Tensile and Impact Properties of Banana Fibre/Glass Fibre Hybrid Polyester Composites

Laly A. Pothan[1], Sabu Thomas[2] and Jayamol George[3]

[1]*Department of Chemistry, Bishop Moore College, Mavelikara 690110, Kerala, India.*
[2]*School Of Chemical Sciences, Mahatma Gandhi University, Priyadarshini Hills P.O., Kottayam 686 560, Kerala, India.*
[3]*Department of Metaalkunde en Toegepaste Materiaalkunde (MTM), Katholieke Universiteit Leuven, de Croylaan 2,B-3001 Leuven, Belgium.*

SUMMARY: Variations in tensile and impact properties of banana fibre reinforced polyester composites caused by the addition of glass fibre have been analysed. Banana fibre in combination with glass is excellent for making cost effective composite materials. The effect of the arrangement of glass and banana fibre in the preparation of composites have also been studied. A volume fraction of 0.11 glass mixed with banana fibre gives 54.5 % increase in the tensile strength and 196 % increase in the impact strength of the composites. Linear increase in tensile strength is noted as a result of the increase of glass. The tensile strength shows the highest value when a glass volume fraction of 0.17 is used and an interleaving arrangement of glass and banana fibre is followed. However, when lower volume fraction of glass is used, an intimate mixture of banana fibre and glass shows the highest tensile strength. The impact strength shows the highest value when a glass volume fraction of 0.11 is used.

KEYWORDS: Cellulose, hybrid, random fibre, banana fibre.

INTRODUCTION

Multi-component composite materials comprising of two or more families of fibres have been attracting the attention of researchers these years. This is because, the usage of one type of fibre alone has proved to be inadequate in satisfactorily tackling all the technical and economic problems confronted by them while making fibre reinforced composites. These types of composites introduce additional degrees of compositional freedom for its making and provide yet another dimension to the potential versatility of fibre reinforced composite materials. Combination of a high performance and a low performance fibre provides versatility in the performance of the product. Various reports of hybrid composites of natural fibres reveal reduction in the material cost due to the low cost of the natural fibres used. The mechanical and physical properties of natural fibre reinforced plastics reach the values of glass fibre reinforced system only on certain conditions. Investigations on lignocellulosic fibre composites have shown that the properties of the fibre can be better utilised in hybrid composites [1-7]. Mohan and Kishore [2] have reported that glass has got good reinforcement effect along with jute. Clark and Ansell [3] have reported improvement of various mechanical properties of jute-glass hybrid laminates with different arrangements of jute and glass in the laminate. Pavithran *et al.* [4] have studied the mechanical properties of coir-glass hybrid composites containing varying amounts of glass fibre. They have noticed a considerable enhancement in the mechanical properties by the incorporation of very small volume fraction of glass. Studies on sisal-glass in polyester have showed a linear increase in the work of fracture by varying the volume fraction of the glass at the core [5]. Attempts have been made in our laboratory to prepare hybrid composites of sisal and glass in polyethylene and oil palm empty fruit bunch fibre and glass in PF. It has been reported that addition of glass has improved the orientation characteristics and thereby the tensile strength of the composites [6]. A ratio of 0.26:0.74 volume fraction of glass and oil palm fibre gave 23% improvement in the Izod impact strength of the composite. Better properties were given by intimately mixed hybrid composites [7].

There is a conservative notion that the strength of a collection of fibres is governed by the fibre component with the smallest elongation to break. The traditional belief is that materials with significant differences in breaking strains will not share the same load path. Based on this view, when a collection of fibres is uniformly strained, the collection tends to break as the strain level reaches the breaking strain level of the fibre which has the smallest breaking strain level. A subsequent infinitesimal increase in strain causes all those fibres characterised by the smallest breaking strain to fail. The sudden transfer of load to the remaining unbroken fibres is presumed to lead to catastrophic failure. Therefore the ultimate strength of the system is the stress level at which the elongation of the system has reached the ultimate elongation of the fibre family [8]. The two fibres in the group are strain compatible only if strain compatibility parameter, λ, has a value ~1 [8]. In banana-glass system, the value of λ is 0.7, i.e., ~1. Therefore the two fibres are strain compatible.

In our earlier studies, it was noted that banana fibre was an effective reinforcement in polyester composites [9]. In this study, attempts have been made to improve the mechanical properties of the composite by the incorporation of glass fibre, based on the reports of other researchers [1-7]. Composites with different volume fraction of glass have been prepared and analysed .

EXPERIMENTAL

Materials used

Banana fibre obtained from Sheeba Fibre and Handicrafts, Poovancode, Tamil Nadu was used in this study. Unsaturated polyester HSR 8131 (sp. gravity 1.12, viscosity 65 cps, gel time 25 min) obtained from M/s Bakelite Hylam, Hyderabad, India was used as matrix. Multidirectional glass strand mat used for the study was supplied by Ceat Ltd., Hyderabad, India. Methyl ethyl ketone peroxide and cobalt naphthenate were of commercial grade supplied by Sharon enterprises, Cochin.

Preparation of composites

Randomly oriented glass mats and neatly separated banana fibre cut at a uniform length of 3 mm were evenly arranged in a mould measuring 150 x 150 x 3 mm in the required layering pattern for preparing the samples. Composite sheets were prepared by impregnating the fibre with the polyester resin to which 0.9 volume percent Cobalt Naphthenate and 1% Methyl Ethyl Ketone Peroxide were added. The resin was degassed before pouring and the air bubbles were removed carefully with a roller. The closed mould was kept under pressure for 12 hours; samples were post cured and test specimens of the required size were cut out from sheets.

Different volume fractions of glass were used for the preparation of samples as detailed in Table 1. In all these samples, glass was used as the core material.

Table 1: Description of composite samples with different glass volume fractions

Sample marking	Volume fraction of glass
A	0.03
B	0.07
C	0.11
D	0.15
E	0.16
F	0.17

Samples with different layering patterns were also made in combinations A, C, and F as given in Table 2 and the pattern is depicted in Fig. 1.

Table 2: Explanation of the various layering patterns

Sample marking	Layering pattern
L_1	G-B-G-B-G-B-G-B-G
L_2	Intimate mixture of G and B
L_3	G-B-G
L_4	G-B
L_5	G-B-G-B-G

G - glass, B - banana.

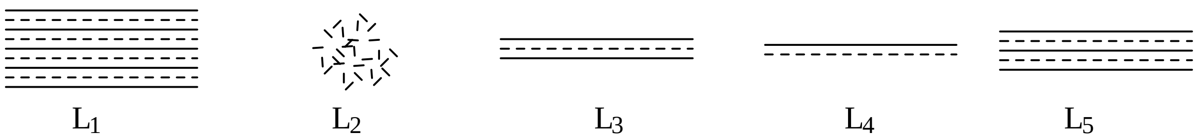


Fig. 1: The layering pattern of composite specimen marked A, C and F.

Mechanical tests

Test specimens were cut from composite sheets. Tensile testing was carried out using FIE electronic tensile testing machine TNE-500 according to ASTM D 638-76. Five samples were tested in each set and the average value is reported. Impact test was done on a Charpy impact tester Instron Wolpert PW5 according to ASTM D256. Minimum of four samples were tested in each case and the average value is reported. Fractography of the failure surfaces of the composites were examined by Scanning Electron Microscope after sputtering the surfaces with gold.

RESULTS AND DISCUSSION

Tensile stress-strain behaviour

Tensile stress-strain behaviour of neat polyester and banana/polyester composite with fibre volume fraction 0.4 are shown in Fig. 2. Stress-strain behaviour of the hybrid composite where the glass volume fraction is 0.03, 0.07, 0.11, 0.15, 0.16, and 0.17 and the total fibre volume fraction is constant are also shown in Fig. 3.

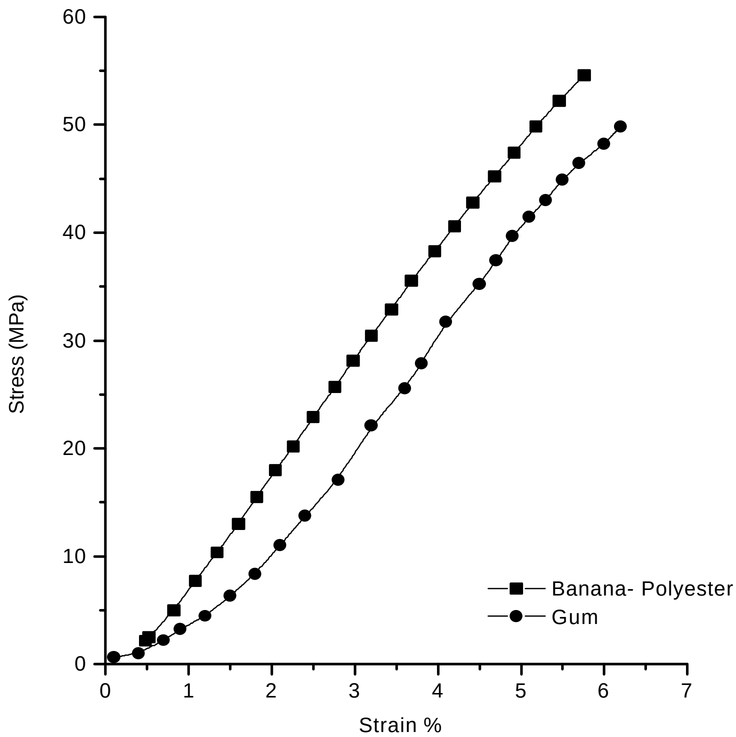


Fig. 2: Comparison of the stress-strain behaviour of neat polyester and banana fibre composite

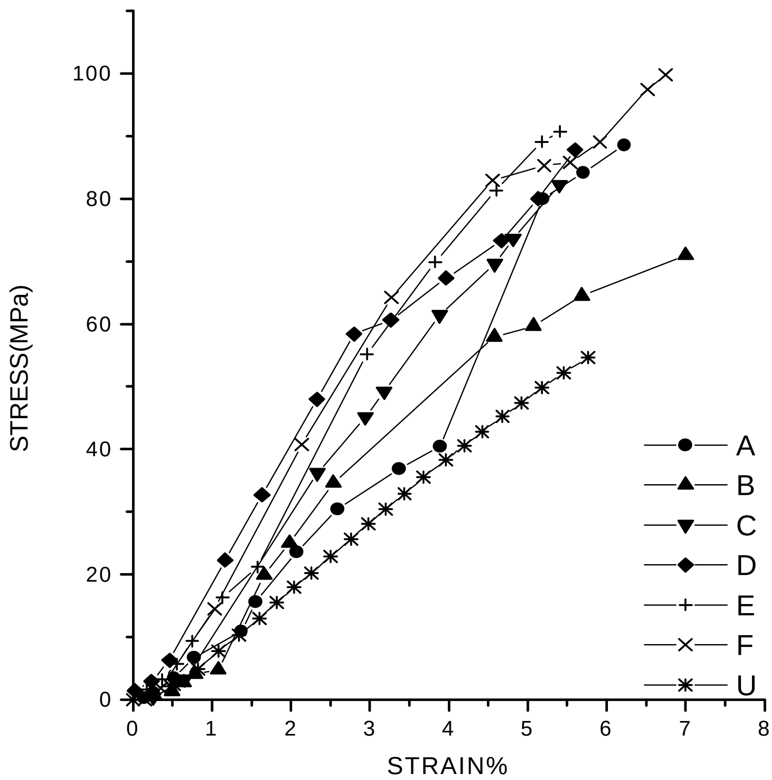


Fig. 3: Effect of glass volume fraction on the stress-strain behaviour of banana-glass polyester composite

The stress-strain curve of pure banana polyester (U) is smooth unlike that of the glass-banana hybrid composites which shows an inflection after the initial linear portion. The stress-strain curve is indicative of the fracture mode of the composite. The tensile stress is found to be maximum for composites with a glass volume fraction 0.17 (Fig. 3). The inflection in the stress-strain diagram, corresponds to the limiting elongation of the high modulus glass. Short and Summerscales [10] have observed that the minimum strength of the hybrid is proportional to the critical content of low modulus fibres. If the content of low modulus fibres in the composite is greater than the critical content, a characteristic inflection occurs in the stress-strain diagram, corresponding to the limiting elongation of the high modulus material.

Tensile modulus

The tensile modulus of the samples at 2, 4 and 5% elongation are compared (Fig. 4). At 2% elongation the modulus is found to be the lowest for the pure banana fibre composite. The modulus value shows an increasing trend with an increase in glass volume fraction. Addition of glass improves the tensile modulus. Tensile modulus values are indicative of the stiffness of the material.

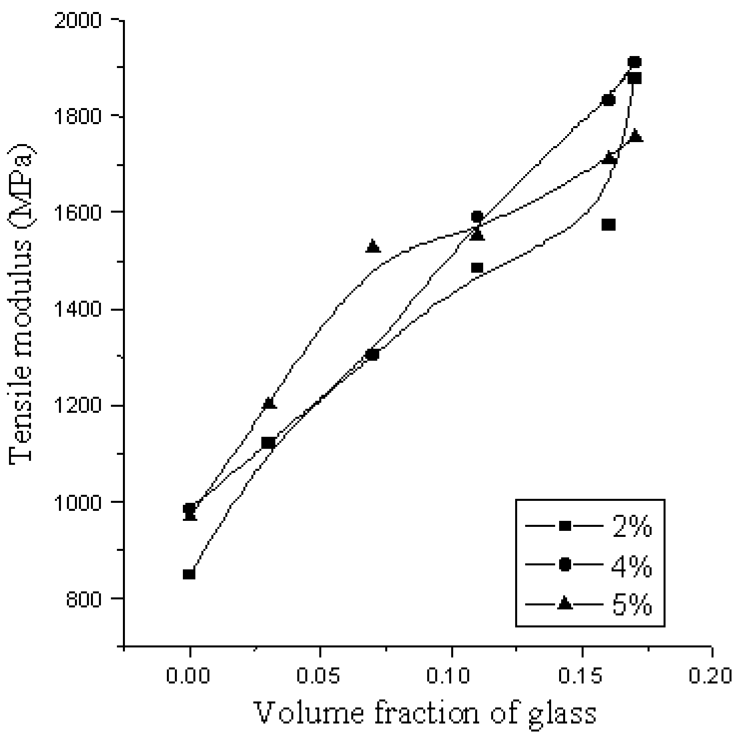


Fig. 4: Effect of glass volume fraction on the tensile modulus

Tensile strength

Fig. 5 shows the variation of tensile strength of the samples with respect to the variation of glass fibre volume fraction when the total volume fraction of the two fibres is kept constant. Tensile strength of the samples increase linearly will the increase in glass volume fraction. In hybrids of carbon and glass the presence of higher extension glass fibre has been found to reduce the probability of failure of the lower extension carbon fibre resulting in a higher breaking strength of the carbon fibres [11]. In the present study, the increased tensile strength of the hybrid can be attributed to the presence of high modulus glass fibres. When the volume fraction of glass is changed from 0.11 to 0.15, the increase in tensile strength is marginal. At high glass volume fraction of glass, the fracture occurs in the composite mainly by interlayer delamination.

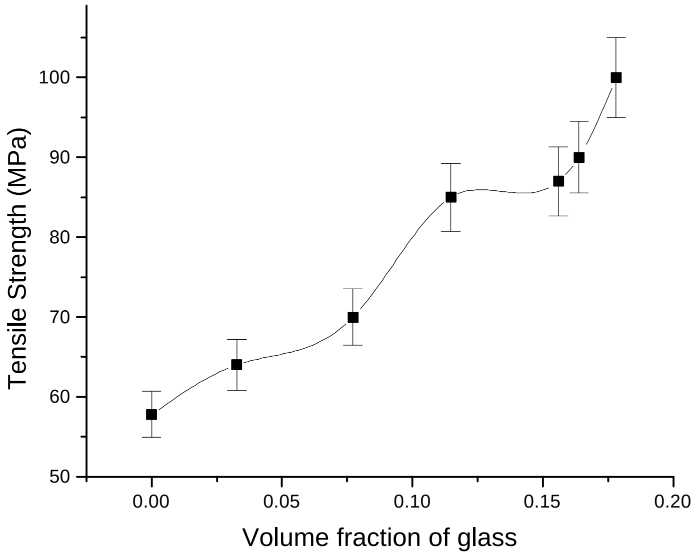
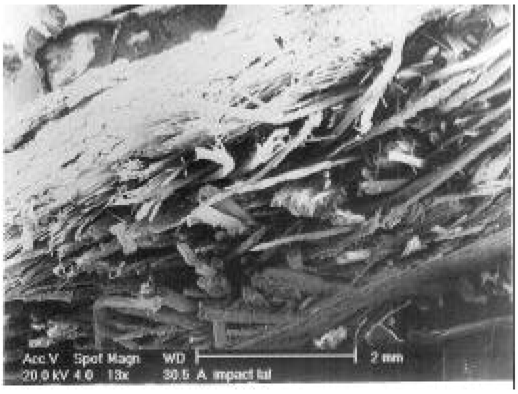


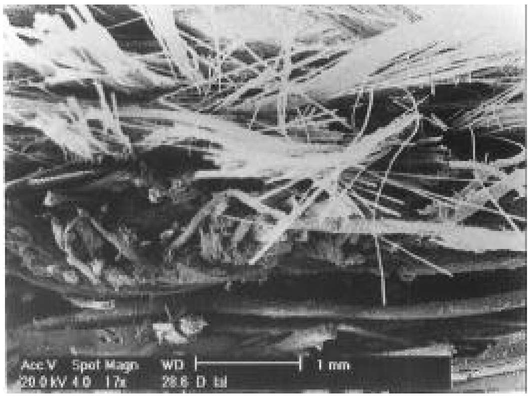
Fig. 5: Effect of glass volume fraction on the tensile strength

SEM photographs of the composites with glass volume fraction 0.03, 0.11 and 0.15 are shown in Figs. 6a, b and c, respectively. Fractograph of the sample with glass volume fraction 0.15 shows delamination of glass/banana and also matrix crack propagation.



(a)

(b)



(c)

Fig. 6: SEM photographs of the composites with glass volume fraction (a) 0.03, (b) 0.11 and (c) 0.15

Effect of banana glass layering on the tensile strength

Different layering patterns were tried for composites marked A, C, and F. Fig. 7 represents the various tensile strength values of the different layering patterns. In composites marked A and C an intimate mixture of the two fibres gave the highest tensile strength. Fischer *et al.* [12] have reported that when the fibres are more intimately mixed, failure by delamination will be more difficult because of the greater energy involved in creating the large amount of new surface in an intimate mix than that required to cause delamination of a layered hybrid. In composite marked F, the tensile strength for layering L_2 and L_5 are almost similar. In intimately mixed hybrids, the area of the high elongation component to the low elongation component interface per unit volume will be high compared to the composites where the fibres are not intimately mixed. In an intimately mixed composite there will be only a small distance from the failed fibre to the fibre which did not fail. The full reinforcing strength therefore, will be redeveloped within the failed fibre within a short distance of the fracture surface. When individual glass and banana layers are made, the tensile strength values are found to be lower than that in an intimate mixture for composites with low glass content. Bader and Manders [13] noted that the hybrid effect was maximum only when the layer thickness had a certain minimum value. Mohan and Kishore [2] also noted that when the glass reinforced plastic shell thickness was small, the resistance to withstand strain was insufficient and thus the specimen failed prematurely by fibre buckling. In samples marked AL_4, where the glass volume fraction is the lowest, the fibres were arranged in an interleaving manner. If the relative low elongation fibre content is less than a specific quantity, the ultimate tensile strength of the hybrid laminate is controlled by high elongation fibres. The tensile strength of the composite did not show much enhancement than a pure banana composite.

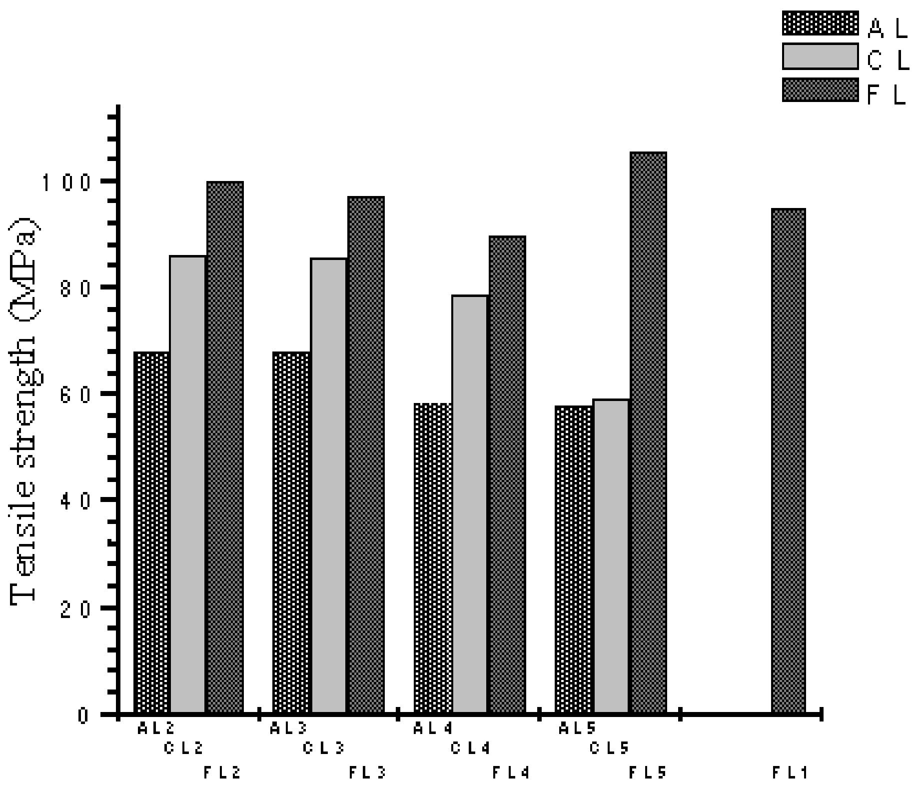


Fig. 7: Effect of layering on the tensile strength of the composites

Impact strength of banana–glass hybrid composites

Fig. 8 shows the impact strength of the composites. Impact strength of the composite does not show much change from that of banana fibre composites when the volume fraction of glass is maintained at 0.03. The impact strength increases to 196% when the glass volume fraction is increased to 0.11. However the impact strength is found to be lower when the concentration of the core material is increased further.

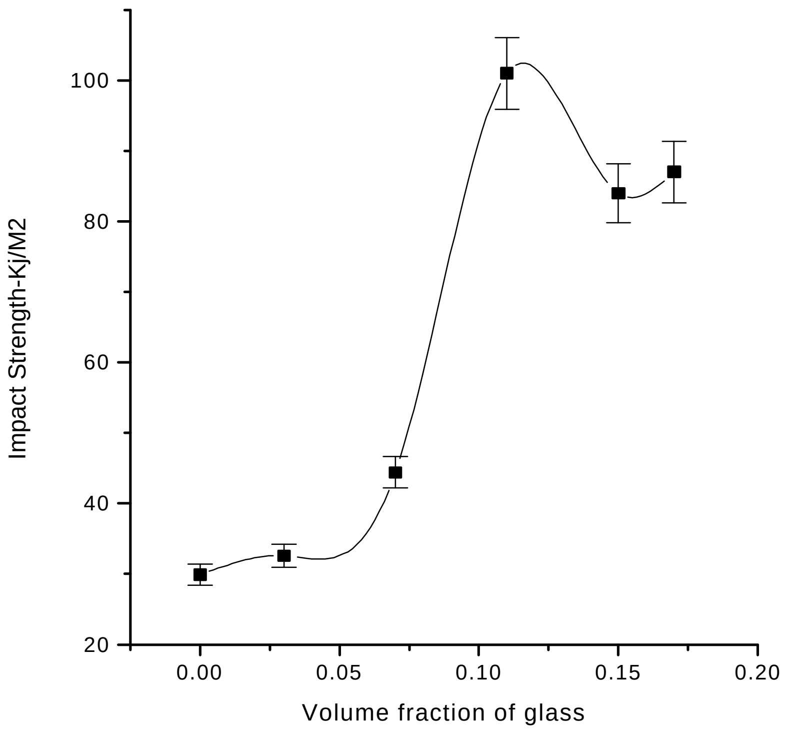


Fig. 8: Effect of glass volume fraction on the impact strength

Effect of glass-banana layering on the impact strength

Mallick and Broutman [14] have reported that stacking sequence is more important than composition in determining toughness, and that different lay-ups maximise different toughness parameters such as total energy, initiation energy or propagation energy. In composites with glass volume fraction 0.03, it is found that the arrangement of the fibre within the composite affects the value of impact strength. The highest value is obtained when banana and glass are kept as interleaving layers G-B-G-B-G. In this arrangement, the core thickness is very small. When a crack tip approaches a fibre, the crack crosses the fibres and cuts them as well as the matrix. Then crack changes its direction and moves through the matrix parallel to the fibres. Such debonding fracture consumes more energy by creation of more surface area within the sample. In composites with the volume fraction of glass 0.11 and 0.17 also, the impact strength shows the highest value where the total number of layers are the maximum. The impact strength shows a decrease with the decrease in the number of layers. Unlike tensile strength, intimately mixed composites shows the lowest impact strength. Short and Summerscales [15] have reported a negative hybrid effect in fracture tests of intimately mixed composites. Harris and Bunsell [16] have reported that intimately mixed composites are inferior to interply lay ups in impact resistance because of the finer state of subdivision.

CONCLUSION

The above study concludes that the tensile strength of banana -glass hybrid composites shows a linear increase as the volume fraction of glass is increased. The geometry or the layering of the fibres affect the mechanical properties of the composites. Tensile strength shows the maximum value in intimately mixed composite at low volume fraction of glass. However when high volume fraction of glass is used, an interleaving arrangement of glass and banana shows a marginal increase in tensile strength of the composite.

The impact strength of the hybrid composite increases when the glass volume fraction is increased up to 0.11. A further increase in glass volume fraction lowers the impact strength slightly. The highest impact strength value of banana-glass hybrid composite is shown by the samples made with a glass volume fraction of 0.11 with the fibres arranged in the layering pattern B-G-B.

ACKNOWLEDGEMENT

The authors thank Science Technology and Environment (B) Department of Government Of Kerala for the financial help extended to them for conducting this study.

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