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Experimental Investigations on Flexural Properties of Longitudinally and Transversely Placed Fiber Reinforced Polymeric Composites

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Abstract

In present study, an experimental investigation is carried out to evaluate flexural properties of longitudinally and transversely placed fiber reinforced polymeric composites. For this purpose, fabrication of composites is carried out by using mould and punch setup and following hand layup technique. Natural fiber yarn: bamboo fiber yarn, jute fiber yarn & flax fiber yarn and synthetic fiber yarn: kevlar fiber yarn, carbon fiber yarn & glass fiber yarn are selected as a reinforcement. Polyester resin is selected as a matrix. The flexural testing of composites is carried out on the universal testing machine as per ASTM D790-10 and evaluates the flexural properties of composites. The paper signifies the outcome as, flexural strength and flexural modulus are dependent on weight fraction of fiber and increases with increase in weight fraction of fiber in longitudinally placed fiber reinforced composites; flexural strength and flexural modulus are dependent on the interphase and its adhesion phenomenon in transversely placed fiber reinforced composites; flexural strength and flexural modulus are higher in longitudinally placed reinforced composites compared to transversely placed reinforced composites.

Keywords: Natural Fiber Composites, Synthetic Fiber Composites, Fabrication of Composites, Flexural Testing, Flexural Strength, Flexural Modulus.

INTRODUCTION

The composite material is fetching an inherent part of in the field of engineering materials because of their advantages as shown in fig.1. Due to this advantages of composites over a conventional material, composites rises the interest of the researchers all over the world. (Kaw, 2006). Here in present study, the composite material is selected as a part of study due to its several advantages and wide usage in today's world.

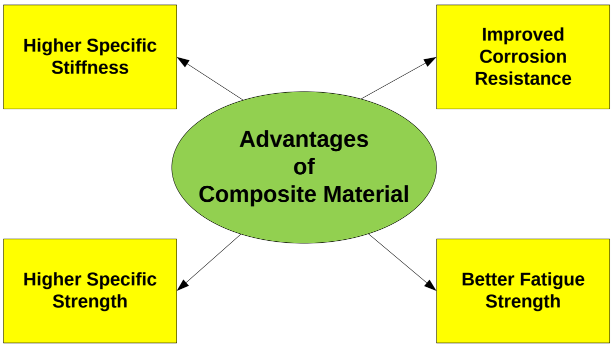

Figure 1. Advantages of composite material over a conventional material

Bax and Mussig (2008); Bledzki and Jaszkiewicz (2010); Coroller et al. (2013); Hojo et al. (2014); Lebrun et al. (2013); Okubo et al. (2004) studied only tensile properties of composites. Biswas et al. (2015); Chokshi et al. (2017); Couture et al. (2016); Khan (2016); Kumar and Boopathy (2014); Liu et al. (2014); Mishra and Biswas (2013); Porras et al. (2010); Saba et al. (2015); Yan et al. (2014); Zhi et al. (2001) studied the tensile and flexural properties of composites. Many of the researchers focused on tensile and flexural properties investigation of unidirectional and bidirectional composites. A very few researchers concentrated on the investigation on properties of composites by varying the fiber direction in longitudinal and transverse conditions. Gohil and Saikh (2010a) endeavored an effort in this direction and investigated the tensile properties of longitudinally placed reinforced cotton/polyester composites and evaluated that the tensile properties: tensile strength and elastic modulus increase with increase in volume fraction of fiber. Gohil and Saikh (2010b) also developed the model to evaluate the elastic modulus of transversally placed unidirectional fiber reinforced composites. Hence, this work is focused on investigation of flexural properties by varying the fiber direction and placing a longitudinal and transverse arrangement of fiber yarn in polymeric composites. Flexural properties are selected as a study due to it is widely usage in the application of automobiles, aircraft etc. For the accurate forecast of flexural properties, the natural fiber yarn and synthetic fiber yarn, both are taken as a part of the study. Flexural properties like flexura1 strength and flexural modulus are determined through the present study. Here, the experimental investigation is carried out for the determination of flexural properties of composites. For this purpose, natural fiber yarn and synthetic fiber yarn were taken and fabricated with polyester resin and prepared the natural fiber unidirectional composites and synthetic fiber yarn composites. The weight fraction of fiber was varied during the fabrication of composites. The samples were cut as per the ASTM D790-10 standards and tested on the universal testing machine. The flexural properties: flexural strength and flexural modulus were determined throgh the flexural testing.

MATERIALS AND METHODS

Natural fiber yarn: bamboo fiber yarn, jute fiber yarn & flax fiber yarn and synthetic fiber yarn: kevlar fiber yarn, carbon fiber yarn & glass fiber yarn were selected to determine the flexural properties of the fiber-reinforced polymeric composite as per their easy availability from the market. Bamboo fiber yarn and Jute fiber yarn were procured from Spinning King (India) Ltd., Ahmedabad as shown in Fig. 1 and Fig. 2 respectively. Flax fiber yarn was procured from Sampoorna Fashion, Surat as shown in Fig. 3. Natural fiber yarn is available in 12 counts, 24 counts etc. To maintain the uniformity and as per the availability, bamboo fiber yarn, jute fiber yarn and flax fiber yarn were taken 24 counts. Kevlar fiber yarn was procured from Chandak Expo International, Thane as shown in Fig. 5. Kevlar fiber yarns are available in 1000 denier, 4000 denier etc. Here, 1000 denier was chosen for kevlar fiber yarn due to it has smaller diameter and good strength. Carbon fiber yarn was procured from Jalrak carbon products, Vadodara as shown in Fig. 4. Carbon fiber yarns are available in 3K, 12K and 24K, among this 3K Carbon fiber yarn (3,000 filaments per "tow") was procured as per their low cost, higher elongation before failure and ultimate strength. Glass fiber yarn is available in the various forms like E-glass fiber yarn, C-glass fiber yarn etc., among this E-glass fiber yarn, was selected as a study due to its high strength and easy availability in the market. E-glass fiber yarn was procured from Aarvi Marketing Pvt. Ltd., Ahmedabad as shown in Fig. 6.


Figure 1. Bamboo fiber yarn


Figure 2. Jute fiber yarn


Figure 3. Flax fiber yarn


Figure 4. Kevlar fiber yarn


Figure 5. Carbon fiber yarn


Figure 6. Glass fiber yarn

E glass fibers are available in many ranges 150 1/0, 75 1/0, 150 1/2, 75 1/2, etc., among this "150 1/0" was procured due to lesser fiber yarn diameter and fibers are straight unidirectional. Here, in 150 1/0, The "150" means that one pound of the yarn has a length of 150*100=15000 yards. The 1 in "1/0" means that this yarn has one single strand in the yarn. The zero in "1/0" means that no twisted strands are pilled together in the completed yarn. E-glass 150 1/0 yarn would be a 300 denier yarn (Knott and George, 2005). The detailed specification of fiber is shown in Table 1.

Table 1. Specification of Fiber Yarn.

Sr. No.	Fiber yarn	Fiber Measurement Parameter (Count/Denier)
1	Bamboo fiber yarn	24 Count
2	Jute fiber yarn	24 Count
3	Flax fiber yarn	24 Count
4	Kevlar fiber yarn	1000 denier
5	Carbon fiber yarn	1800 denier
6	Glass fiber yarn	300 denier

Fabrication of composites

To determine a flexural behavior of longitudinally and transversely placed fiber reinforced composites, the fiber layers were arranged unidirectionally. For this purpose, the fibers were wounded on the wrapping machine and obtained the unidirectional layers for the fabrication of the composites. A sample of bamboo fiber yarn layer is shown in Fig. 7. The fabrication of composites was carried out by using hand layup technique and with the help of wooden mould and punch setup which is shown in Fig. 8.


Figure 7. Unidirectional bamboo fiber yarn layer


Figure 8. Mould and punch setup

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The resin was poured into the die. One layer of fiber yarn was laid down into the die over resin. The resin was poured again over the fiber and with the help of roller, the resin was spread uniformly among the fibers. One by one all the layers were inserted into the die and resin was poured and spread among the die. The punch is inserted into the die with the help of press to achieve desired thickness of the plate as per the ASTM D790-10 standard. Hardener (MEKP) and accelerator (Cobalt) were used in fabrication and curing was carried out for 24 hours. The fabrication of the composites was carried out by varying weight fraction of fibers. Here, for each type of fibers, 4 variations of weight fraction of fibers were taken for the fabrication of composites. So, total 24 composite plates were fabricated by using bamboo fiber yarn, jute fiber yarn, flax fiber yarn, Kevlar fiber yarn, carbon fiber yarn and glass fiber yarn. The sample of composites plates are shown in Fig. 9. The achieved weight fraction of fiber details and coding of composites are shown in Table 2.

(a) Bamboo/polyester composites plate-UDBPC

(b) Jute/polyester composites plate-UDJPC

(c) Flax/polyester composites plate-UDFPC

(d) Kevlar/polyester composites plate-UDKPC

(e) Carbon /polyester composites plate-UDCPC

(f) Glass/polyester composites plate- UDGPC

Figure 9. Composites Plate

Table 2. Coding and weight fraction of fiber details for composites.

Sr. No.	Composites Plate code	Weight fraction of fiber (%)
1	UDBPC-1	35.7895
2	UDBPC-2	30.0668
3	UDBPC-3	21.0993
4	UDBPC-4	15.3677
5	UDFPC-1	34.5016
6	UDFPC-2	27.8351
7	UDFPC-3	23.6345
8	UDFPC-4	19.4384
9	UDJPC-1	27.7778
10	UDJPC-2	24.1779
11	UDJPC-3	20.3459
12	UDJPC-4	18.1159
13	UDKPC-1	38.8727
14	UDKPC-2	31.4961
15	UDKPC-3	23.9044
16	UDKPC-4	16.4706
17	UDCPC-1	42.1687
18	UDCPC-2	35.0318
19	UDCPC-3	22.3464
20	UDCPC-4	11.5607
21	UDGPC-1	40.0433
22	UDGPC-2	31.4815
23	UDGPC-3	23.5897
24	UDGPC-4	16.4706

Flexural Testing of Composites

The specimens were cut on surface planner machine as per the ASTM D790-10 standard. Here, the specimens were cut in longitudinal (cutting is parallel to the line of direction of the fiber, at 0^0 orientation) and transverse direction (cutting is perpendicular to the line of direction of the fiber, at 90^0 orientation). The flexural testing was carried out on the universal testing machine (Make: TINIUS OLSEN, Model: L-H50KL) as shown in Fig. 10. Here, five specimens were tested and average of five specimens is considered as a result of composites as per ASTM D790-10.

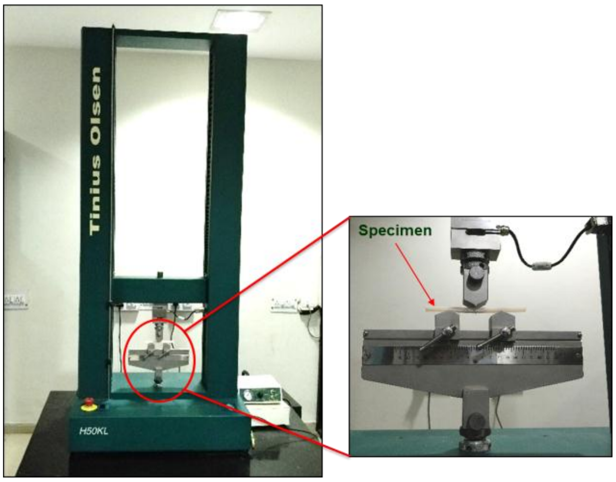

Figure 10. Universal Testing Machine (Make: TINIUS OLSEN, Model: L-H50KL)

RESULTS AND DISCUSSION

The results of flexural testing are shown and discussed below. The results of flexural strength and flexural modulus of longitudinally placed fiber reinforced composites are shown in Fig. 11 and Fig. 12.

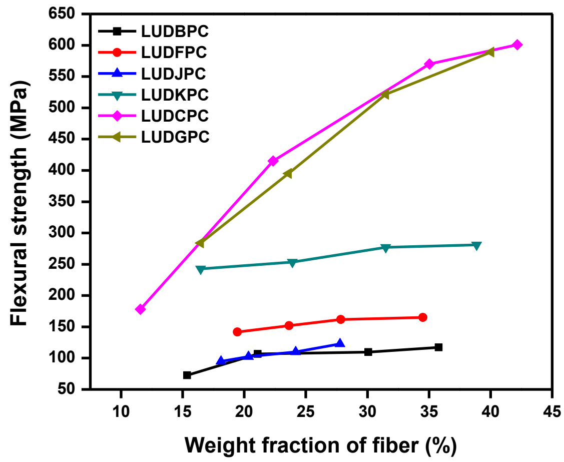

Figure 11. Flexural strength of longitudinal placed polymeric composites

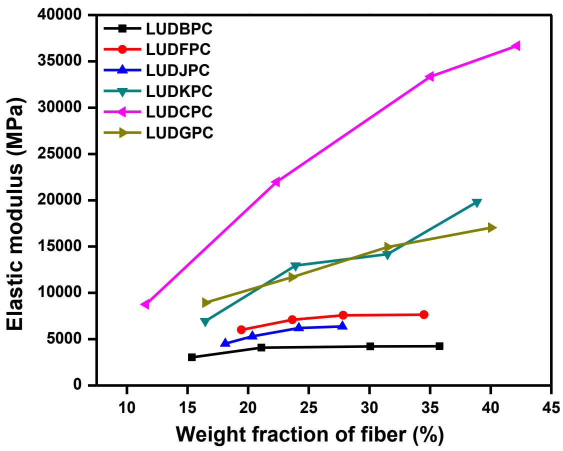

Figure 12. Flexural modulus of longitudinal placed polymeric composites

Fig. 11 shows that, with an increase in weight fraction of fiber, flexural strength of the composites increases gradually for all the types of fiber reinforced polymeric composites. Fig. 12 shows that, with an increase in weight fraction of fiber, flexural modulus of the composites increases gradually for all the types of fiber reinforced polymeric composites. The similar kind of results were observed by Ochi 2008 for kenaf/PLA composites. Hence, it can be said that in the longitudinally placed arrangement of the fiber, flexural properties are dependent on weight fraction of fiber and increases with increase in weight fraction of fiber. Here, the maximum weight fraction of fiber is achieved at 42.1687% for carbon/polyester composites. So, in this study, the behavior of flexural properties are determined up to the weight fraction of fiber 42.1687%. The comparison of natural fiber yarn composites with synthetic fiber yarn composites for the longitudinally placed arrangement of the fiber was carried out. Fig. 13 shows the comparison of flexural strength for natural fiber composites with synthetic fiber composites. Fig. 14 shows the comparison of elastic modulus for natural fiber composites with synthetic fiber composites. Here, the composites plate nos. are the numbers of plates which are having a different weight fraction of fiber in decrement order from 1 to 4.

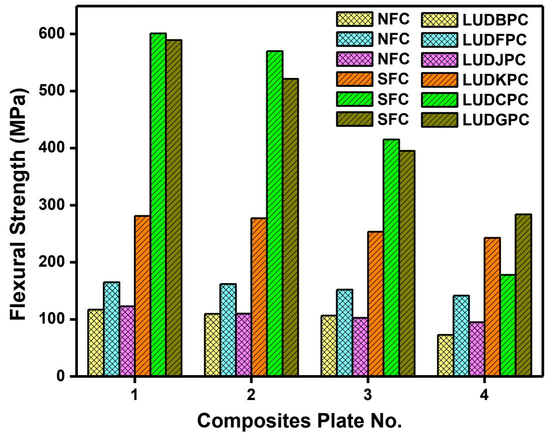

Figure 13. Comparison of flexural strength for natural fiber composites with synthetic fiber composites

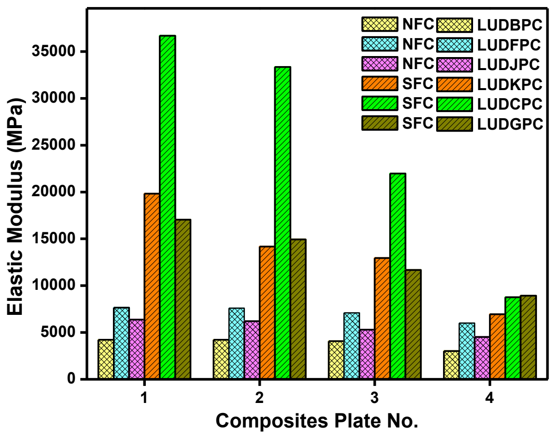

Figure 14. Comparison of elastic modulus for natural fiber composites with synthetic fiber composites

Fig.13 and Fig. 14 shows that the flexural strength and flexural modulus of synthetic fiber reinforced composites (Kevlar/Polyester Composites, Carbon/Polyester Composites and Glass/Polyester Composites) are higher than the natural fiber reinforced composites (Bamboo/Polyester Composites, Jute/Polyester Composites and Flax/Polyester Composites) as synthetic fibers are stronger than natural fibers. So, the synthetic fiber-reinforced composites can be preferred in the high strength applications and natural fiber-reinforced composites can be preferred in the medium strength applications. The results of flexural strength and flexural modulus of transversely placed fiber reinforced composites are shown in Fig. 15 & Fig. 16 and discussed below.

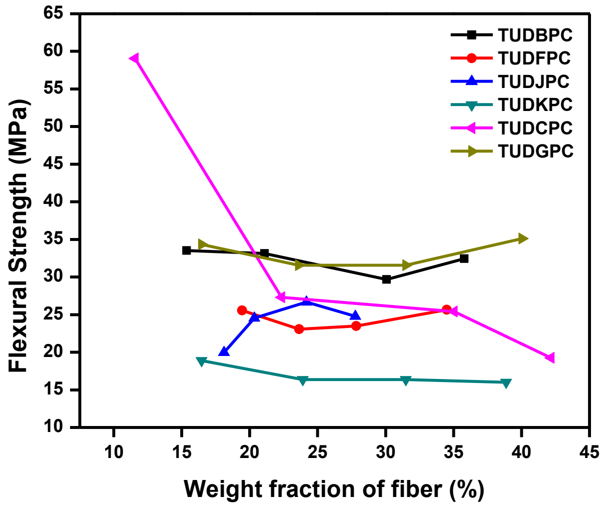

Figure 15. Flexural strength of transversely placed polymeric composites

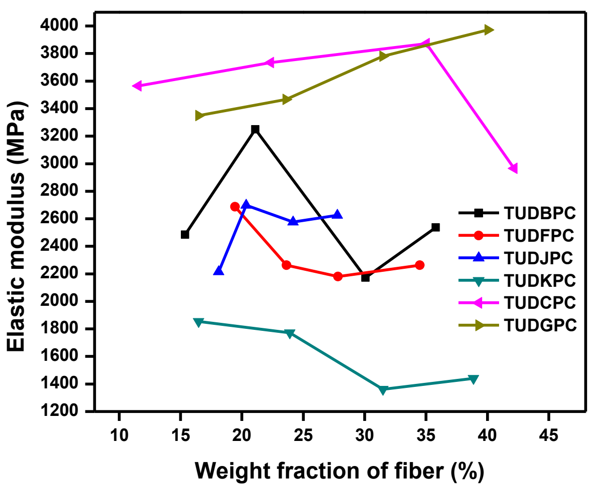

Figure 16. Elastic modulus of transversely placed polymeric composites

Fig. 16 shows that, in bamboo/polyester composites, flexural modulus follows uneven trend with increase in weight fraction of fiber. In flax/polyester composites, flexural modulus decreases gradually with increases in weight fraction of fiber up to 23.6345% and becomes stable after it with increase in weight fraction of fiber. In jute/polyester composites, flexural modulus increases gradually with increase in weight fraction of fiber up to 20.3459% and becomes stable after it with increase in weight fraction of fiber. In kevlar/polyester composites, flexural modulus decreases gradually with increase in weight fraction of fiber up to 31.4961% and becomes stable after it with increase in weight fraction of fiber. In carbon/polyester composites, flexural modulus increases gradually up to 35.0318% of weight fraction of fiber then decreases with increase in weight fraction of fiber. In glass/polyester composites, flexural modulus increases gradually with increase in weight fraction of fiber. These types of uneven responses are observed for flexural strength and flexural modulus because during the testing of transversely fiber reinforced composites, the flexural load (3-point bending) is distributed through the bonding between the fiber and resin and the failure of the bonding becomes the failure of the composite. Whereas in longitudinal fiber reinforced composites, fiber failure becomes the composite failure due to their longitudinal arrangement of the fiber. Bonding depends on adhesion, which was generated between fiber and matrix. So, in transversely placed fiber reinforced composites, the failure occurs at bonding says “interphase” due to the quality of adhesion generated within fiber and matrix. Here, fiber does not contribute to the performance of the composite due to inhomogeineties and imperfections of the adhesion within interphase. Here, in above results, the failure may be occurred due to adhesion was generated different with varying sample to sample. Hence, in transversely placed fiber reinforced composites, the adhesion phenomenon plays an important role for the determination of flexural properties of the composite.

Through the comparison of flexural properties of longitudinally placed fiber reinforced composites with transversely placed fiber reinforced composites composites, it is observed that flexural strength and flexural modulus are higher in longitudinally placed fiber reinforced composites.

CONCLUSIONS

The following significance outcomes are concluded through the present study.

- In longitudinally placed fiber reinforced composites, flexural properties: flexural strength and flexural modulus are dependent on weight fraction of fiber and increase with increase in weight fraction of fiber.
- In transversely placed fiber reinforced composites, flexural properties: flexural strength and flexural modulus are dependent on the interphase and its adhesion phenomenon engendered between fiber and matrix. Fiber does not contribute to the performance of the composite due to inhomogeineties and imperfections of the adhesion within interphase.
- Flexural strength and flexural modulus are higher in longitudinally placed reinforced composites compared to transversely placed reinforced composites.

NOMENCLATURES

NFC	Natural fiber composites
SFC	Synthetic fiber composites
UDBPC	Unidirectional bamboo/ polyester composites
UDFPC	Unidirectional flax/ polyester composites
UDJPC	Unidirectional jute/ polyester composites
UDKPC	Unidirectional kevlar/ polyester composites
UDCPC	Unidirectional carbon/ polyester composites
UDGPC	Unidirectional glass/ polyester composites
LUDBPC	Longitudinally placed bamboo reinforced polyester composites
LUDFPC	Longitudinally placed flax reinforced polyester composites
LUDJPC	Longitudinally placed jute reinforced polyester composites
LUDKPC	Longitudinally placed kevlar reinforced polyester composites
LUDCPC	Longitudinally placed carbon reinforced polyester composites
LUDGPC	Longitudinally placed glass reinforced polyester composites
TUDBPC	Transversely placed bamboo reinforced polyester composites
TUDFPC	Transversely placed flax reinforced polyester composites
TUDJPC	Transversely placed jute reinforced polyester composites
TUDKPC	Transversely placed kevlar reinforced polyester composites
TUDCPC	Transversely placed carbon reinforced polyester composites
TUDGPC	Transversely placed glass reinforced polyester composites

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