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Investigation of Mechanical Properties of Jute, Cotton and Glass Fiber Reinforced Hybrid Composites

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ABSTRACT
Natural fiber concentrates on controlling the nature impact, diminish item weight, and lessen the expense of items. The improvement of composite materials and their parts are expanding quickly. The natural fiber incorporated with synthetic fiber provides a material with better strength. Synthetic fiber is mostly not eco-friendly, and they are not recyclable, so it is harmful to nature. The natural fiber is renewable and biodegradable. In this work, hybridization was done using jute, cotton, and glass fiber combination. For the fabrication of the hybrid composite material, the hand lay-up process was followed. The work objectives were to investigate the jute, cotton, and glass fiber reinforced epoxy hybrid composites' mechanical properties and compare them with jute fiber and glass fiber composite. The properties of that hybrid composite were dictated by testing tensile, flexural, and impact strength experimentally, as indicated by ASTM standards. The analysis's after-effects through various tests show that the hybrid composite of jute, cotton, and glass fiber indicated better mechanical properties over jute fiber composite and glass fiber composite except for the tensile strength. However, this hybrid composite's tensile strength is 42.09 MPa, enough for real-life applications in automobile industries. From all results, it can say that the hybrid composite can replace the glass fiber composite.

Key Words: Hybrid composite, jute fiber, glass fiber, epoxy resin.

1. Introduction

Recent research has found that natural fiber has replaced a large portion of the polymer materials in various applications. Natural fiber composites and hybrid composite material are developing day by day for nature-friendly behaviors of the composite. The composite material consists of reinforcement (fiber) and matrix (resin). A composite material is formed by a mix of two or different materials that give different properties. A pure polymer cannot give better properties, so the composite's hybridization gives excellent properties over pure polymer. "Hybrid materials are composites consisting of two constituents at the nanometer or sub-atomic level. Regularly one of these mixes is inorganic and the other one natural. In this way, they contrast from conventional composites where the constituents are at the macroscopic (micrometer to the millimeter) level" (Hybrid material, 2020). Natural fiber has functioned as an alternative reinforcement in polymer composites and has held onto the consideration of numerous analysts and researchers because of the upsides of natural fibers over regular glass and carbon fibers. There are numerous favorable natural fibers' favorable circumstances over glass and carbon fibers because they are low cost, low CO_2 absorption, low density, non-abrasive to the equipment, low energy consumption, recyclable, renewable, biodegradable, and many more. Begum, et al. (2013) introduced a brief improvement of natural fiber reinforced polymer materials' mechanical properties. They compared the mechanical quality of natural fiber reinforced polymer composite with glass fiber and found that natural fiber's higher volume fraction than glass fiber delivered equivalent mechanical quality of the natural fiber. Additionally, they discussed the eco-friendly nature of the produced natural fiber reinforced polymer composites. Joshia, et al. (2004) considered natural fiber and glass fiber composite's existence pattern. They observed that natural fiber composites are environmentally better than the glass fiber composites much of the time for natural fiber production has lower ecological effects contrasted with glass fiber production. Natural fiber composites have higher fiber content for parallel execution, lessening all the more polluting-based polymer content. Likewise, light-weight natural fiber composites improve fuel efficiency and reduce emissions in the component's utilization period, particularly in auto applications. Sanjay, et al. (2015) reviewed natural-glass fiber reinforced polymer hybrid composite. They conclude that incorporating natural fibers with GFRP can improve the properties and is used as a substitute material for glass fiber reinforced polymer composites. Rafiquzzaman, et al. (2016) considered the mechanical properties of jute and glass fiber reinforced polymer hybrid composites. They observed that about 30% of expenses could be limited by utilizing the jute and glass fiber, the jute, and glass fiber reinforced epoxy composites. The examining electron microscope taste had been conducted to determine the facture condition of the composite. Gowda, et al. (1999) observed jute fiber-reinforced composites' mechanical properties and found that only jute fiber-based composites material shows better mechanical properties than wood fiber-based composite. Dhawan, et al. (2013) studied the impact of natural fillers on glass fiber reinforced plastic composite's mechanical properties. In that work, glass fiber reinforced epoxy and glass fiber polyester composites were compared. Among these wheat husk fillers, coconut coir filler, rice filler, and coconut filled demonstrated better mechanical properties and rice filler marginally lesser than the coconut filler. Moreover, glass fiber reinforced epoxy composite shows much-preferred quality over glass fiber polyester composites. Pickering, et al. (2016) studied the tensile, flexural, and compressive strength of hybrid composites

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with various fiber lengths of coir/silk in an unsaturated polyester matrix. Coir/silk filaments taken with various lengths, such as 1, 2, and 3 cm, finally observed that 2 cm fiber length produced higher, flexural, and compressive strength than others. Prétot, et al. (2014) show hemp/epoxy used to replace glass/epoxy at Naca cowlings ultra-light aircraft. A recommended, more moderate methodology respects the number of employees to be utilized. Wambua, et al. (2003) investigate natural fibers used to replace glass fiber, which was better in some cases over glass fiber. Additionally, proposed that natural fiber composites have the potential to replace glass in numerous applications that do not require very high load-bearing capabilities. Berhanu, et al. (2014) studied the mechanical behavior of jute fiber reinforced polymer composites. For various weight percentages, 30%, 40%, and 50% of fiber reinforcement were utilized, and checking electron magnifying instrument, X-ray diffraction, and thermal analysis test had been directed to observe better mechanical properties. The outcomes found that polypropylene with jute fiber composite improved the mechanical properties. Jagannatha, et al. (2015) studies about jute fiber and carbon fiber reinforced epoxy hybrid composites. In this work, the vacuum bagging technique was conducted for the preparation of composite material. The mechanical properties are checked, and it had been observed that the increased amount of carbon fiber showed better properties than the same portion of glass fiber.

2. Materials and Methods

2.1 Materials

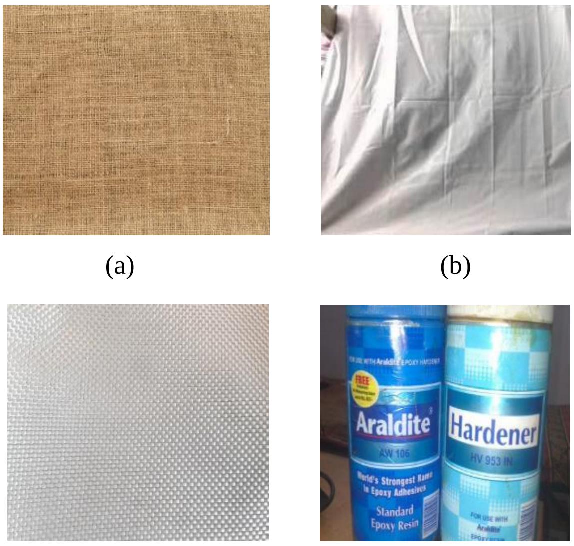
In this study, jute, cotton, and glass fiber were utilized as reinforcement, and the epoxy resin (Araldite AW 106) was utilized as the matrix and Hardener HV 953 IN was utilized to interferential bond and impart strength to the composites. They have shown in Fig.1. The glass fiber, hardener and resin were bought from a nearby chemical shop. The woven jute fiber and cotton was collected from the local market. All of the materials are low cost and easily available in the market.

2.2 Fabrication procedure

The fabrication of hybrid composites was done by using a hand layup process. The jute, cotton, and glass fiber were used as reinforcement, and epoxy was taken as matrix material. The following steps were maintained in the preparation of the composites.

Firstly, a lubricating oil (grease) was used as a release gel on the stainless-steel plate, then covered the plate with transparent polyethylene paper to remove the paper easily after preparing the composite. Mirror stainless steel was utilized at the top and bottom of the mold plate to get a great surface completion of the composite. Reinforced material as a woven mat was utilized in the arrangement of the hybrid composite. Those woven mats were cut as per mold size 12×12 inches. The epoxy resin and hardener were blended in a 10:1 weight proportion. Approximately 400 gm resin and hardener mixers were used. Furthermore, blended it properly as the resin and hardener can mix easily at room temperature so that there was no need for temperature control. The blend of resin and hardener was spread with a brush in the rapped plate first. Then mats were placed on the plate. For excellent surface finish and get rid of bubbles, a roller was used with a little pressure on the composite layer. Then the mixer of resin and hardener was spread again with the help of a brush. Another layer of mats was placed and, in the same way, coated with a mixture of resin and hardener. The procedure was reappeared for each layer of matrix material and mat until the necessary layers are obtained. In this work, five layers were used for the hybrid composite, three layers were used for jute fiber, and four layers were used for glass fiber. In the hybrid composite, two layers of jute fiber, one layer of glass fiber, and two cotton fiber layers were used. Then placed the stainless-steel sheet at the top.

Finally, the laminate was kept in the weight press for over 24 hours to get the perfect shape and thickness. After curing at room temperature, mold was opened, and the prepared composite part was taken out and then cut into desired shapes for performing different tests.



(a) (b)

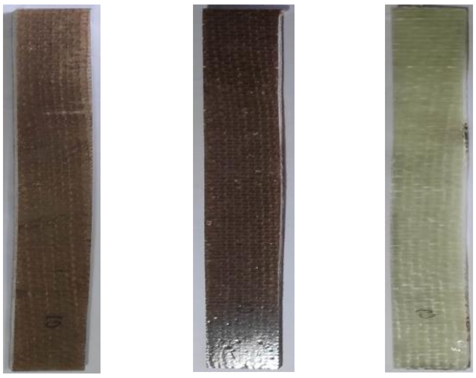
(c) (d)

Fig.1 (a) Jute fiber, (b) Cotton fiber, (c) Glass fiber, (d) Epoxy resin and hardener.

Table 1 Properties of jute fiber, cotton fiber, glass fiber and epoxy resin

Properties	Jute fiber	Cotton fiber	Glass fiber	Epoxy resin
Density (g/cm^3)	1.46	1.51	2.55	1.15-1.25
E-Modulus (GPa)	10-30	12	73	2.7
Elongation at failure	1.8	3-10	3	-

Source: (Huntsman, 2004, p.3) and (Jagannatha, 2015)



(a) (b) (c)

Fig.2 Picture of test specimens (a) Hybrid composite (Jute, cotton and glass fiber), (b) Jute fiber composite, (c) Glass fiber composite.

2.3 Experimental procedure

The tensile test was performed utilizing the SHIMADZU Universal Testing Machine (UTM). It was directed with a displacement rate of 2mm/min. Fabricated composites were cut into three samples for each specimen, and samples were prepared for the tensile test according to the ASTM D3039 standard [14]. The test was performed, applying tension until failure at room temperature. From the test, load and strain acquired were plotted on the graphs. At that point, the strength was determined from the maximum load at failure of the tensile stress.

Impact tests are used to study the toughness of a material. A material's toughness indicates the capacity of the material to absorb energy during plastic deformation. The impact test was done in an Izod impact testing machine. Specimens were cut according to the ASTM D256 standard for the impact test. The specimen was stacked in the testing machine and permitted the pendulum until it cracks. Utilizing the test, energy needed to break the material is noted and used to gauge the material's durability and yield strength. The rate of failure and ductility of the material were analyzed.

The three-point flexural bending test was done for the flexural test of those specimens. Specimens were cut according to the ASTM D7264 standard. 16:1 span length to specimen thickness ratio was used. The test was finished in the UTM from which the breaking load was recorded. All experimental tests were rehashed multiple times to create the information.

3. Experimental results and discussions

In this experiment, three samples were taken for each test of each material. Fig.3 shows the stress-strain graph of the tensile test for the hybrid composite, where the results are almost the same. The tensile force acted on the material up to the rupture point or breakdown point of the material. According to hooks law, they show stress-stress is proportional at first. Due to the orientation and molecular behaviors of the material, the nature of the curve changed slightly. In fig.6, fig.7, and fig.8 show the stress vs. displacement graph of the flexural test. Due to fibers orientation, densities, and molecular behaviors, the load was the same, but displacement changed up to certain portions.

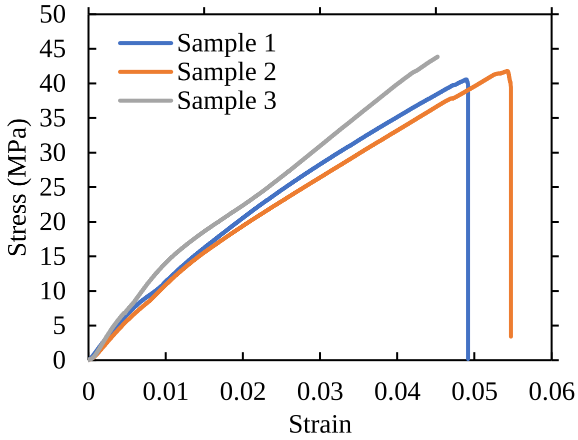


Fig.3 Stress vs Strain graph of tensile test for jute, cotton and glass fiber reinforced hybrid composite.

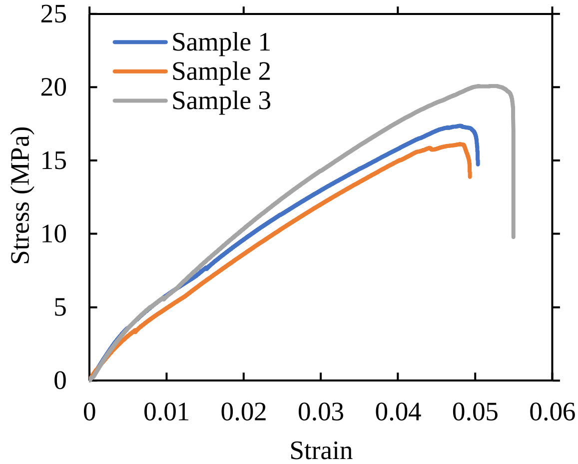


Fig.4 Stress vs Strain graph of tensile test for jute fiber composite.

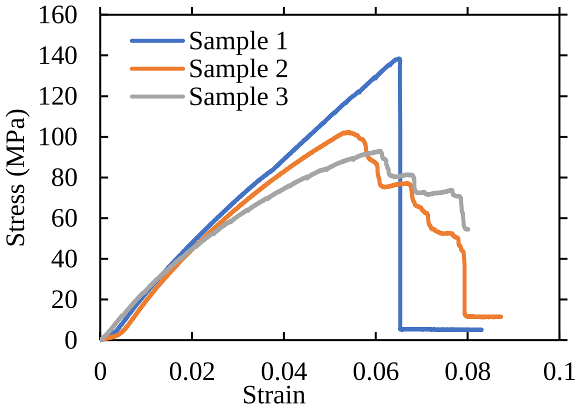


Fig.5 Stress vs Strain graph of tensile test for glass fiber composite

Table 2 Experimental results of tensile, flexural and impact test.

Composite	Tensile Strength (MPa)	Flexural strength (MPa)	Impact strength (KJ/m^2)
Jute fiber	17.86±2.03	30.80±3.67	461.21±79.79
Glass fiber	111.27±23.96	32.55±5.19	350.40±9.79
Hybrid	42.09±1.65	32.35±2.05	831.74±48.12

Table 3 Experimental results of tensile and flexural modulus of elasticity.

Composite	Tensile modulus of elasticity (GPa)	Flexural modulus of elasticity (MPa)
Jute fiber	0.74±0.11	648.89±81.34
Glass fiber	1.55±1.07	387.09±68.22
Hybrid	1.33±0.04	534.87±111.07

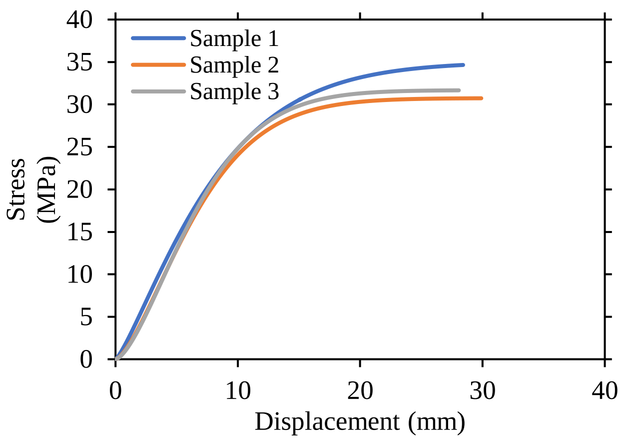


Fig.6 Stress vs Displacement graph of flexural test for the hybrid composite.

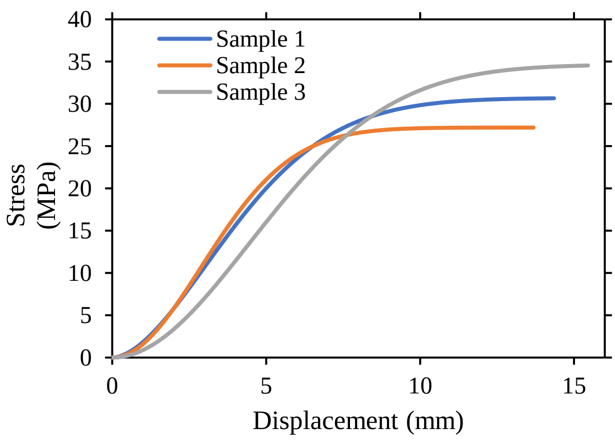


Fig.7 Stress vs Displacement graph of flexural test for the jute fiber composite.

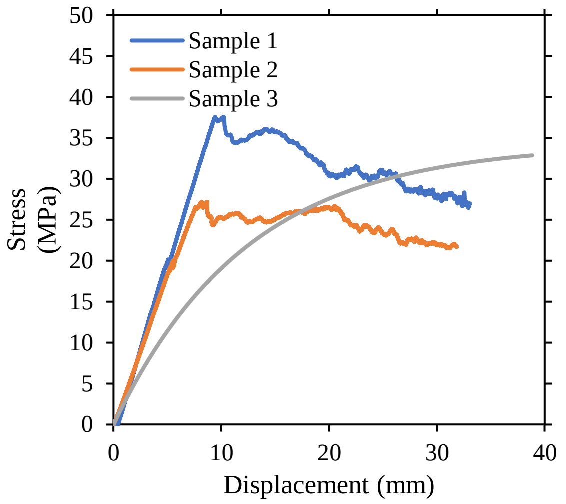


Fig.8 Stress vs Displacement graph of flexural test for the glass fiber composite.

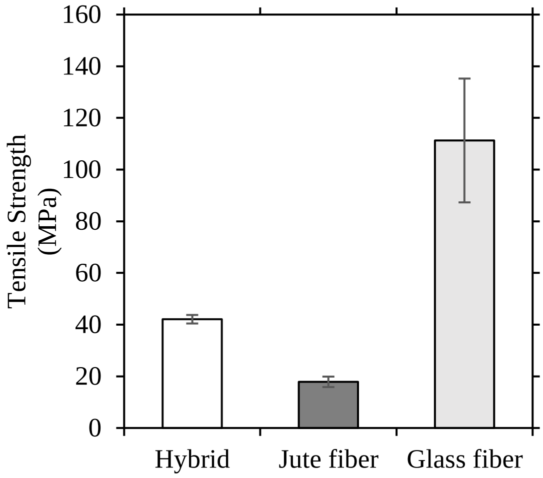


Fig.9 Comparison of tensile strength.

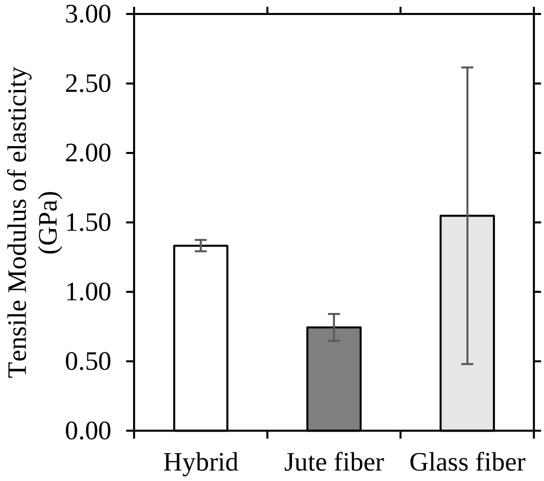


Fig.10 Comparison of tensile modulus of elasticity.

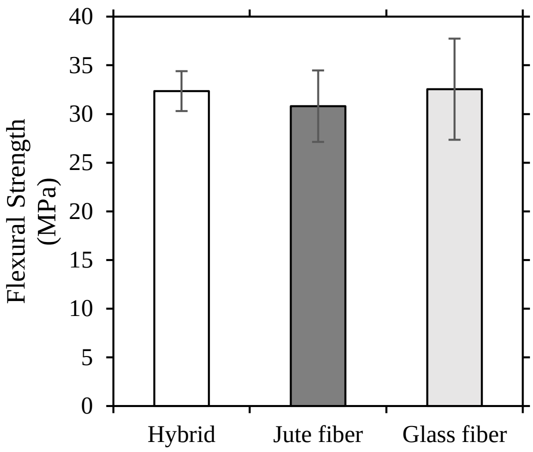


Fig.11 Comparison of flexural strength.

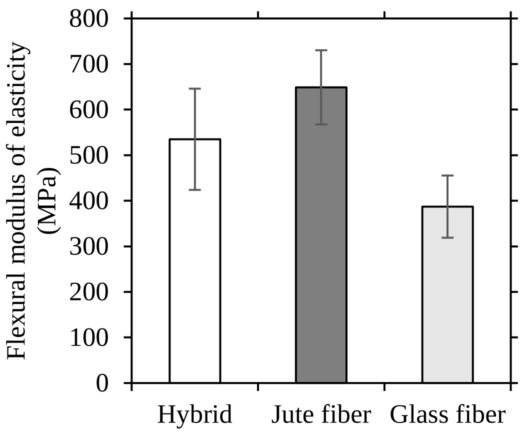


Fig.12 Comparison of flexural modulus of elasticity.

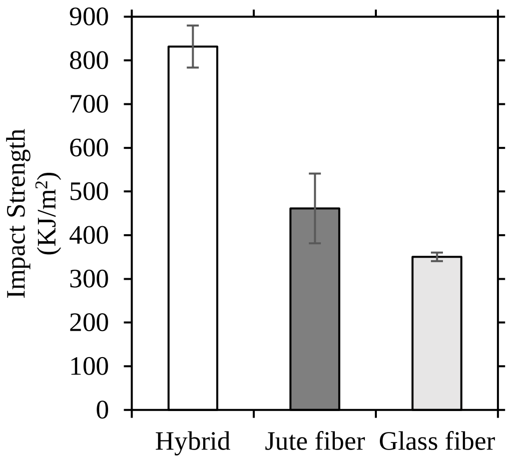


Fig.13 Comparison of impact strength.

The tested specimen results were varied due to the number of plies used in the tested sample that were not the same. Also, the thickness of the jute fiber composite, glass fiber composite, and hybrid composite was not the same. Due to the difference in volume fraction and molecular orientation, it was not easy to control the material's thickness.

The above result of composite mechanical properties indicates that the best tensile properties were found in glass fiber composite, and for other properties, jute, cotton, and glass fiber hybrid composite is the best.

In terms of tensile strength, the highest strength is observed in glass fiber composite, which is 111.27 MPa (Fig.9). If we want to compare it with the other strength like flexural and impact then jute, cotton, and glass fiber hybrid composite show the appealing result. The hybrid composite shows 42.09 MPa tensile strength, which is enough for the real-life application. The hybrid composite gives preferred strength over jute fiber composite.

From fig.10, the tensile modulus of elasticity higher value was observed in the glass fiber composite, which is 1.55 GPa. The hybrid composite provides 1.33 GPa close to glass fiber composite. The hybrid composite provides a better modulus of elasticity than jute fiber composite.

The best impact strength is measured in value 831.74 KJ/m^2 in jute, cotton, and glass fiber hybrid composite. In jute fiber composite, 461.21 KJ/m^2 impact strength is measured. For glass fiber composite, the value is 350.39 KJ/m^2. So, the hybrid composite provides the best impact strength than others.

A similar kind of result is also observed for flexural strength for fig.11. The hybrid composite provides flexural strength, which is 32.35 MPa. Jute fiber composite and glass fiber composite provides 30.80 MPa and 32.55 MPa flexural strength.

Due to the difference in volume fraction, dimension, and orientation, the flexural strength is lower than the tensile strength in this experiment.

There is a versatile application of these composites in the automobile industries and other production industries as raw material. Glass fiber is vastly used in the vehicle. We can also use jute, cotton, and glass fiber hybrid composite to replace glass fiber. It can also be used as speed boat material, so it can play a role in green technology, which will help nature.

4. Conclusion

The experimental study on the investigation of mechanical properties of hybrid composite leads to the following conclusions:

A hybrid composite of jute, cotton and glass fiber combinations, a jute fiber composite and a glass fiber composite has been prepared for experimental work in hand lay-up process. Mechanical properties of those composites were also evaluated. A comparison was also employed among the prepared composite materials. The best performing material was the hybrid composite except for tensile strength. The tensile strength of the hybrid composite was moderate, which is enough for real-life applications in the automobile industries. So, it can be said that the hybrid composite of jute, cotton and glass fiber can easily replace the glass fiber composite and jute fiber composite.

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