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Interlaminar Shear Strength of Polycarbonate Toughened Epoxy- Bamboo Fiber Composites

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Abstract: The effect of polycarbonate content on Interlaminar Shear Strength of Epoxy-PC blend matrix is studied and it is observed that the blend matrix Epoxy-PC containing 10% of weight of PC showed to have maximum Interlaminar Shear strength. Poly carbonate (10% of weight) toughened epoxy-bamboo fiber composites have been developed with varying fiber content and it is evident that the Interlaminar Shear strength of the composites is increased with the increase in the fiber content. It is further observed that the Interlaminar Shear Strength is low in pure epoxy when compared to Epoxy-PC blend matrix, due to excellent toughness of PC.

Keywords: Poly carbonate, Interlaminar shear strength, fiber content, Epoxy-PC blend matrix.

Introduction

As the usage of polymer composite is increasing, several methods have been adopted to improve their properties and reduce the cost. Matrix modification is one such method. Epoxy resin can be toughened by mixing it either with elastomers or even with ductile thermoplastics before curing. Epoxy resin is toughened with polycarbonate (PC) by Chen et al. [1]. Recently Varadarajulu et al. [2] studied the miscibility of Epoxy/PC blends in dichloromethane by viscosity, ultrasonic and refractive index methods. They reported that the blend is miscible at all proportions. Varadarajulu et al. [3] coated bamboo fibers with the blends of epoxy, PC and reported improved mechanical and chemical resistance properties upon coating. Hourston et al. [4] toughened epoxy with polyetherimide (PEI) in varying proportions.

They reported that the blend is homogeneous in nature. They further reported that the addition of PEI gave a significant improvement in fracture properties. D' Almeida [5] studied the effects of distilled water and saline solution on the interlaminar shear strength (ILSS) of an aramid/epoxy composite. Their experimental results showed that the composite is affected by a similar degradation mechanism in both media. However, a greater absorption rate measured for specimens immersed in distilled water resulted in a faster decrease of ILSS values in distilled water than in saltwater.

Deng and Ye [6] studied the influence of fiber/matrix adhesion on mechanical properties of graphite/epoxy composites. They reported that, with the improvement of fiber/matrix adhesion by fiber surface treatment and sizing, Mode-I and Mode-II IFT, ILSS, and in-plane shear strength (ISS) of the composite clearly increased. Varadarajulu et al. [7] studied the ILSS of PC toughened epoxy composites reinforced with glass roving's. The ILSS of PC toughened epoxy composite reinforced with glass roving's is found to be lower than that with epoxy alone as matrix. In the present work, bamboo fiber reinforced polycarbonate epoxy composites have been developed and studied their interlaminar shear strength (ILSS) properties by varying the mat content. The effect of polycarbonate content on interlaminar shear strength of Epoxy-PC blend matrix is also studied and the results are presented in this paper.

Materials and Methods

A. Materials:

The Epoxy resin araldite LY–556 (M/s Huntsman advanced materials) and curing agent, hardener HY–951 and polycarbonate (M/s Dow chemical company) system is used as the matrix. Dichloromethane (M/s S.D. Fine chemicals) is used as the solvent in the preparation of the blend, sodium hydroxide is used for surface modification of fibers. The Bamboo fiber mat (Dendrocalamus strictus) is used as the reinforcement and cut according to mould dimensions.

B. Methods:

- **Sample preparation**

A glass mould with 150 x 150 x 3 mm [Length x Width x Depth] dimensions is employed for the preparation of ILSS test specimens. The mould is coated with a thin layer of aqueous solution of poly vinyl alcohol (PVA) which acted as a good releasing agent. In order to make the blend, the epoxy resin is added with polycarbonate dissolved in dichloromethane. The solvent is removed by degassing in vacuum for about one hour. The blend and the hardener are mixed in the ratio 100:10 parts by weight respectively. Composites with bamboo fiber mat as reinforcement are prepared using PC toughened epoxy resin and cured for 24 hrs at room temperature. To ensure complete curing, the composite sheets are post cured at 100^0C for three hours. Then they are cut to required size and shape according to the ASTM standards. In order to obtain optimum content of polycarbonate in Epoxy-PC blend, the specimens of matrix material are also prepared in similar lines.

- **Testing**

The ILSS test is performed using Instron 3369 Universal Testing Machine. The test specimens with 22 mm x 6 mm x 3 mm dimensions are cut as per ASTM D 2344–84 specifications. The cross-head speed is maintained at 1 mm/minute. The temperature and humidity for this test are maintained at 22^OC and 50% respectively. In each case, seven specimens are tested and average value is recorded.

Results and Discussions

A. Effect of Poly carbonates Content on ILSS of Epoxy-Pc Blend Matrix:

The blend matrices Epoxy–PC with varying weight percentage (wt%) of PC content in epoxy are prepared. They are first subjected to mechanical strength analysis and then the blend matrix that showed the maximum interlaminar shear strength among the combinations is chosen to be the matrix for developing composites. From Table 3.1 it is observed that the blend matrix Epoxy–PC containing 10 wt% of PC showed to have maximum interlaminar shear strength. On the basis of the result, this combination is selected as the matrix to prepare composites. The variation of interlaminar shear strength with varying polycarbonate content in Epoxy–PC blend matrix is presented in Figure 1. From the Figure 1 and Table 1, it is evident that the interlaminar shear strength of Epoxy-PC blend increased upto 10 wt% of PC content in epoxy and on further increase in the PC content, the strength decreased. It is further observed that the ILSS is low in pure epoxy when compared to Epoxy-PC blend matrix, due to excellent toughness of PC.

Table 1: Interlaminar Shear Strength of Epoxy-PC blend matrix.

Sample No	Wt. % of PC in Epoxy	Interlaminar shear strength	% increment over pure epoxy
1	0	10.30	--
2	2.5	13.88	34.75
3	5	15.47	50.19
4	7.5	16.25	57.71
5	10	16.88	63.88
6	12.5	15.89	54.27
7	15	13.42	30.29

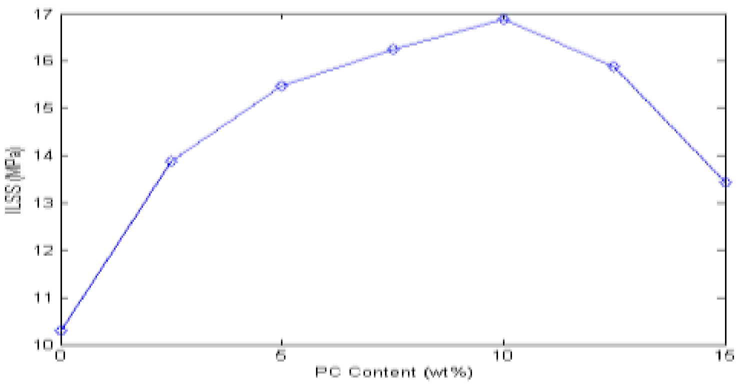

Figure 1: Variation of interlaminar shear strength with PC content in Epoxy-PC blend matrix.

B. Effect of fiber mat content on ILSS of the composite

The interlaminar shear strength of longitudinally oriented and transversely oriented PC toughened epoxy-bamboo fiber composites with different fiber mat content are presented in Table 2. For comparison, the value for the matrix is also presented in the same table. The total fiber loading of the composites is varied from 10 to 40 wt%. The variation of interlaminar shear strength of the composites with fiber mat content is presented in Figure 2. From the Figure 2, it is clearly evident that, in both the cases (longitudinally oriented and transversely orientated), for 40 wt% of fiber mat content, the interlaminar shear strength is found to be lower than that of the composites with 30 wt% fiber mat content, The decrease in the ILSS at higher fiber loading (>30 wt%) is due to the increased fiber-fiber interactions, leading to a poor load transmission between the fibers. Moreover, higher fiber contents also imply resin starved areas which lead to a generally insufficient fiber-matrix adhesion for stress transfer.

From the Table 2, it is observed that the longitudinally oriented composites showed superior properties than transversely oriented composites. This is due to the fact that the longitudinally oriented composites are inherently anisotropic in that the maximum strength is achieved along the direction of fiber alignment. Similar observation was made by Geethamma et al. In the case of short coir fiber reinforced natural rubber composites and concluded that in general, the mechanical properties of the composites in the longitudinal direction are superior to those in the transverse direction. On the other hand, in the case of transverse fiber orientation bamboo fiber does not reinforce, it even weakens the characteristics of Epoxy–PC blend, just like other fibers.

From Table 2, it is further observed that the interlaminar shear strength for longitudinally oriented composites is higher than that of the matrix. This observation indicates that the surface condition of bamboo fibers is good for adhesion with matrix. The longitudinally oriented PC toughened epoxy-bamboo fiber composites are having improved ILSS values over the matrix. Thus, the bamboo fibers have good compatibility with Epoxy–PC blend matrix used in the present work.

Table 2: Variation of ILSS of PC toughened epoxy-bamboo fiber composites with fiber mat content

S. No	Fiber mat content (wt %)	Interlaminar shear strength (Mpa)		Modulas (Mpa)	
		Longitudinal	Transverse	Longitudinal	Transverse
1	10	17.83	3.10	3395.29	2566.12
2	20	19.56	3.95	3919.60	2159.40
3	30	22.87	5.44	4120.15	2516.72
4	40	19.15	4.46	3783.50	2083.82
5	Matrix	16.80		3158.08	

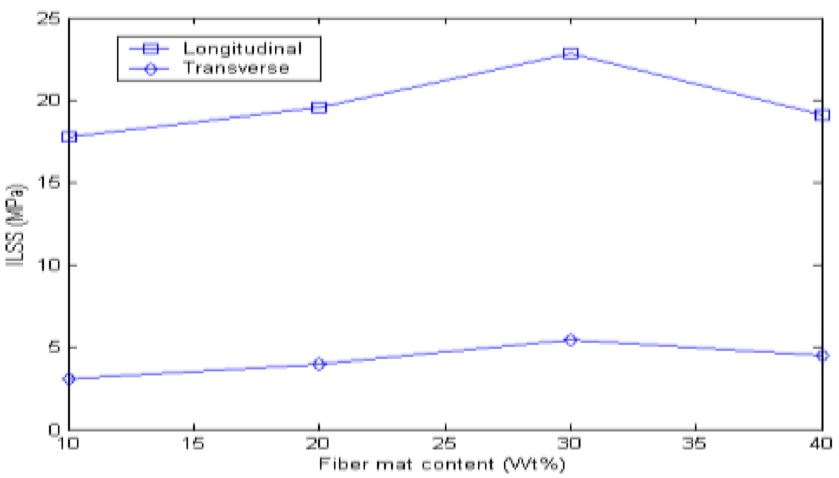

Figure 2: Variation of ILSS of longitudinal and transverse oriented PC toughened epoxy-bamboo fiber composites with fiber mat content

Conclusion

The critical study of results and discussion presented in this paper, yields note worthy conclusions. The conclusions are identified and listed below:

- The blend matrix Epoxy–PC containing 10 wt% of PC showed to have maximum interlaminar shear strength. On the basis of the result, this combination is selected as the matrix to prepare composites.
- The ILSS is low in pure epoxy when compared to Epoxy-PC blend matrix, due to excellent toughness of PC.
- The interlaminar shear strength of longitudinally oriented bamboo fiber composites is higher than that of the blend matrix. This observation indicates that the surface condition of bamboo fibers is good for adhesion with matrix.
- The interlaminar shear strength of longitudinally and transversely oriented composites increase with increase in fiber content of upto 10 wt% and on further increase in the fiber content, the strength decreases. This decrease is mainly associated to the likelihood of fiber–fiber contact at high percentages (i.e. >30 wt %), leading to a poor load transmission between the fibers. Moreover, high fiber contents also imply resin starved areas which lead to generally insufficient fiber– matrix adhesion for stress transfer.
- The longitudinally oriented composites showed superior properties than transversely oriented composites. This is due to the fact that the longitudinally oriented composites are inherently anisotropic in that the maximum strength is achieved along the direction of fiber alignment.

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