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Effect of Flame Retardant on Physical Properties of Banana Fiber Reinforced Polyester Composites

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ABSTRACT
In this investigation a class of polymer composites consisting of polyester as a matrix material with a short banana fiber as a reinforcing material is developed. A set of composite specimen with fiber content ranging up to 15 wt. % has been fabricated using simple hand lay-up technique. In addition with filler, flame retardants were also added to enhance fire worthiness behavior of material. The effect of filler content and flame retardants on different physical property of the prepared sample is studied. The various physical property evaluated density, void content and water absorption behavior. From the experimental results, it is found that banana fiber reinforced polyester composites possess low density but voids and water absorption rate increases with fiber content. Addition of flame retards reduces the void content and decreases the water absorption rate of material.

Keywords: *Polymer matrix composites, polyester, banana fiber, physical properties.*

INTRODUCTION
Composite materials are having tailor made properties which is impossible to achieve in single materials. Composite materials is an advanced material and used in various sectors due to its outstanding properties [1]. Natural fiber-polymer composites (NFPCs) are becoming increasingly utilized in a wide variety of applications because they represent an ecological and inexpensive alternative to conventional petroleum-derived materials. Huge amount of work is going on around the world with natural fiber as a reinforcing material in polymer matrix. Mohanty et al. [2] used jute fiber as reinforcement in polymer matrix. They found around 50% enhancement in tensile strength, 30% in bending strength and 90% in impact strength of the composites. Lundquist et al. [3] used pulp fiber as reinforcement in polymer. They reported that stiffness of the fabricated composite increased by a factor of 5.2 and their strength increased by a factor of 2.3 relative to the pure polymer. Later, Mohammed et al. [4] presented a review article to provide a comprehensive review of widely used natural fiber reinforced polymer composites and their applications.

In a very recent work Kiruthika [5] presented a review on physico-mechanical properties of bast fiber reinforced polymer composites. Flandez et al. [6] used corn fiber as reinforcement in polypropylene polymer and tested their mechanical properties. Fan and Dai [7] had given a perspective of utilization of natural fiber reinforced composite for construction purpose which require high strength properties. Wang et al. [8] used furan fiber as reinforcement in epoxy matrix and its mechanical properties were evaluated. Rashid et al. [9], for the first time used sugar palm fiber (SPF) in phenolic matrix and investigate its tribological properties.

Banana fibers, a well-known natural fiber is a promising reinforcement for use in composites on account of its low cost, low density, high specific strength and low modulus, no health risk, easy availability and renewability. Joseph et al. [10] compared the mechanical properties of glass fiber reinforced composites with banana fiber reinforced composites. In their study, they used both the fibers in the form of long fibers and fabricated composites with varying filler loading. They performed fiber pull out test to evaluate the adhesion between fiber and matrix body.

S.M. Sapuan et al [11] studied the mechanical properties of woven banana fibre reinforced epoxy composites. The experiments of tensile and flexural tests were carried out using natural fibre with composite materials. Three samples prepared from woven banana fibre composites of different geometries were used in this research. Idicula et al. [12] studied the thermophysical properties of banana fiber reinforced polyester composites. Liu et al. [13] used banana fiber in high density polyethylene in their study and evaluated the morphological, water absorption and thermal stability of the fabricated samples. From the DSC curve it is seen that the addition of fiber remarkably changed the magnitude of crystallization peak as well as its peak position. Against this background, the present research work is undertaken which explores the possible utilization of banana fiber in the form of short fiber in polyester with and without incorporation of fire retardant. Effect of flame retardants (Magnesium hydroxide and zinc borate) on various physical properties of banana fiber/polyester composites is studied.

MATERIALS AND METHODS

Unsaturated isophthalic polyester supplied by Ciba-Geigy India Ltd. is taken as the matrix materials in the present investigation. Polyester resins are relatively inexpensive, fast processing and due to their ease of fabrication they are used generally for low-cost applications. Banana fiber, a natural fiber is used in present investigation as reinforcement.Banana fiber with its good mechanical strength has an appreciable specific property, even comparable to glass fiber. In addition to that, it possesses lower density than glass fibers. Apart from good specific properties, smaller elongation, fire resistance quality, great potentialities and biodegradability are the major advantages of this fiber.Natural magnesium hydroxide (brucite) and Zinc Borate ($2Zn0 \cdot 3B_20_3 \cdot 3.5H_20$) is used as a fire retardant. The average density of magnesium hydroxide and Zinc Borate is 2.34 g/cm^3 and 3.64 g/cm^{3}respectively.

Table 1. Polyester based Composites Reinforced with Banana Fiber

S.No.	Composition			
	Category I		Category II	
1	Set A1	Neat Polyester	Set B1	Neat Polyester + 5 % $Mg(OH)_2$ + 5% $2Zn0 \cdot 3B_20_3 \cdot 3.5H_20$
2	Set A2	Polyester + 3% weight banana fiber	Set B2	Polyester + 3% weight banana fiber + 5 % $Mg(OH)_2$ + 5% $2Zn0 \cdot 3B_20_3 \cdot 3.5H_20$
3	Set A3	Polyester + 6% weight banana fiber	Set B3	Polyester + 6% weight banana fiber + 5 % $Mg(OH)_2$ + 5% $2Zn0 \cdot 3B_20_3 \cdot 3.5H_20$

4	Set A4	Polyester + 9% weight banana fiber	Set B4	Polyester + 9% weight banana fiber + 5 % $Mg(OH)_2$ + 5% $2Zn0•3B_20_3•3.5H_20$
5	Set A5	Polyester + 12% weight banana fiber	Set B5	Polyester + 12% weight banana fiber + 5 % $Mg(OH)_2$ + 5% $2Zn0•3B_20_3•3.5H_20$
6	Set A6	Polyester + 15% weight banana fiber	Set B6	Polyester + 15% weight banana fiber + 5 % $Mg(OH)_2$ + 5% $2Zn0•3B_20_3•3.5H_20$

In this experiment composite fabrication done with varies weight percentage of banana fiber with polyester resin to identify physical behavior of composite material by hand lay-up method. For fabrication of composites, mould is prepared. The mould 320×320×3 mm was used for fabrication of composites. The various sets of composite fabricated during present work are listed in Table 1.The experimental density (ρ_{ce}) of composites under study is determined by using Archimedes principle using distilled water as a medium (ASTM D 792-91).The theoretical density (ρ_{ct}) of composite materials in terms of weight fractions of different constituents can easily be obtained using rule of mixture model. Water absorption test were carried out to analyze the behaviour of composite in the presence of water affected environments. This test is to assess the amount of water absorbed in mineral water. According to ASTM D 570, the specimen immersed in mineral water for 24 hours at room temperature and to determine apparent gain in weight or amount of water absorbed by the specimen is calculated after every 24 hours.

RESULTS AND DISCUSSION

Density and void content

The measured density obtained from Archimedes method, theoretical density obtained from rule of mixture model along with the corresponding void content of polyester based composites are presented in Tables 2.

Table 2. Variation of Theoretical and Measured Density with Different Fiber Content

Category I				Category II			
SET	Measured density (gm/cm^3)	Theoretical density (gm/cm^3)	Volume fraction of voids (%)	SET	Measured density (gm/cm^3)	Theoretical density (gm/cm^3)	Volume fraction of voids (%)
Set A1	1.09	1.09	-	Set B1	1.10	1.103	0.2
Set A2	1.06	1.081	1.92	Set B2	1.08	1.093	1.24
Set A3	1.04	1.072	2.97	Set B3	1.06	1.084	2.24
Set A4	1.01	1.063	4.98	Set B4	1.03	1.075	4.21
Set A5	0.99	1.054	6.09	Set B5	1.01	1.066	5.28
Set A6	0.96	1.045	8.19	Set B6	0.98	1.057	7.33

From the table it can be seen that the density of composite decreases with increase in fiber content. The decreasing trend observed is for densities obtained from measured values as well as theoretical values. The trend obtained is obvious because banana fibers used in present work are having low density as compared to polyester resin. The minimum density value under category I is 0.96 g/cm^3 for set A6 composites. Again, the minimum density value under category II is 0.98 g/cm^3 for set B6 composites. From the results it is clear that addition of fire retardant slightly increases the density of the composites, which subsequently decrease with the increase of fiber loading in the composites. This slight rise in density because of higher density of $Mg(OH)_2$ and zinc borate, that will increase the whole density of the composites.

Also, theoretically calculated density values are higher as compared to the measured values. It is because, while calculating the density, it has been assumed that the composites are free from voids, but actually, fabrication of composites gives rise to a certain amount of voids within the composite body. It can further be observed that densities of category II composites are higher as compared to the density of category I composite for corresponding sets. It is because of the presence of additives used for fabricating category II composites, as densities of used additives are higher than that of neat polyester. The void fraction presented in the present investigation is calculated with the help of measured density and theoretical density.

Water absorption Behaviour

Weight of all sets of specimen is measured in dried condition, than specimens are dipped into distilled water for a span of seven days. After every 24 hour, weights of the composites are measured again. The various data obtained under both the conditions are shown in the table 3 for category I composites and in table 4 for category II composites. The percentage of water absorption by composite specimen is recorded and from these values it is observed that as the fiber loading increases, water absorption percentage increases. The maximum water absorption percentage is recorded for composite with maximum fiber loading i.e. set A6 and set B6. These values recorded to 2.96 % and 2.79 % respectively for category I and category II composites.

Table 3. Water Absorption Percentages in Distilled Water of Category I Composites

SET	Water absorption percentage after 24 hour	Water absorption percentage after 48 hour	Water absorption percentage after 72 hour	Water absorption percentage after 96 hour	Water absorption percentage after 120 hour	Water absorption percentage after 144 hour	Water absorption percentage after 168 hour
Set A1	0.04	0.17	0.47	0.64	0.82	0.95	0.96
Set A2	0.16	0.48	0.82	0.96	1.12	1.24	1.24
Set A3	0.44	0.85	1.04	1.21	1.45	1.62	1.62
Set A4	0.52	0.91	1.09	1.22	1.52	1.79	1.79
Set A5	0.75	1.12	1.36	1.65	1.89	2.12	2.12
Set A6	0.96	1.53	1.89	2.18	2.48	2.95	2.96

Table 4. Water Absorption Percentages in Distilled Water of Category II Composites

SET	Water absorption percentage after 24 hour	Water absorption percentage after 48 hour	Water absorption percentage after 72 hour	Water absorption percentage after 96 hour	Water absorption percentage after 120 hour	Water absorption percentage after 144 hour	Water absorption percentage after 168 hour
Set A1	0.06	0.21	0.52	0.71	0.88	1.08	1.25
Set A2	0.13	0.44	0.78	0.91	1.05	1.16	1.17
Set A3	0.38	0.81	0.96	1.16	1.36	1.49	1.48
Set A4	0.57	0.86	1.02	1.19	1.43	1.65	1.65
Set A5	0.68	1.05	1.26	1.57	1.81	2.02	2.02
Set A6	0.88	1.42	1.76	2.12	2.35	2.78	2.79

The results show that with higher fiber content has a greater diffusion coefficient, due to the fact that absorption of water is higher, as a result of a higher content of cellulose.The formation of micro-cracks at the interface region, induced by fiber swelling, can increase the diffusion transport of water via them. Furthermore a capillarity mechanism becomes active, water molecules flow through the interface of fiber and matrix, leading to greater water absorption. Further it is observed that, with inclusion of fire retardant, water absorption rate decreases slightly as compared to the composites without flame retardant. Water absorption rate depends upon the void content as well. For category I composites, voids generated are more and hence water absorption rate is high.

CONCLUSION

This experimental investigation on short banana fiber reinforced polyester composites has led to the following specific conclusions:

1) Successful fabrication of polyester matrix composites reinforced with short banana fiber is possible by simple hand-lay-up technique.
2) The density of the fabricated composites decreases with increase in weight fraction of the fiber content. The reduction in density is slightly compromised when flame retardant are used along with banana fiber. Again, composites with flame retardant shows less porosity as compared to it counterpart.
3) The water absorption rate increases with increase in fiber content and duration of immersion of composite body inside the water. The rate of increment decreases when flame retardant are used along with banana fiber. This is mainly due to reduction in voids with flame retardant.

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