1930 in industrial applications, is a high temperature insulator for electrical conductors. It is widely used in textiles and composite materials, and is rot-proof, resistant to chemical agents, and dimensionally stable. However, filaments exceeding 9µm can cause skin irritations, so cords are produced from textured and twisted strands ranging from 6 to 9 µm. These products complement Newtek's product range. It is made from silica, lime, alumina, and magnesia, with boron oxide added. It is ignited, and the molten paste becomes viscous and liquid. Glass thread is produced by refining the molten bulk and running it through dies. Excellent flexibility, a greater specific resistance than steel, and resilience to vibration and abrasion are all features of e-glass fibre. In addition to being non-combustible and having a low thermal conductivity, it can tolerate temperatures beyond 600°C. Oils, solvents, and chemical agents cannot harm e-glass goods, nor can they decay. The low expansion coefficient of glass thread makes it resistant to changes in humidity and temperature.

Epoxy is utilized as an adhesive in this study. Monomers containing two or more epoxide groups are converted into a class of thermosetting polymers known as epoxy resins. They offer strong adherence, chemical resistance, and other particular properties. Because of these qualities, epoxy resins are used in a wide range of consumer and commercial products. Alternative terms for epoxy resins include α-epoxy, 1, 2-epoxy, and "epoxide" (European use). They comprise a wide range of reactive substances. The presence of an epoxy ring or oxidase characterizes these reactive groups. This can be represented as a three-member ring where two carbon atoms have previously been connected in some other way and one oxygen atom is bound to them.

Fig. 3. Epoxy Resin

IV. SPECIMEN PREPARATION

The first process for producing woven composites is called hand lay-up, which entails sample preparation, the release of an antiadhesive agent, the application of a thin plastic sheet, and the positioning of woven reinforcing layers on the surface of the mold. Using a brush, the resin is combined with other chemicals and applied to the reinforcing surface. To eliminate trapped air bubbles and extra polymer, more mats are positioned on top of the polymer layer and compressed. The weaved composite is extracted from the surface, the mold is shut, and the pressure is released. A large range of composite goods may be produced with hand lay-up, which has the capacity to generate large quantities utilizing several moulds and a low production volume per mold. It provides a large range of part sizes, straightforward processing, and affordable equipment. Design modifications are easily implemented, and competent operators may achieve high production rates and reliable quality.

For a high-quality finish, a gel coat is sprayed over the mold using a spray gun. Then, roll stock fiberglass reinforcement is physically fitted onto the mold. Applying laminating resin involves pouring to fully wet the reinforcement, eliminating trapped air, and consolidating the laminate. Known as sandwich construction, low-density core materials like end-grain balsa, foam, and honeycomb are frequently employed to reinforce the laminate.

Fig. 4. Hand Layup Process

In the moulding process, we have to clean the steel Molds and then when the wax is applied, (here the wax is used for non-sticking purpose - in this project we use the wax as a transparent sheet) then we have to add the resin. (50% epoxy and 50% hardener) mixture was applied into the Mold by hand layout as shown in Figure 4. These 3 differential ratios gave a 3 different type of result and it was formed by a thickness as 5mm and a mass of 500g. Here 3 different material proportions can be chosen as shown in Table 1, then apply a resin mixture on top of the compounds and add wax to cover the compounds. In that mixture we give a firm pressure (mass) on the mixture and leave it for dry purpose at room temperature for 24 hours. Then the specimens are taken into laboratory to check its mechanical properties like tensile, Impact and Flexural Test.

Table 1. Various Material Combination

Specimen ID	Glass Fibre	Pineapple Fibre	Resin
1	50	10	40
2	40	20	40
3	30	30	40

V. EXPERIMENTAL TEST

Impact tests measure the energy absorbed by a material during fracture to determine its toughness and temperature-dependent brittle-ductile transition. They include giving parts like dies, shafts, bolts, and anvils an abrupt, dynamic load. There are several types of impact tests, all of which include striking a test object with a weight and materials testing standards. Impact tests are helpful in characterizing a material's ability to withstand sudden pressures, but they don't account for cyclical loads or loading conditions that occur in daily life. Despite this, the test makes it easy to compare the impact strengths of the materials assuming they were assessed according to the same standard. For the tensile test in this case, we used a specimen (ASTM D 256), which was shown in Fig. 5.

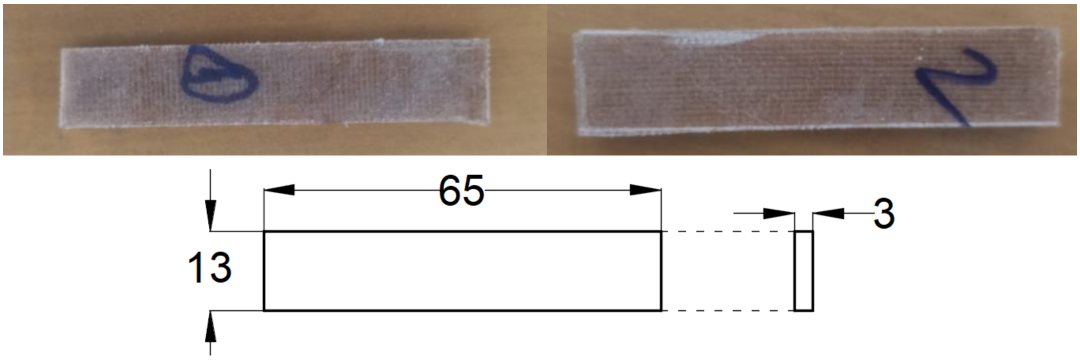

Fig. 5. Impact Test Specimen (ASTM D 256)

Tensile testing is a type of mechanical testing that uses tensile force to determine how a material reacts to stress. It determines a material's strength and elongation capacity. Tensile tests are simple to conduct and may be carried out with universal testing equipment or electromechanical testing equipment. They are frequently employed in material testing and force measurement to ascertain how a material, part, or component will behave mechanically under static, axial tension. Despite the identical test procedures, the test results for force measurement and material testing are not comparable. The yield point, elastic limit, percentage elongation, elastic modulus, brittleness, tensile strength, ductility, and toughness of the test sample are all revealed by its deformation. Figure 6 displays the ASTM D 638 specimens that were selected for the tensile test.

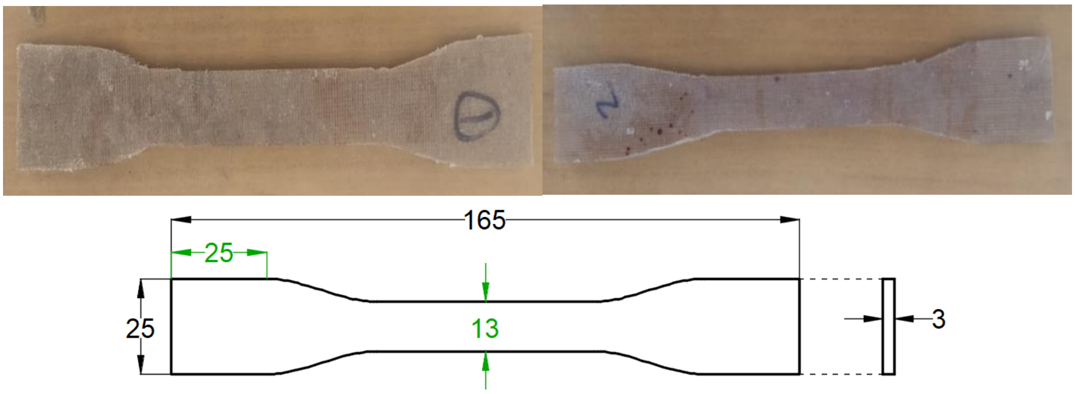

Fig. 6. Tensile Test specimen (ASTM D 638)

Flexural tests are often carried out by employing platens or certain fixtures on a universal testing machine to impart compressive pressure to a test specimen, which is typically cylindrical or cuboid in shape. Finding out how a material will respond to applied crushing forces is the goal of test testing. By determining the force required to bend a plastic beam, flexural testing evaluates a material's stiffness or resistance to bending. What may be bent before irreversible deformation occurs is indicated by the material's flex modulus. For flexural test, the specimen has been prepared about the ASTM D 790 standard (figure 7).

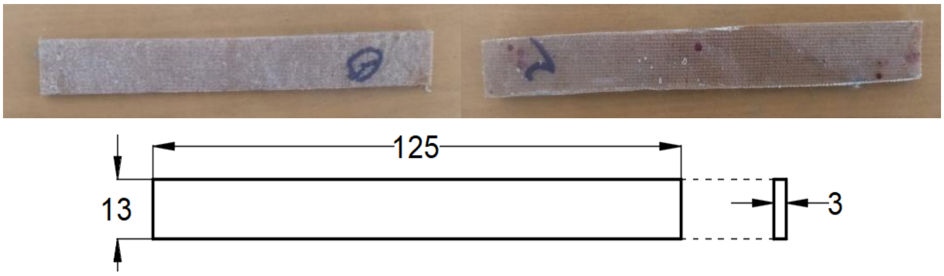

Fig. 7. Flexural Test specimen (ASTM D 790)

VI. RESULT & DISCUSSION

In this work, tensile, impact, and flexural, tests were performed on three different material compositions for a variety of composites. These tests' outcomes have shed important light on the mechanical characteristics of the composites and how material mix affects those characteristics. We can identify which material composition has the best overall mechanical capabilities by analyzing how well the composites performed in each test. Choosing the best composite material for a given engineering application will need careful consideration of this information.

In this current study the three different composition specimen were carried out for the tensile test. Tensile tests are simple to conduct and may be carried out with universal testing equipment or electromechanical testing equipment. The test results are shown in table 2 and it was also represent in a graphical method in Fig 8. This results shows that the specimen 1 had an Ultimate tensile strength (UTS) and the grater elongation (%) of 57.094 N/mm^2 & 2.790% respectively at a peak load of 4453.083 N, On the other hand, Sample 2 and Sample 3 had lower tensile strengths of 31.363N/mm^2 and 17.942N/mm^2, respectively. The combination of Pineapple and glass fibres in the composite resulted in improved mechanical properties, as demonstrated by the ultimate tensile strength and percentage of elongation. This suggests that the composition of pineapple, glass, and epoxy in the composite material is well-suited for applications requiring high resistance to Elongation.

Table 2. Results of Tensile Test

S. No	CS Area (mm2)	Peak Load (N)	% Elongation	UTS (N/mm^2)
1	78	4453.083	2.790	57.094
2	78	2446.241	2.060	31.363
3	78	1399.593	1.960	17.942

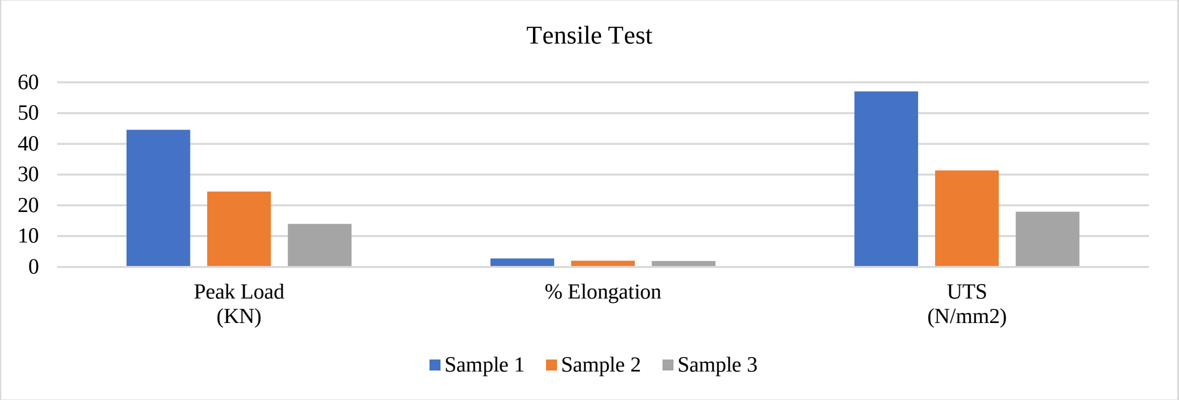

Fig. 8. Variation of Tensile Strength

A cross section of 52 mm^2 specimen was used for the experiment test results for the flexural test on the ASTM D 790 specimen (as indicated in Fig. 7). With a peak load of 521.539 N, specimen 2 can withstand 188.055 MPa and 1787.109 GPa, indicating substantially higher flexural strength and modulus, respectively, indicating superior deformation resistance (Table 2). A composite consisting of 40% pineapple, 20% glass, and 40% epoxy was mixed due to the natural characteristics of the fibers from pineapple and glass. As a consequence, specimen 2 is stronger than specimens 1 and 3, according to the flexural data. This information was also graphically displayed, as seen in figure 9.

The composite's flexural strength and modulus measurements show that the addition of pineapple and glass fibers increased its mechanical qualities. This shows that applications with strong resilience to flexural stress conditions are a good fit for the composite material's pineapple, glass, and epoxy composition. In addition, the use of pineapple fibers enhanced the composite material's sustainability, rendering it a sustainable choice for a range of technical uses. The effective fusion of these materials creates opportunities for the development of robust and lightweight goods in sectors like construction and automotive.

Table 3. Results of Flexural Test

S. No	CS Area (mm^2)	Peak Load (N)	Flexural Strength (MPa)	Flexural Modulus (GPa)
Sample 1	52	670.67	107.479	614.083
Sample 2	52	521.539	188.055	1787.109
Sample 3	52	231.153	83.348	931.753

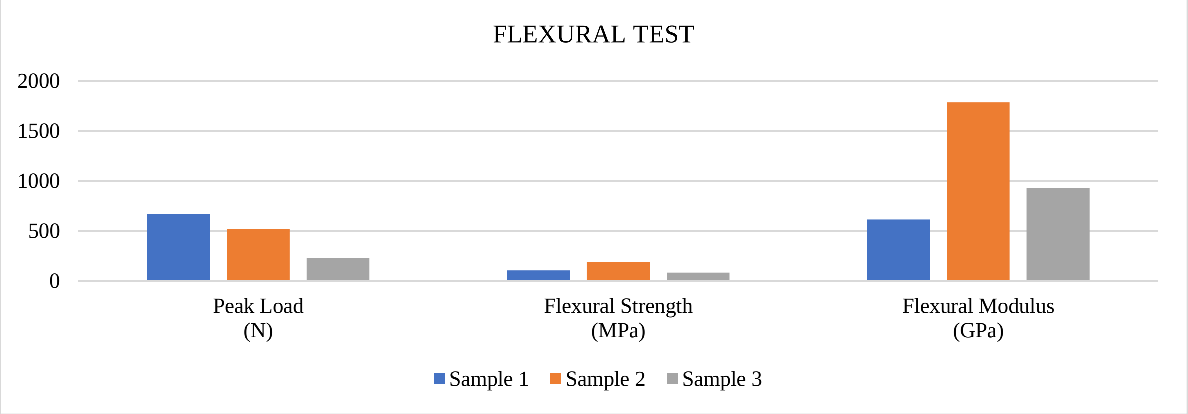

Figure 9. Variation of Flexural Strength

The impact test was conducted on the specimen ASTM D 256, as shown in Fig. 7. The results are presented in Table 4 and illustrated in Figure 10. It has a 3.1 J impact load on 52 mm^2. This indicates that specimen 1 is more resistant to impact forces compared to other specimens, making it a potentially better choice for applications requiring high impact strength. Additionally, the presence of glass fibre in specimen 1 resulted in a higher impact load compared to specimens 2 and 3. This suggests that incorporating glass fibre can enhance the impact resistance of materials, making them suitable for demanding applications.

Table 4. Izod Test Results (Impact)

S. No	CS Area (mm^2)	Izod Impact Value (J)
Sample 1	52	3.1
Sample 2	52	3.0
Sample 3	52	2.0

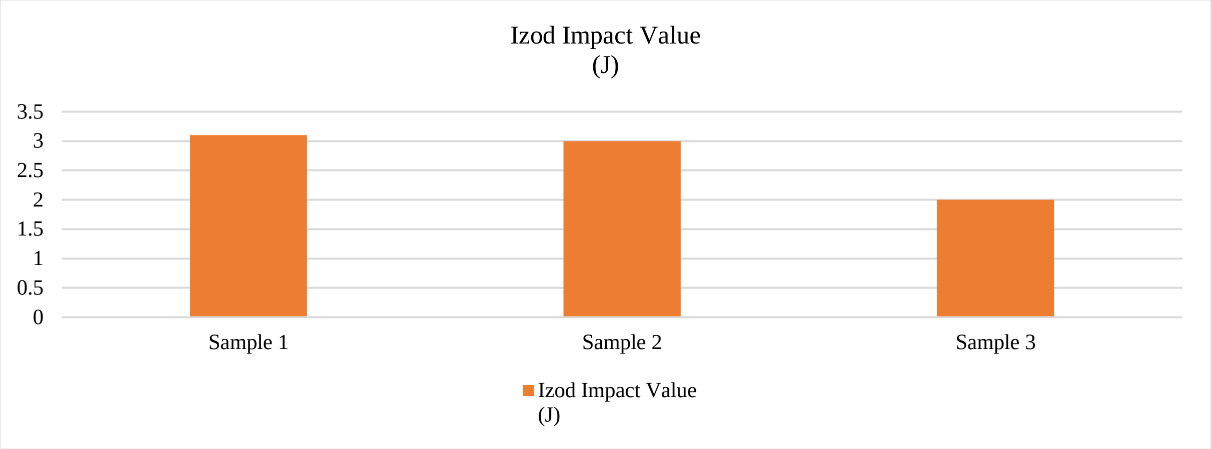

Figure 10. Variance of Impact Energy

VII. CONCLUSION

The study offers a hybrid composite made of glass fibre and epoxy resins combined with natural materials like pineapple. These composites are ideal for a range of industrial applications because of their high hardness and lightweight construction, which provide them with superior mechanical qualities over traditional materials. Three distinct material compositions have been studied experimentally in order to examine the flexural, tensile, and impact mechanical characteristics of the suggested composite. The system's examination leads to the conclusion that This result shows that the specimen 1 had an Ultimate tensile strength (UTS) and the grater elongation (%) of 57.094 N/mm^2 & 2.790% respectively at a peak load of 4453.083 N.

According to the ultimate tensile strength and percentage of elongation, the composite material, which contained pineapple and glass fibers, exhibited improved mechanical properties.

Specimen 2 has much better flexural strength and modulus, with a peak load capacity of 521.539 N, corresponding to 188.055 MPa and 1787.109 GPa.

In addition, the use of pineapple fibers enhanced the composite material's sustainability, rendering it a sustainable choice for a range of technical uses Specimen 1 is deemed more resilient to impact forces, making it an optimal choice for applications requiring high impact strength. After examining the trial outcomes of the suggested fiber metal laminate, it was determined that Sample 1 (Glass 50 + Pineapple 10 + Resin 40) had a stronger composite than Samples 2 and 3.

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