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Production and characterization of bamboo and sisal fiber reinforced hybrid composite for interior automotive body application

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ABSTRACT

Composite materials have high strength to weight ratio with low density and high stiffness to weight, high strength ratios, and high fatigue strength to weight ratio compared to traditional engineering materials making them find wide applications in structural constructions. When the lightweight composite materials which are made of lightweight natural fibres are used in automotive application, the fuel economy of the vehicle improves reducing the related harmful emissions. The aim of this research is to develop and characterize the performance of sisal and bamboo reinforced polyester hybrid composite (BSFRHC) with different fibre orientation of sisal and unidirectional (UD) bamboo fibre. Next, BSFRHC was fabricated with 20% total fibre volume fraction. Of this total fibre volume, the composite is fabricated in 3:1 bamboo to sisal fibre ratio using hand lay-up technique. Then tensile, compressive, impact and flexural tests were carried out. In general, it is concluded that as varying fiber orientation, the tensile strength varies. The higher tensile strength is observed with 0° fibre orientation of bamboo/sisal fiber reinforced hybrid composite. From compressive strength of the hybrid composite reinforced with bamboo/sisal fibre, it is observed that the 0°-fibre orientation composite is exhibiting higher compressive strength than 90° fibre orientation composite and bidirectional (0°/90°) fibre orientation composite. Unidirectional 90° fibre orientation was found to have a higher tensile and flexural strength whereas unidirectional 90° and bidirectional (0°/90°) fibre orientation nearly have the same value of tensile strength, whereas bidirectional (0°/90°) was found to be having higher flexural strength than unidirectional 90° fibre orientation. Impact analysis of vehicle internal door panel made of BSFRHC was done using ANSYS Software. Furthermore, it is found that the bamboo and sisal fibre reinforced hybrid composite in unidirectional 0° has the potential to be used for automotive interior part application.

1. Introduction

It is a natural phenomenon that human beings keep on moving place to place to perform their day to day activities within a given time range. And vehicles are the dominant way of the transportation system in many countries, including Ethiopia. Thus, researching in this area to design and provide a well improved, fast, economic, and aesthetically attractive vehicles is a crucial idea for the development of these countries by providing fast, effective, and sufficient way of transportation. Better and efficient transportation vehicles can be developed with the development of better materials and design improvement. Wood was used in early days of automobiles. Now a day most sophisticated and modern materials are being developed for automotive industries [1–3].

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Reduction of the weight of the vehicle for the sake of saving fuel is the major purpose of developing new materials for automotive application. It is also necessary to improve aesthetical appearance of vehicles, by conducting research modern materials. From the research works of previous researchers, it is observed that, the composite materials which are lightweight, fatigue resistant and easily molded to any shape, are promising alternatives to conventional metallic materials. The Automotive industries are to exploit the positive features of the composite materials like high specific energy absorption ability, lightweight, good aesthetical value, durability, and ease of forming etc., solving the other technical issues raising due to usage of them.

In the present scenario, the focus of automobile manufacturers and designers is to economize energy, weight reduction and, conserve natural resources, etc. Primarily weight reduction can be achieved by adopting better manufacturing processes, by design optimisation and by using better materials. Day by day the demand for light and better performing vehicles is increasing. Due to this the lightweight materials like plastics and composites materials in various combinations are being used in the construction of different structural parts of the vehicles. Already the composite materials are being used by Automotive Industries in the construction of the vehicle parts like passenger safety cell, door panels, front and back bumper, roof, floor, dashboard etc. [3–5].

Kenaf is cultivated globally for natural fibres. It is one of the industrial crop in Malaysia. The composite material with poly vinyl butyral (PVB) with kenaf fibre-reinforcement was prepared. The tensile and flexural strengths of composites with different fibre orientations were measured. Morphological properties were also measured. The results revealed that impact properties were affected in markedly different ways by different orientations. The composite at 45°/−45° offered better impact properties than the composites at 0°/90°. In addition, scanning electron microscopy for impact specimens was employed to demonstrate the different failures in the fracture surfaces [6].

Natural fiber hybrid composites are cost effective and possess impressive mechanical and thermal stability and might partially replace and reduce the utilization of synthetic fibers as reinforcements of polymeric composites. The use of natural fibers in various applications provides researchers with the challenge of developing suitable techniques to obtain high properties of the fibers that are up to the required standard, in order to use them to reinforce polymer composites. The mechanical, physical, and thermal properties of hybrid composites made of cellulosic fibers are to be investigated [7].

Hybrid composite of unsaturated polyester sandwich reinforced with woven kenaf/glass was prepared and experimentally investigated for its properties. It was found that kneaf fibre can be used as a replacement for natural fibres [8].

The composite materials are replacing the traditional materials, because of its superior properties such as high tensile strength, low thermal expansion, high strength to weight ratio. The developments of new materials are on the anvil and are growing day by day. Natural fiber composites such as sisal and jute polymer composites became more attractive due to their high specific strength, lightweight and biodegradability. Mixing of natural fiber with Glass-Fiber Reinforced Polymers (GFRPs) are finding increased applications [9].

The incorporation of natural fibers with polymer matrix composites (PMCs) has increasing applications in many fields of engineering due to the growing concerns regarding the environmental impact and energy crisis. The results indicated that the hybrid composites had shown better performance and the fiber orientation and fiber content play major role in strength and water absorption properties [10,11].

2. Methodology

2.1. Fabrication approach

The fabrications of the composite sample are prepared by a conventional hand layup procedure. The bi-directional (woven form/90°) and unidirectional sisal fibre (0°/90°) and unidirectional (0°) bamboo fibre are used as reinforcement and polyester as a matrix.

2.2. Sandwich hybrids

One material is sandwiched between two layers of another, in case of sandwich hybrids which are also known as core–shell as shown in Fig. 1. Two natural fibres are incorporated in matrix material in the preparation of composite in this work. The mechanical performance of long unidirectional oriented bamboo fibre and long unidirectional horizontal/unidirectional vertical and bidirectional sisal fibre reinforced polyester hybrid composites with reference to the relative volume fraction of the two fibres at a constant total fibre loading of 0.20 vol fraction (V_f), keeping sisal fibre as the shell material and bamboo fibre as the core material.

Preparation of bamboo and sisal fibre reinforced polyester resin hybrid composite is shown schematically in Fig. 1. Open mold

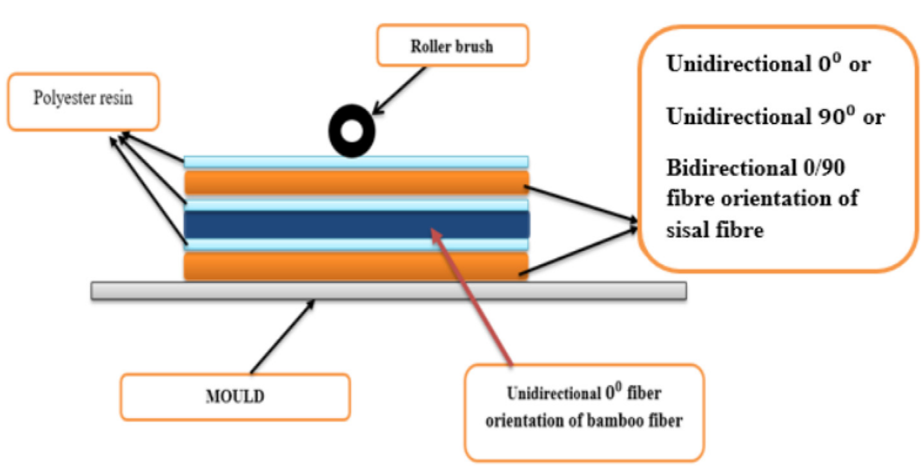


Fig. 1. Fabrication approach composite with different sisal fiber orientation.

Fig. 2. Unidirectional (UD) bamboo fibre.

(a)Drying sisal fibre (b) Weaving at $0^0/90^0$ fibre (bidirectional)

Fig. 3. Unidirectional (UD) and plain weave sisal fibre.

method was used for the preparation of the composite specimens. Unidirectional bamboo fibre and sisal fibre in different orientation were used to prepare the samples. Mixing of polyester resin and hardener (catalyst) was done in plastic bottle and made ready for layup reinforced sisal fibre.

2.3. Preparation of unsaturated polyester resin and hardener

The mixture of unsaturated polyester and hardener was used for preparation of the composite plate. The weight ratio for mixing epoxy and hardener is 10:1. The mixture was mixed thoroughly by stirring continuously with stirrer for about one minute. The mixing is performed in the mixing within plastic bottle, during the exothermic reaction taking place with the tongue depressor the mixing is done slowly to not entrain any excess air bubbles in the resin.

2.4. Alkaline/mercerization/treatments bamboo fibres

First Prepare bamboo fibre bundles. The NaOH solution was prepared with 5% concentration. Next soaked the fibres in NaOH solution for 24 h in distilled water to neutralize it, the fibre washed many times with tap water as shown in Fig. 2. Finally, these fibres were dried for two days in sunlight. After the fibre dried then prepared unidirectional (0°) fibre orientation.

2.5. Alkaline/mercerization/treatments of sisal fibres

After extraction of sisal fibre in order to increase interfacial surface adhesion fibre are chemically treated using NaOH. NaOH solution was prepared with 5% concentration. Next soaked the fibres in NaOH solution for 24 h and then in distilled water in order to neutralize it. The fibre was washed many times with tap water. Finally, these fibres dried in sunlight for two days. After the fibre dried, the woven (0°/90°), 0° unidirectional fibre orientation and 90° unidirectional fibre layers are prepared as shown Fig. 3.

2.6. Hand lay-up technique

This is an open mold method of shaping to form a structure since the layers laid are in direct contact with the atmosphere; the processing steps are quite simple. Bamboo and sisal fibre reinforced hybrid composite are fabricated using this method First of all, the mold surface was polished by applying release gel/wax to avoid the sticking of polyester resin to the surface. For the sake of getting good surface finish for the product, polyethylene Plastic was used at the top and bottom of the mold plate.

A suitable proportion of Polyester resin was mixed with prescribed hardener (curing agent) and poured onto the surface of woven which is already placed in the mold.

The polyester resin was uniformly smeared using the Brush. The second layer of unidirectional bamboo fibre was then placed on the resin surface. Excess resin present and air trapped were removed by moving a roller with mild pressure on the fibre-resin layer. The process was repeated for making sandwiches structure and woven, till the required layers are stacked after placing the sheet metal, the release gel was applied on inner surface of the top mold plate and it was kept on the stacked layers and the pressure was applied. The mold was opened after curing at some specific temperature or at room temperature and the developed composite product was released and processed further.

2.7. Preparation of sample

For all tests, we use three-fibre orientation as shown in Fig. 4.

A) Bidirectional ($0^0/90^0$)

B) Unidirectional 90 degree fiber orientation

C) Unidirectional 0-degree fiber orientation

Fig. 4. Samples with different fiber orientation.

2.8. The dimension of test pieces

ASTM was used to prepare and conduct a test of this bamboo and sisal fibre reinforced hybrid composite. All the test pieces for tensile, compressive, and Flexural testing based on ASTM standard and their value as shown Fig. 5–7.

2.9. Testing procedure of specimen

After the bamboo and Sisal fiber reinforced hybrid composite Specimen were cut into the standard Dimension they were tested for tensile strength, compression and flexural following standard procedure as shown in Figs. 8–10 respectively.

A. Tensile Strength Test

B. Compression Strength Test

C. Flexural Strength Test

3. Result and discussion

3.1. Experimental results

3.1.1. Tensile test

Bamboo and sisal fibre reinforced hybrid composite (BSRFHC) was fabricated in a different fibre orientation sandwich structural composite. Based on mass 75% bamboo fibre and 25% sisal fibre used for the preparation of the composite.

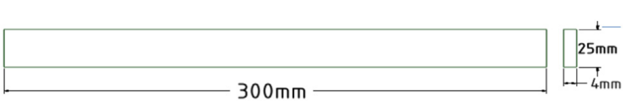


Fig. 5. Tensile test specimen.

Fig. 6. Compression test specimen dimension.

A total of three specimens for each orientation were used for repeatability. The variation in the recorded test result among the three specimens in each of the orientation is not significant. Typical stress–strain curves of BSRFHC under tensile loading for different fibre orientation is presented in Figs. 11–13.

From tensile strength of bamboo/sisal fibre reinforced hybrid composites, it is observed that the 0° fiber orientation composite is exhibiting higher tensile strength than 90° fiber orientation composite and bidirectional (0°/90°) fiber orientation composite.

0° Fiber orientation of bamboo/sisal fibre reinforced hybrid composites, tensile strength is higher than bidirectional (0°/90°) fiber orientation bamboo/sisal fiber reinforced hybrid composite. The increase in tensile strength of hybrid composite is because of by varying sisal fiber orientation. And fixing bamboo (0°) fiber orientation. The variation Tensile strength with fibre orientation as shown in Fig. 14.

From Fig. 14: Force Vs Elongation diagram for three fibre orientation, the percent elongation as well as force varies in different fibre orientation the maximum 8.97 kN force is with 15.39% E for 0° fibre orientation of bamboo/sisal fibre reinforced hybrid composite is observed. Whereas 5.45 KN with 3.8% E and 4.61KN with 15.42 for 90° fiber orientation composite and bidirectional (0°/90°) fiber orientation composite respectively.

The tensile strength, output force and elongation at break is clearly illustrated in figure above. The maximum tensile strength is 88.43 MPa for 0° Fiber orientation composite and the maximum percent elongation is 15.39 with 8.97 kN.

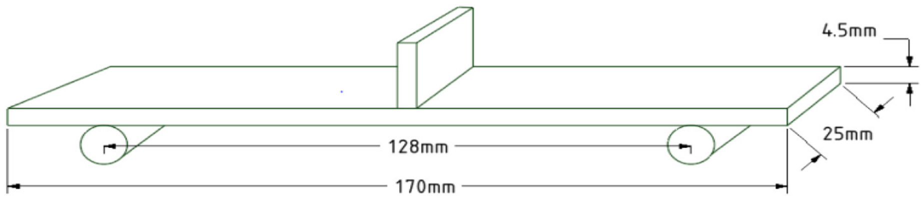
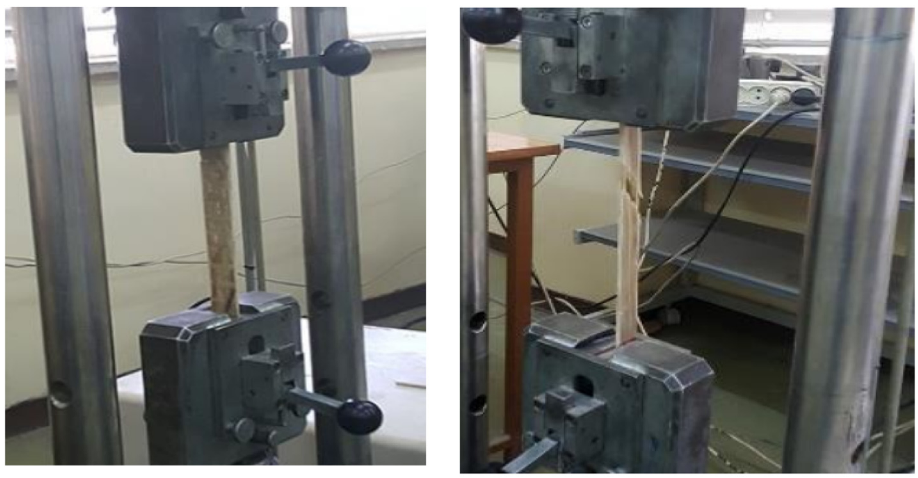


Fig. 7. Flexural test specimen dimension.



A. During specimen B) After failure

Fig. 8. Tensile strength test.

A. During specimen testing B) After Fracture

Fig. 9. Compression strength test.

In general, conclude that as varying fiber orientation, the tensile strength varies the higher tensile strength is observed 0° Fiber orientation of bamboo/sisal fiber reinforced hybrid composite.

3.1.2. Compression test

Compressive strength is the capacity of a material to withstand loads tending to reduce its size. Compressive strength is opposite to tensile strength. Compressive strength is so important in deriving the compressive load limit since, at times there might be a fracture in the structure at this limit. Compressive test specimens were prepared with three fibre orientation. For each fibre orientation, their specimens were prepared for repeatability (Figs. 15–18).

From compressive strength of the hybrid composite reinforced with bamboo/sisal fibre, it is observed that the 0° fibre orientation composite is exhibiting higher compressive strength than 90° fibre orientation composite and bidirectional (0°/90°) fibre orientation composite.

3.1.3. Flexural test

Three-point bend test was done using UTM machine in accordance with ASTM standard to Measure the flexural strength of

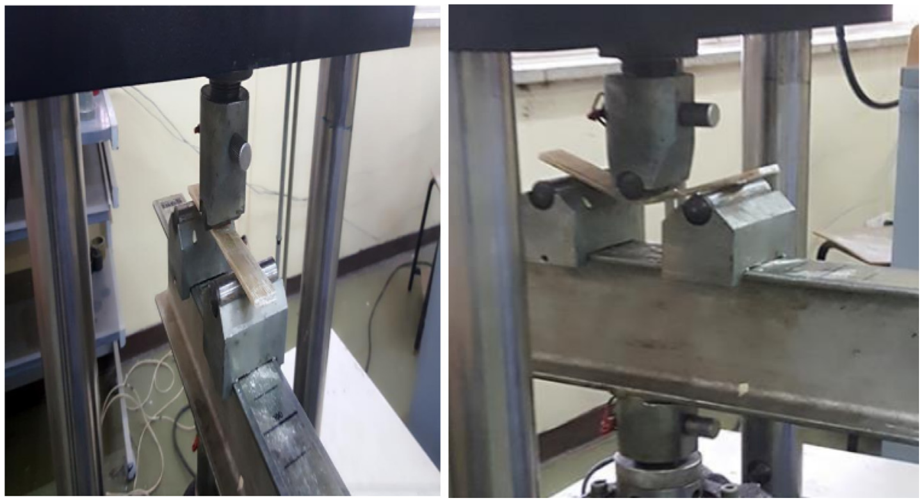


Fig. 10. Specimen under flexural testing.

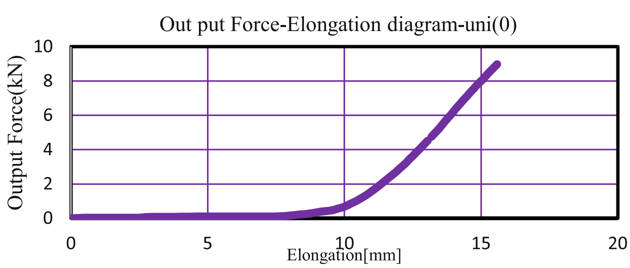


Fig. 11. Force Vs Elongation for 0° fiber orientation tensile test result.

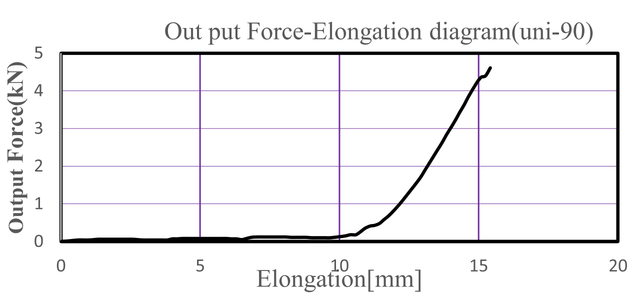


Fig. 12. Force Vs Elongation for 90° fiber orientation tensile test result.

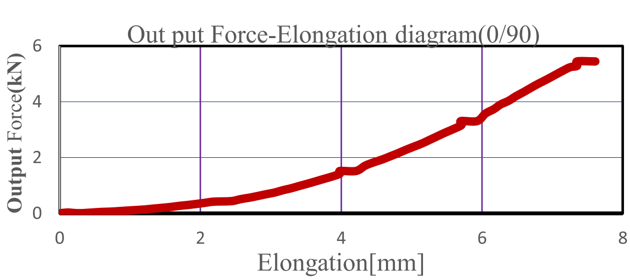


Fig. 13. Force Vs Elongation for (0/90) fiber orientation tensile test result.

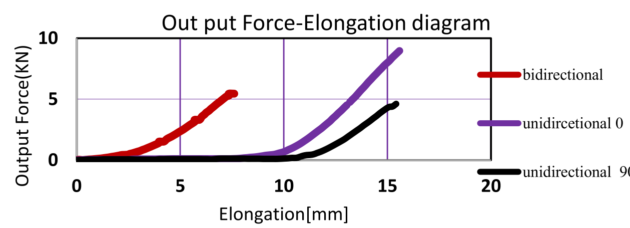


Fig. 14. Force Vs Elongation for three fibre orientation tensile test.

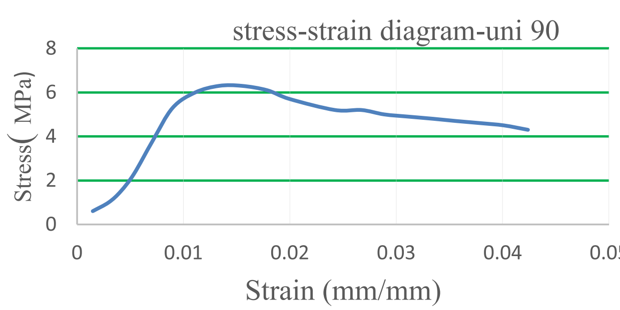


Fig. 15. Stress–strain for unidirectional 90° fiber orientation compression test result.

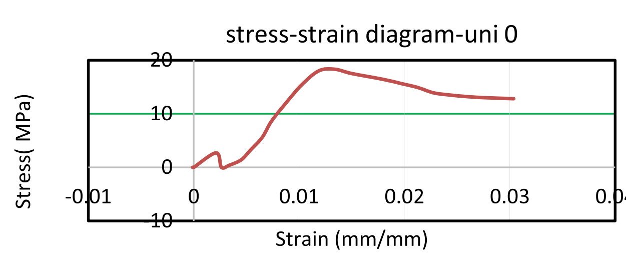


Fig. 16. Stress–strain for unidirectional 0° fiber orientation compression test result.

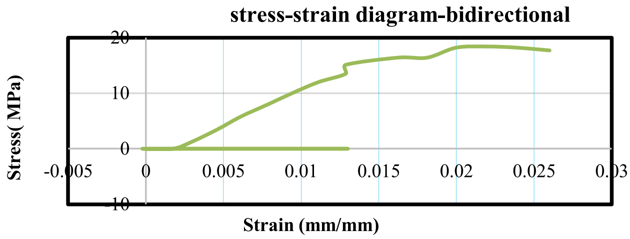


Fig. 17. Stress–strain for unidirectional (90°/0°) fiber orientation compression test result.

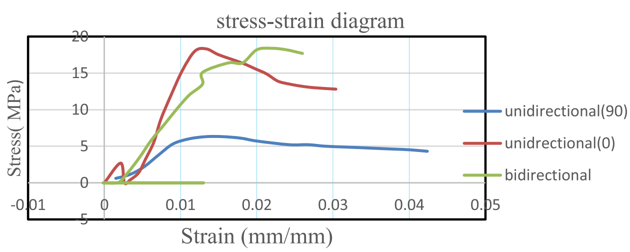


Fig. 18. Stress Vs. Strain for Each Fiber Orientation in Compression Test Result.

the composites. The load was applied in the middle span of the specimen. The span length was 128 mm, 25 mm width, and 170 mm overall length the test results are tabulated and presented in the Table 1 depending on the maximum values of the three specimens for each test condition.

From Table 1 as shown the above comparing three different fibre orientation of bamboo/sisal fibre reinforced hybrid composite the highest flexural strength is observed for 0° fibre orientation (149.1 MPa) and lowest in the case of 90° fibre orientation (79.55 MPa).

The maximum tensile force applied on the specimen is highest for bidirectional fibre orientation even its flexural strength is less than 0° fibre orientation due to its sample thickness of bidirectional fibre orientation. Maximum bending moment is observed on bidirectional fibre orientation and maximum bending stress observed in unidirectional 0° fibre orientation.

4. Conclusion

After determining properties of the composite material made of bamboo/sisal fiber reinforced hybrid composites with three different fiber orientation of the composite material the following conclusions can be drawn

Successful fabrication of the hybrid composite using bamboo/-sisal fiber reinforced polyester has been done by the hand layup technique.
Different mechanical properties of BSFRHC were determined from different fiber orientation.
In general, it is concluded that as varying fiber orientation, the tensile strength varies. The higher tensile strength is observed with 0° fibre orientation of bamboo/sisal fiber reinforced hybrid composite. From compressive strength of the hybrid composite reinforced with bamboo/sisal fibre, it is observed that the 0°-fibre orientation composite is exhibiting higher compressive strength than 90° fibre orientation composite and bidirectional (0°/90°) fibre orientation composite.
0° fiber orientation of bamboo/sisal hybrid composite samples have shown good strength in tension and by withstanding up to 84.4 MPa.
The 0°-fiber orientation of bamboo/sisal hybrid composite hybrid composite samples maximum flexural strength of 149.1 MPa.
Synthetic fibers are used to replace the natural fibers which are not comparable in properties. Two natural fibers can be used in combination instead of synthetic fibers. Now a day's most of automobile manufacture companies are trying to replace synthetic fibers with natural fibers. Fabrication of hybrid composite material with two natural fibers is advantageous for replacing synthetic fibers.
In this work, it is demonstrated the potential benefits of hybrid composite material as useful materials in the construction of lightweight vehicles.
From all the results and comparisons, we can conclude that the fabricated hybrid composite can be used in automobile parts which do not need a very high mechanical performance but need lightweight and recyclability such as an interior panel.

Table 1
Flexural test results.

No	Orientation	Designation	Width (**mm**)	Thickness (**mm**)	Initial measurement (**mm**)	**Maximum test force (N)**	Flexural Strength **MPa**
1	Unidirectional 90°	BSH-FS-1	66.666	5440	170	81.608	81.60
		BSH-FS-2	66.66	5312	166	79.68	80.27
		BSH-FS-3	66.66	5312	160	76.87	76.80
		Average					79.55
2	Bidirectional/plain woven	BSH-FS-1	96	12,096	378 N	126	118.12
		BSH-FS-2	96	12,160	380 N	126.6	118.75
		BSH-FS-3	96	12,288	384 N	128	120
		Average					118.9
3	Unidirectional 00	BSH-FS-1	66.66	9856	308	147.85	147.83
		BSH-FS-2	66.66	9920	310	148.94	148.80
		BSH-FS-3	66.66	10,048	314	150.87	150.71
		Average					149.1

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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