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Effect of inter-laminar fibre orientation on the tensile properties of sisal fibre reinforced polyester composites

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Abstract. In this present work, effects of interlamina fibre orientation on the tensile properties of composites were studied and the results were discussed. The varying types of fibre oriented composites were prepared using the compression moulding technique at a pressure of 17 MPa. The different types of oriented composites investigated were 90°/0°/90°, 0°/90°/0°, 90°/0°/0°/90°, 0°/45°/0°, 0°/90°/45°/45°/90°/0°, 0°/45°/90°/90°/45°/0° and these composites were subjected to tensile testing according to ASTM: D3039-08. The sisal fibres were arranged in various angles with the help of specially designed mould. It was found that the tensile strength of sisal fibre composites improved when 0° oriented fibres were positioned at the extreme layers of the composites compared to 90° oriented fibres. The highest tensile strength among the types of composites was observed for 0°/90°/0°. The scanning electron microscopy (SEM) analysis was performed to understand the interphase adhesion mechanism.

1. Introduction

Increasing fear over the greenhouse effects and environmental awareness have stimulated the use of natural fibres to replace the synthetic polymeric fibres in many fields such as automotive, construction, packing and civil industries. Since natural fibres are easily available in fibrous form and cheaper to buy than the synthetic fibres, they are a good replacement of conventional synthetic fibres.

Silva *et al.* [1] studied the behaviour of high performance sisal fibres. They investigated the cross sectional areas of sisal fibres using the scanning electron microscopy technique. Moreover, Belaadi *et al.* [2] studied the tensile properties of the sisal fibres. They reported that the sisal fibres offer a good reinforcement compared to other natural fibres, owing to the less extraction cost for retting process from the plants. They found that the diameter of the fibres, strength and strain to failure and Young's modulus of about 15 different fibres. The same results have been compared with literatures [3-5]. Ku *et al.* [6] investigated the mechanical properties of natural fibre composites. Owing to their favourable characteristics like low cost, high specific strength, good mechanical properties, eco-friendly, non-abrasive and bio-degradability, the natural fibres are proposed as the alternative to synthetic/artificial fibres such as carbon, aramid, glass, etc. They also reported that the tensile properties of natural fibre composites are dependent on the interfacial bond between the fibres and the matrix. Sen and Reddy [7]



described the many applications of natural fibres such as coir, bamboo, sisal and jute. They reported that amongst the many natural fibres, bamboo, sisal, coir and jute have higher impact strength and moderate flexural and tensile properties. Among the applications of sisal fibres include ropes, mats, cement reinforcements, carpets etc. Li and Shen [8] studied a single fibre pull out test for sisal fibre and analyzed its multi scale structures and dimensional parameters. In addition, the researchers also developed many theoretical models and compared the results with the experimental results.

Alavudeen *et al.* [9] studied the effect of fibre orientations in the natural fibre composites. They found that the properties of composites are influenced by varying the fibre orientations. Bennet *et al.* [10] studied the effects of lamina fibre orientation using the natural fibres. The orientations of fibre composites that were investigated include 0 °, 30 °, 45 °, 60 ° and 90 °. Among the composites, 0 ° oriented fibres composite provided the highest strength in tensile properties. Furthermore, they also studied the vibration properties of these oriented fibre composites. Almeida *et al.* [11] studied the fibre orientation on shear behaviour of synthetic fibre composites. They prepared [0]₅, [90]₅, [0/90/0/90/0] and randomly-oriented (mat) types of composite. Mortazavian and Fatemi [12] investigated the effects of fibre orientation and anisotropy properties of natural fibre composites. They found that the tensile and elastic modulus of the composites decreased with the specimen angle. Effects of fibre orientation and fibre aspect ratio on the tensile strength of carbon fibres reinforced magnesium matrix composites (Csf /Mg) were analyzed by Qi *et al.* [13]. They found that the angle between the fibres and applied load on the composites played an important role on the strength of the composites. Therefore, in this present study, natural fibre composites with varying fibre orientations were fabricated by using the compression moulding machine and subjected to tensile test.

2. Experimental details

2.1. Materials

Sisal fibre used in this study was supplied by Shiva exports, Tirunelveli, Tamilnadu, India. On the other hand, the unsaturated isophthalic polyester resin, initiator and accelerator were supplied by Vasivibala resins (P) Ltd, Chennai, Tamilnadu, India.

2.2. Fabrication of composites

Initially, the sisal fibres were combed and arranged carefully as long fibres in the mould according to the type of selected orientation of the composite. To achieve the fibre weight percentage of 50±2, the desired amount of fibres was taken into the specially designed mould. To ensure the desired angle of fibre orientation, the mould consisted of markings for every angle at the periphery. Then, 100 ml of resin, 1.5 % of catalyst and 1.5 % of accelerator were added to it. The mixture was poured over the fibres and kept in the compression moulding machine at a pressure of 17 MPa. The composite was left about 24 hours in the moulding machine for curing and were later cut according to ASTM standard.

2.3. Tensile testing

Tensile tests were carried out using Instron (Series-3382) testing machine according to ASTM: D3039-08. The specimens were cut according to the dimension of 200 × 20 × 3 mm. A 100 kN load cell was used and a speed of 2 mm/min was applied on the samples. An average of five specimens were used in each test.

3. Result and discussion

To ease the discussion, the notations tabulated in Table 1 will be used in this paper after this point to indicate the different fibre orientations for the sisal fibre oriented composites. The effect of interlamina fibre orientation on the tensile strength of sisal fibre polyester composites is shown in Figure 1. The tensile strength was determined for the different fibre orientation and it was found that the orientation 0 ° /90° /0° had the greatest tensile strength of 46.716 MPa when compared to other types of oriented composites. It was noticed that the extreme layers of fibres oriented in 0 ° at both ends of composites

($0^\circ/90^\circ/0^\circ$, $0^\circ/45^\circ/0^\circ$, $0^\circ/90^\circ/45^\circ/45^\circ/90^\circ/0^\circ$ and $0^\circ/45^\circ/90^\circ/90^\circ/45^\circ/0^\circ$) showed higher tensile strength than the other types of composites. This is due to the fact that 0° fibres were arranged longitudinally (i.e along the direction to the applied loading condition). Hence the fibres oriented at 0° along the applying load conditions would withstand higher load while testing. On the other hand, the lower tensile strengths were measured in $90^\circ/0^\circ/90^\circ$ and $90^\circ/0^\circ/0^\circ/90^\circ$ oriented fibre composites. It was noticed that among the different types of oriented fibre composites, 90° at the extreme layered composites gave the lowest tensile strength. While testing these composites, the fibres were oriented at 90° that were perpendicular to the loading conditions. Therefore, the fibres did not withstand any load while testing the composites.

Table 1. Notations and descriptions

Notation	Description
1	$90^\circ/0^\circ/90^\circ$
2	$0^\circ/90^\circ/0^\circ$
3	$90^\circ/0^\circ/0^\circ/90^\circ$
4	$0^\circ/45^\circ/0^\circ$
5	$0^\circ/90^\circ/45^\circ/45^\circ/90^\circ/0^\circ$
6	$0^\circ/45^\circ/90^\circ/90^\circ/45^\circ/0^\circ$

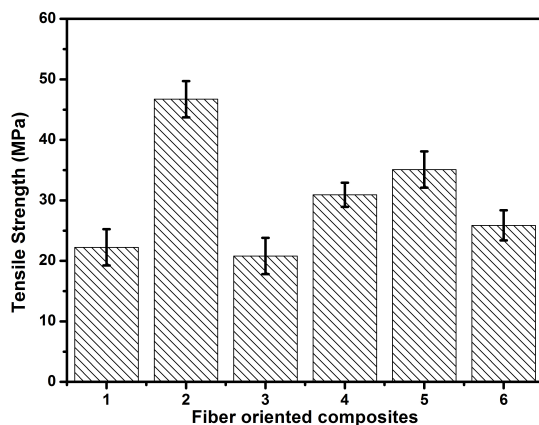


Figure 1. Effect of inter lamina fibre orientation on tensile strength of sisal fibre polyester composites

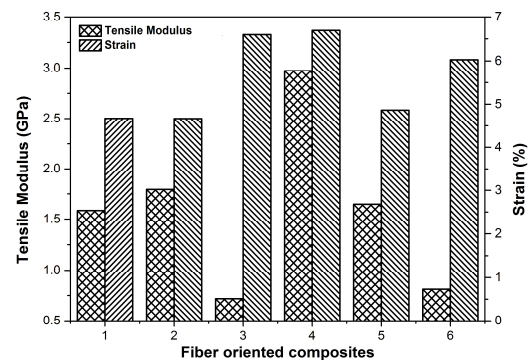


Figure 2. Tensile modulus vs strain of sisal fibre polyester composites

The tensile strengths of the panels measured at $90^\circ/0^\circ/90^\circ$ and $90^\circ/0^\circ/0^\circ/90^\circ$ were 22.24 MPa and 20.80 MPa, respectively. Comparing the $0^\circ/90^\circ/45^\circ/45^\circ/90^\circ/0^\circ$ types of composites with the $0^\circ/45^\circ/0^\circ$ and $0^\circ/45^\circ/90^\circ/90^\circ/45^\circ/0^\circ$, they were able to withstand more loads in testing. It was confirmed that next to 0° oriented fibres, 90° oriented fibre composites had a higher strength than the 45° oriented fibre composites. The effects of tensile modulus and strain of fibre oriented composites are shown in Figure 2. The increase in the stiffness of the composites was observed for the 0° fibres that were positioned as the skin of composites. From Figure 2, it is shown that the tensile modulus of $90^\circ/0^\circ/0^\circ/90^\circ$ and $0^\circ/45^\circ/90^\circ/90^\circ/45^\circ/0^\circ$ composites was not appreciably increased. The tensile modulus of $0^\circ/45^\circ/0^\circ$ oriented fibre composite was 76 % higher than that of the $90^\circ/0^\circ/0^\circ/90^\circ$ fibre composites. Figure 2 shows the strain of the sisal fibre reinforced polyester composites. Higher strain was observed in $0^\circ/45^\circ/0^\circ$ type of fibre composites than the other types of combinations.

The SEM micrograph of the $0^\circ/90^\circ/0^\circ$ sisal fibre oriented composite is shown in Figure 3(a). It is inferred from this figure that the fibre is tightly covered by the strong matrix and this strong bonded matrix could be used to hold the fibres in their position. Consequently, the fibre pull out is avoided

owing to its strong interfacial bonding. Furthermore, the resin rich area shown in Figure 3(a) indicates the lack of cracking in the matrix, which can be attributed to a good packaging of materials. SEM images of the $90^\circ/0^\circ/0^\circ/90^\circ$ oriented sisal fibre composites taken after fracture under the tensile loading of fibre reinforced composites are shown in Figure 3(b) in which the separation of sisal fibres and hollow portion are clearly seen. This shows that the fibre pull-out have occurred in the composites.



Figure 3a. SEM studies on the effect of $0^\circ/90^\circ/0^\circ/90^\circ$ fibre orientation on the tensile strength of sisal fibre polyester composites

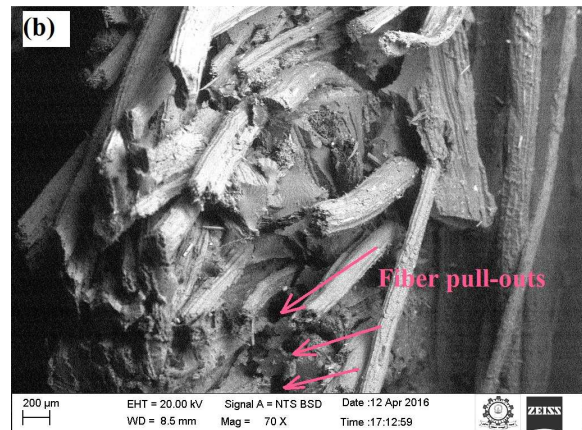


Figure 3b. SEM studies on the effect of $90^\circ/0^\circ/0^\circ/90^\circ$ fibre orientation on the tensile strength of sisal fibre polyester composites

4. Conclusion

The sisal fibre reinforced polyester composites were fabricated with different fibre orientations using a specially-designed mould in compressing moulding machine at a pressure of 17 MPa. Experimental results showed that $0^\circ/90^\circ/0^\circ$ type of composites gave the highest strength than the other types of combinations. It was also found that the tensile strength of the composite was lower when the extreme fibres were oriented in 90° compared to the 0° oriented fibre composites. The highest tensile modulus and strain were measured for $0^\circ/45^\circ/0^\circ$ oriented fibre composite.

Acknowledgments

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References

- [1] Silva F A, Nikhilesh C and Romildo D 2008 *Compos. Sci. Technol.* **68** 3438-43
- [2] Belaadi A, Bezazia A, Bourchakb M and Scarpac F 2013 *Mater. Des.* **46** 76-83
- [3] Munawar S S, Umemura K and Kawai S 2007 *Journal of Wood Science* **53** 108–13
- [4] Filho T R D 1997 *Natural fiber reinforced mortar composites: Experimental characterization* PhD thesis PUC-Rio (Brazil), Department of Civil Engineering
- [5] Bessell T J and Mutuli S M 1982 *J. Mater. Sci. Lett.* **1** 244–6
- [6] Ku H, Wang H, Pattarachaiyakooop N and Trada M 2011 *Composites Part B* **42** 856-73
- [7] Tara S and Jagannatha R 2011 *International Journal of Innovation, Management and Technology* **2** 186-91
- [8] Li Y and Shen Y O 2015 *Biofiber reinforcement in composite materials* (Netherland, Wood Head Publishing) 165-210

- [9] Alavudeen A, Rajini N, Karthikeyan S, Thiruchitrabalam M and Venkateshwareen N 2015 *Mater. Des.* **66** 246-57
- [10] Bennet C, Rajini N, Winowlin Jappes J T, Venkatesh A, Harinarayanan S and Vinothkumar G 2014 *Advanced Material Research* **984-985** 172-77
- [11] Almeida J H, Angrizani C C, Botelho E C and Amico S C 2015 *Mater. Des.* **65** 789-95
- [12] Mortazavian S and Ali F 2014 *Composites Part B* **72** 116-29
- [13] Qi L H, Ma Y Q, Zhou J M, Hou X H and Li H J 2015 *Mater. Sci. Eng. A* **652** 343-49