Impact and Flexural Testing of Jute and Flax Fiber Reinforced Composites Fabricated by VARTM Process

Chandresh B. Kumbhani, Harshit K. Dave, and Himanshu V. Patel

1 Introduction

The composite material is finding a broad area of application due to their superior property like increased tensile strength, good wear rate, high corrosion resistance, low density, etc. Development of new material is trending in today's time for penetrating more and more field of application. Glass fiber and carbon fiber has the highest strength to weight ratio but usage is limited due to non-bio degradability and high cost of synthetic fibers. So the interest of the researcher is rapidly growing towards natural fiber-reinforced composites (NFRC) in terms of their fundamental research and industrial applications. Their availability, price, recyclability, and strength make them attractive and alternative to glass, carbon fibers used for the manufacturing of composites. The advantage of NFRC in the automobile is a lightweight and high efficiency of the automobile [1, 2].

The orientation of fiber plays an important role in the mechanical properties of polymer composites like tensile strength, Compressive strength, impact strength, flexural strength, etc. [3]. If fibers are placed parallel to the loading direction then it gives the highest strength compared to other combinations. Properties of NFRC can be improved by providing some surface treatment like coating [4–8].

The addition of nanoparticle can improve the mechanical properties but the uniform dispersion is the main issue in addition to the nanoparticle. Nanoparticle develops a good fiber-matrix interface and due to this the tensile, flexural, and impact strength increases [9]. Hybrid composite gives a combination of different reinforcement and results in an improvement in properties. It can also improve the moisture

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H. K. Dave and D. Nedelcu (eds.), *Advances in Manufacturing Processes*, Lecture Notes in Mechanical Engineering, https://doi.org/10.1007/978-981-15-9117-4_30

absorption capacity of the composites [10, 11]. The water absorption tendency is the main drawback of NFRC. This property varies for different natural fibers. Fiber volume fraction (FVF) has a significant effect on the mechanical properties of NFRC [12, 13]. In an automobile, if we are able to reduce the weight of the system then efficiency and mileage can be increased. This is possible by the use of polymer composite using glass and carbon fiber as a recent trend but usage is limited due to environmental issues. So natural fiber is another option provided that NFRC should resist different types of load such as impact, bending, etc. Here, two different NFRC is prepared and mechanical testing (Impact and flexural) is carried out to see the effect of a number of layers on impact and flexural strength [13–16]. Fabrication of NFRC is done with the VARTM process as it gives good quality of components [17–19].

The reason behind these two testings is to check the suitability of natural fiber in the application where components are subjected to impact and flexural load like leaf spring in the automobile. A lot of researcher tries to implement synthetic composite material in leaf spring but the problem is with cost and we have to add number of leaf as compared to steel leaf. So natural fiber can reduce the cost of spring because they are easily available and reduce the weight of spring but number of leaf will be highest as compared to other all materials.

2 Materials and Methods

2.1 Materials

Details of material requirements and its supplier are given in Table 1 below. The Density and GSM are taken from the technical data sheet of the material provided by the supplier. Jute fiber and flax fiber are supplied by Basu jutex, Kolkata, and Vrukhsha Composites, Tenali respectively. The Mixing ratio is 100:30 by weight percentage of resin and hardener as per technical specification given by the supplier. The chemical Name of epoxy resin is bisphenol A diglycidyl ether and amines is used as hardener (Fig. 1).

Table 1 Properties of reinforcement material

Material	GSM	Density (g/cc)	Thickness (mm)
Jute fiber	215	1.3	0.70
Flax fiber	210	1.5	0.52

(a) Jute Fiber Fabric (b) Flax fiber Fabric

Fig. 1 Reinforcement materials

2.2 Fabrication of NFRC

For the fabrication of jute and flax fiber-reinforced composites, the experimental setup of the VARTM process is prepared as shown in Fig. 2. VARTM process gives good quality than hand layup and RTM process, especially in complex geometry. The strength obtained from the VARTM process-based composites is more due to high FVF (up to 60%) compared to other processes. Two types of mould are used one is glass mould and the other is flexible mould. The mould release agent is used for easy removal of the final part from the glass mould. The preform is placed over the glass mould and peel ply and infusion mesh is placed over it.

Fig. 2 Complete mould setup for VARTM process

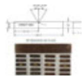


Fig. 3 Impact testing specimens

The preform is covered with sealant tape with the provision of inlet and outlet and the vacuum bag is covered on the mould. After mould preparation, the connection is given to the pump, and a vacuum is applied to check the leakage from the mould and ensure a pure vacuum environment inside the mould. Now by giving the pressure difference, the resin will flow from the preform and converge towards the outlet. After complete mould filling of resin, the mould is kept for 24 h for the curing of the resin.

2.3 Impact Test

Impact testing of flax and jute fiber-reinforced composites is carried out as per the ASTM D 256 standard. The specimen length is 63.5 mm, width is 12.7 mm and thickness varies from 3.5 mm to 5 mm. 2.5 mm deep V type notch with 45^0 angles and 0.25 mm radius is cut by AWJM. Five specimens from each specification are tested under the same conditions as shown in Figs. 3 and 4.

2.4 Flexural Test

3 point flexural testing of flax and jute fiber-reinforced composites is carried out as per ASTM D 7264 standard. The span to thickness ratio of 20:1 (20 × Thickness) is maintained in all specimens. The thickness of the specimen varies from 3.5 mm to 5 mm and the width of the specimen is 13 mm. the support span is 80 mm for flax 3 layer, flax 5 layer, and jute 5 layer and 100 mm for jute 7 layer. Three specimens from each specification are tested under the same conditions as shown in the figure. Specimens for flexural testing are shown in Fig. 5.

The maximum load that specimen can withstand up to failure is recorded and flexural strength is calculated using 3 points bending equation as shown below [ASTM D 7264].

$$\text{Flexural stress}\,\sigma = \frac{3PL}{2bh^2} \tag{1}$$

where P is load in N, L is supported span, b is the width of a specimen, and h is the thickness of the specimen.

Flexural testing of jute and flax fiber-reinforced composite is carried out using a tensometer of 20KN load cell supplied by kudale instruments private limited, Pune. The testing speed is 1 mm/min.

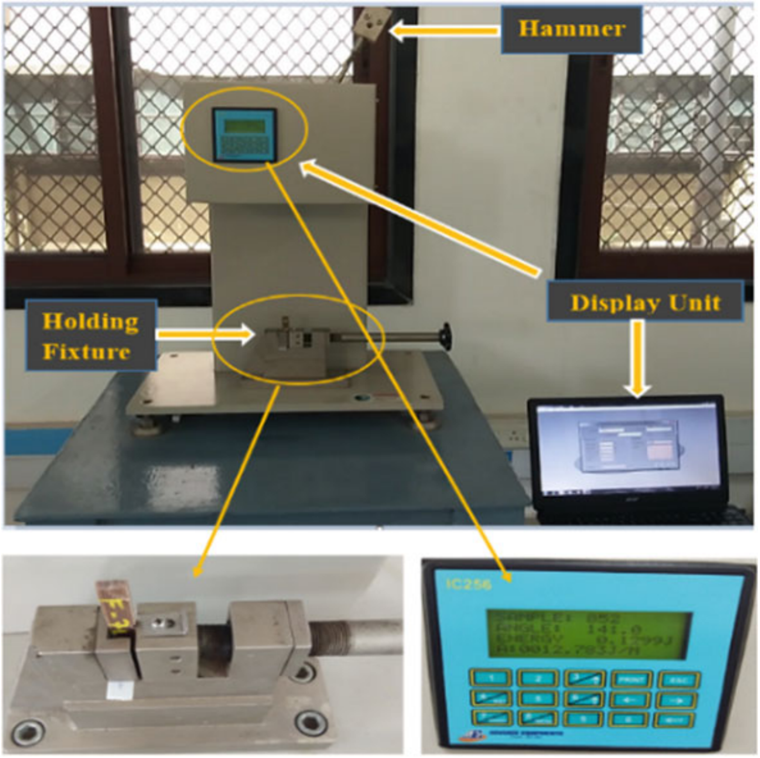


Fig. 4 Izod impact testing machine

3 Results and Discussion

3.1 Impact Test

The energy absorbed by the material is recorded for all specimens and impact energy calculated in J/m.

The reason for lower energy absorption is defects and notching of the specimen. The unnotched impact energy will more as compared to notched impact energy. The mean of all 5 specimens is taken and it is shown in Fig. 6.

The highest impact strength is found to be 44 J/m for flax 7 layer and lowest impact strength is found to be 37 J/m for jute 5 layer. The impact strength increases with an increase in a number of layers for both jute and flax fiber-reinforced composites. The FVF varies from 0.19 to 0.24 and this is the main reason for the small increase in impact strength. Energy absorbed by material increases with an increase in a number of the layer due to thickness variation.

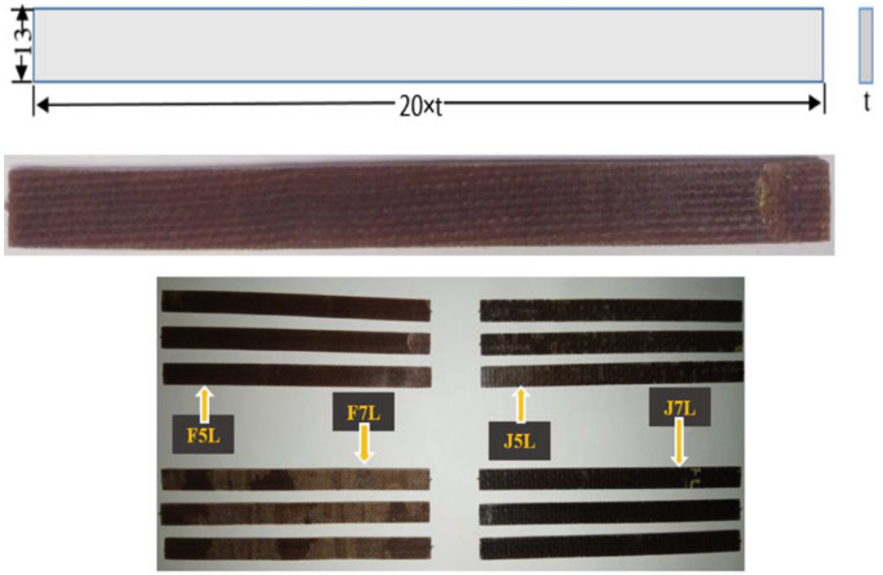
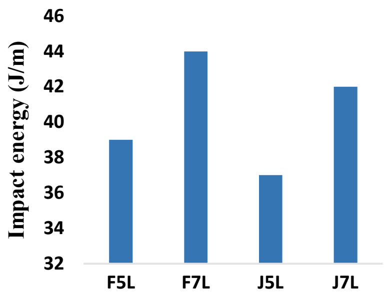


Fig. 5 Flexural testing specimens

Fig. 6 Impact strength of jute and flax fiber-reinforced composites



As we know that impact strength is low for both fiber as compared to synthetic fiber, but by this strength, we can calculate the approximate number of leaf required as per design procedure (Fig. 7).

Some images taken by a vision measuring system is shown in Fig. 8. The notch defect and voids are the main reasons for the low strength of the composites. The failure of the impact specimen is also shown in Fig. 8.

The failure in the notched specimen will always start from the notch and it will propagate into thickness direction. So fibers that are in a parallel direction to loading will not break but it will slip to adjacent layers and fibers which are perpendicular loading direction will first break as shown in the figure. First crack initiation will start from resin and after it suddenly breaks. Due to the brittle nature of this composite, the capacity of absorbing impact energy is less as compared to ductile materials.

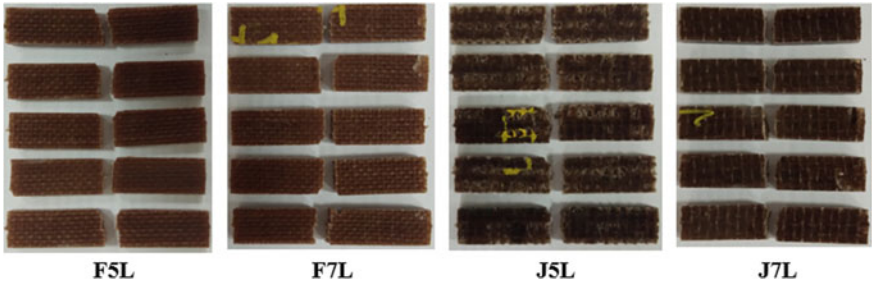


Fig. 7 Break sample after impact strength

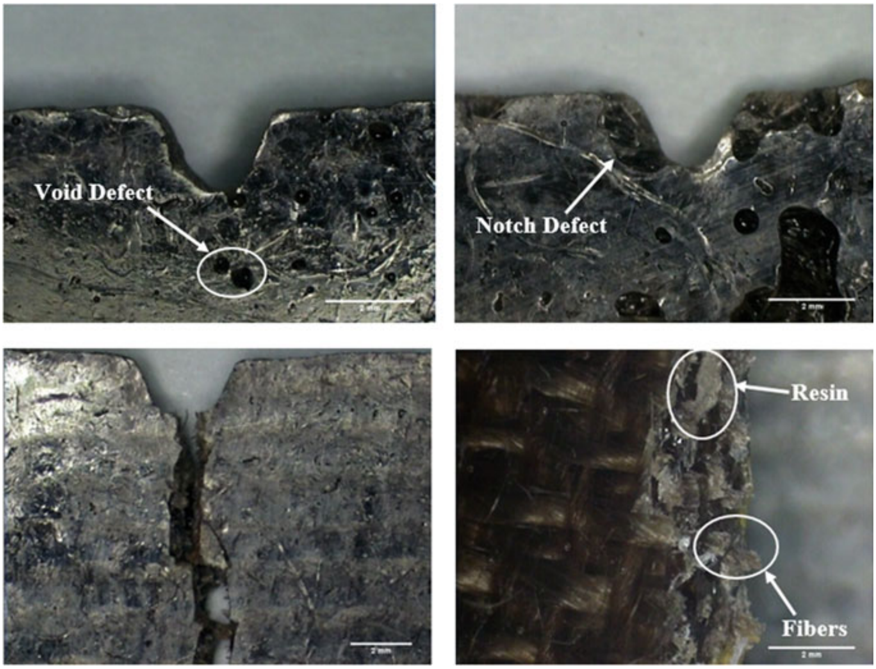


Fig. 8 Images captured by the vision measuring system

So the impact strength greatly depends on the amount of fiber presents in perpendicular to the loading direction. If we have more fibers in perpendicular to loading direction then impact strength will be high and vice versa.

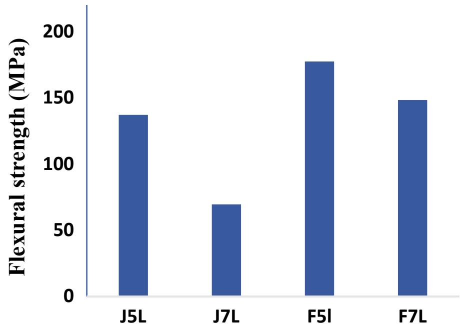


Fig. 9 Flexural strength of jute and flax fiber-reinforced composites

3.2 Flexural Testing

Total 4 combinations two for jute fiber and two for flax fiber with three replication is tested in tensometer. The results obtained from the flexural test is shown below (Fig. 9).

If we increase the number of the layer then the load required to break the specimen will increase but at the same time, the thickness of the specimen will also increase. The flexural strength is directly proportional to the load required to break the specimen and inversely proportional to the square of the thickness of the specimen. The denominator increases by square but the nominator will increases linearly as we can see in Eq. 5.1. That's why the flexural strength of the flax 5 layer is more as compared to the flax 7 layer.

Due to bending, the portion above the neutral layer will experience a tensile load, and the portion below will experience a compressive load. So failure will always happen at the top surface due to maximum stress and fiber is pulling out from the upper surface but here we cannot see fracture at the upper layer due to brittle fracture. The fracture of the flexural component is shown in Fig. 10.

4 Conclusion

The impact and flexural test for 5 and 7 layers of jute and flax fiber-reinforced composites are carried out and the following conclusion can be made.

1. Impact strength is found to be high for flax fiber-reinforced composites as compared to jute fiber-reinforced composites. The impact strength increases by increasing the number of layers.
2. Impact strength and flexural strength can be improved by increasing the fiber volume fraction of material.
3. Flexural strength of flax fiber-reinforced composite is high as compared to jute fiber-reinforced composite but it is decreasing by increasing number of layers.

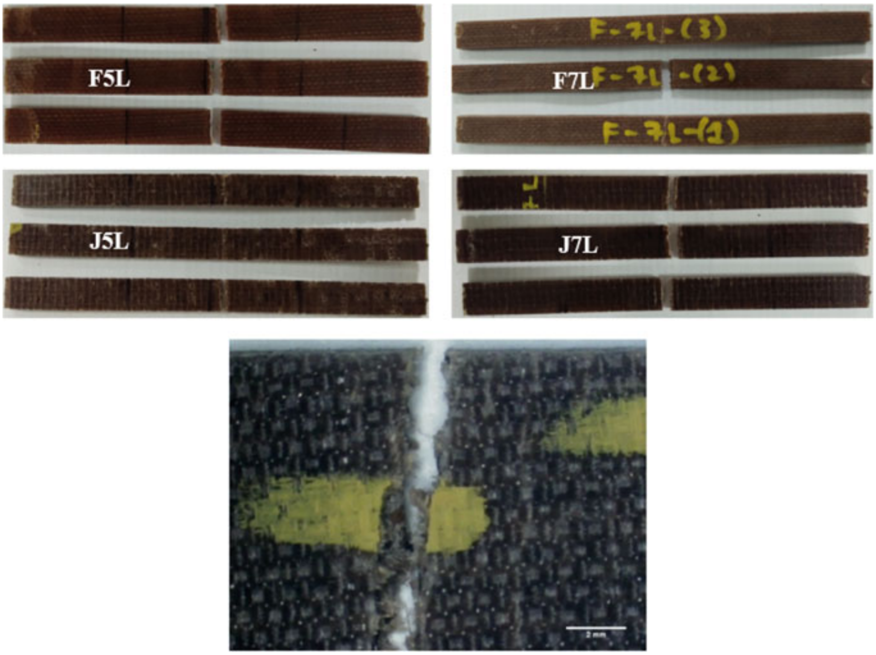


Fig. 10 Fracture behavior during flexural strength

4. By using natural fiber reinforced composite in leaf spring material, the number of leaf will be highest as it shows lower impact and flexural strength. It can minimize cost and weight of leaf spring.

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