Esterification effect of maleic anhydride on swelling and mechanical properties of natural fiber/polystyrene composites

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Abstract: The natural fibers (banana, hemp and sisal) and polystyrene were taken for the formation of natural fiber polymer composites in the ratios of 55: 45 (wt/wt) respectively. These natural fibers were esterified with maleic anhydride (MA) and the esterification effect of maleic anhydride was studied on swelling properties (i.e. absorption of water at ambient temperature and steam) of natural fiber polymer composites. It was found that the steam penetrates more within lesser period of time than the water at ambient temperature. Untreated fibers composites show more absorption of steam and water in comparison to maleic anhydride treated fibers composites. The maximum absorption of water and steam was found in hemp fibers composites and minimum in sisal fibers composites followed by banana fiber composites. Steam absorption in MA treated and untreated fibers composites are higher than the water absorption in respective fibers composites. Maleic anhydride treatment improves all mechanical properties of respective composites. Untreated banana fiber composites show least mechanical properties while maleic anhydride treated sisal fiber composites show highest mechanical properties.

General Introduction: We have studied [1, 2, 3] the effect of absorption of steam and water at ambient temperature on wood polymer composites. From this study it was observed that the absorption of steam is more than the water due to the higher penetration of steam. The natural fibers such as jute, flax and kenaf used as a reinforcing fibers are able to satisfy economical as well as ecological interests while there low cost and high performance are able to fulfill the economic interest of industries. One of the physical properties of these natural fibers is a hydrophilic characteristic. The hydrophilic lignocellulosic fibers do not adhere well to the hydrophobic thermoplastics used as a matrix materials[4-6]. Ismail et al[7] studied the effect of absorption of on tensile property of polymer composites and found the water uptake is depends on sample preparation Satoko Okubayashi et al[8] studied the kinetics of dynamic water vapor sorption and desorption on viscose, modal, cotton, wool and polyester fibers. He found that according to the parallel exponential kinetics (PEK) model the total equilibrium moisture regain in all the materials decreases with increasing temperature.

In the present work we have studied the swelling properties natural fiber-reinforced polymer composites prepared from banana, hemp and sisal fibers with polystyrene. The maleic anhydride is used for esterification of fibers (banana, hemp and sisal) and the esterification effect of maleic anhydride on swelling properties (steam and water absorption) of natural fiber-reinforced polystyrene composites is studied.

Experimental Work: Plant fibers (Banana, hemp and sisal) were obtained from the raw material by the process of retting[2]. The fibers obtained were washed with water and dried in sunlight. These fibers further dried in oven and cut into 2.0 to 2.5 mm in length. The fibers were esterified using 2 % maleic anhydride in xylene keeping fiber-solvent ratio 1: 20 (wt/v). The soaking of maleic anhydride was allowed for 18 h at 65 ^{o}C. The fibers were filtered out and dried in oven at 60 ^{o}C till constant weight of fibers was achieved. Polystron 678 SF1 having specific gravity 1.05 and MFI 15 gm/10 min. is used for preparation of fibers/polymer composites. This sample was obtained form Polychem limited, Mumbai. Natural fibers and polystyrene (55: 45, wt/wt) were mixed on a two-roll mill at 195 $\pm$2 ^{o}C for about 10 min. The mixture of fiber and resin was then cooled and molded to 2 mm thick sheet in a compression-molding machine. The molding was carried out at 195 $\pm$2 ^{o}C for 4 min employing pressure in the sequence of 4.8, 9.8, 14.7, 19.6 MPa with a duration of 1 min each. The mold was then cooled under pressure by circulating cold water and the molded sheet was ejected from the mold after releasing the pressure.

The natural fiber reinforced polystyrene composites were allowed to swell for 2 to 30 h in water at ambient temperature and in steam (at 100 ^{o}C) at atmospheric pressure. The swelling of natural fiber reinforced polystyrene composites was determined by the weight difference of composites before and after treatment of water and steam.

Results and Discussion

Mechanical Properties of Fiber: Polystyrene (55:45 wt/wt) Composites Based on With and Without Treatment of Maleic Anhydride.

Table 1 shows the results of mechanical properties of fiber: polystyrene composites based on with and without treatment of maleic anhydride. From the table it was found that the treatment of maleic anhydride on these fibers shows improvement in mechanical properties than the untreated respective fibers. Maleic anhydride treated sisal fiber composites shows all mechanical properties higher than the untreated sisal fiber composites followed by MA treated hemp and banana fiber composites. Untreated banana fiber composites show all mechanical properties less than the other fiber composites.

Table 1: Mechanical properties of fiber: polystyrene composites based on with and without treatment of maleic anhydride.

Mechanical properties (Kg/cm^2)	Untreated fibers: polystyrene		
	Banana	Hemp	Sisal
Tensile strength)	28.49	34.16	58.96
Young's modulus	3398.5	3506.5	4748.3
Flex strength	152.35	160.05	165.47
Flex modulus	12301	23514	25183
Impact strength	0.45	0.61	0.73
Hardness (Shore-D)	59.4	60.1	63.2
	MA treated fibers: polystyrene		
	Banana	Hemp	Sisal
Tensile strength	42.5	81.26	98.15
Young's modulus	3969.2	4545.9	5660.4
Flex strength	188.78	202.03	247.93
Flex modulus	23040	30852	32798
Impact strength	0.75	0.90	0.99
Hardness (Shore-D)	64.3	66.8	70.2

Absorption of Steam by Composites Based on Maleic Anhydride Treated and Untreated Fiber: Polystyrene (55:45, Wt/Wt).

The composites based on MA untreated banana, hemp and sisal fibers with polystyrene were taken for the steam absorption for 2 – 30 h. The absorption of steam in these fibers composites is compared in figure 1. From the results it is observed that the absorption of steam at 2 h is less in the banana fiber composite. Further there is sharp increment of absorption of steam up to 18 h and hemp fiber composite absorbs the maximum of steam amongst the above said fiber composites. The minimum absorption of steam is observed in sisal fiber sisal fiber followed by banana fiber at 24 h. From the results it is also observed that banana and hemp fibers composites show isosorption of steam at 4 h period of time. The order of rate of absorption of steam in MA untreated fiber is hemp > Agave > banana up to 2 h. further the

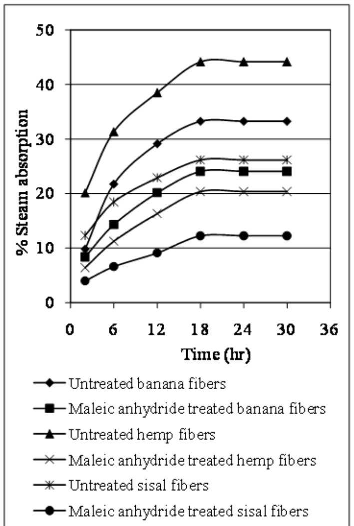

Fig.1 Comparison of absorption of steam in banana, hemp and sisal fibers/PS composites with and without treatment MA

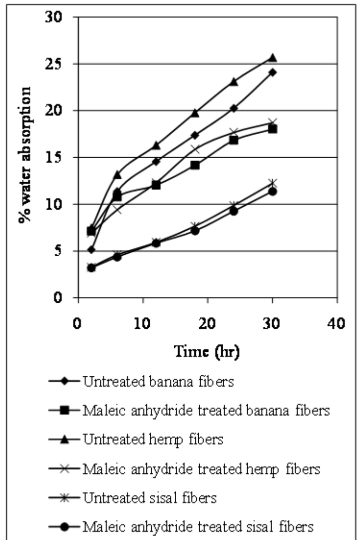

Fig.2 Comparison of absorption of water at ambient temperature in banana, hemp and sisal fibers/PS composites with and without treatment of MA

change in order of absorption of steam is hemp > banana > agave up to 24 h. The composites based on maleic anhydride treated fiber show lower absorption of steam than untreated fiber composites. The MA treated banana fiber composite shows more absorption of steam than the MA treated hemp fiber composite; while MA treated agave fiber composite shows lesser absorption of steam. The order of absorption of steam in MA treated fiber composites is banana > hemp > agave.

Absorption of Water at Ambient Temperature by Composites Based on MA Treated and Untreated Fiber: Polystyrene (55:45 Wt/Wt)

Figure 2 shows the results of water absorption at ambient temperature by composites based on maleic anhydride treated and untreated banana, hemp and sisal fibers with polystyrene (55:45, wt/wt). From the results it is observed that the absorption of water increases in all MA treated and untreated fibers composites as the period of time increases. Untreated banana and sisal fibers composites show lesser absorption of water than the MA treated fiber composites up to 5 h and 28 h respectively. Beyond this period of time there is increase in absorption of water in untreated fibers composites than the MA treated respective fiber composites. The rate of absorption of water in all fiber-based composites is maximum up to 2 h and further it gets reduced in all composites except untreated banana fiber composites. It is also observed that the composites based on maleic anhydride treated hemp and banana fibers absorbed more water than the composite based on maleic anhydride untreated sisal fibers.

The results of MA treated and untreated fibers/polystyrene composites are compared to see the effect of MA on water absorption at ambient temperature as MA is being used as compatibiliser. The maximum effect of MA is observed in hemp fibers composite. However the untreated hemp fibers composite absorbs maximum water with respect to other fibers, which is due to the maximum number of free -OH groups present in hemp fibers. The groups get esterified with MA and thus the absorption of water gets declined. In banana fibers, free -OH groups are lesser than the hemp fibers and thus it shows less absorption of water. It is observed from the MA soaking results that hemp fibers soak maximum MA followed by banana fibers. The least amount of MA soaking is observed in sisal fibers. Thus it is very clear that hemp fibers react maximum with MA. The absorption of water is the capillary phenomenon but the presence of -OH groups enhance the absorption of water by forming hydrogen bonding, it is therefore possible that the free -OH group present in banana fibers are not fully esterified which causes the more absorption of water than MA treated hemp fibers composite. The sisal fibers composites are compactly bonded and have less free -OH groups, due to that the penetration of water is very less. Further the free -OH groups available in sisal fibers get esterified with MA and thus it declines the absorption of water. The difference in MA treated and untreated sisal fibers composites is also very less and thus it strengthen the above said phenomenon.

Conclusions:

Maleic anhydride treatment improves all mechanical properties of composites. Untreated banana fiber composites show least mechanical properties while maleic anhydride treated sisal fiber composites show highest mechanical properties. The absorption of water increases with increase in time in all fibers composites. The maleic anhydride treated fibers composites show lesser absorption of steam and water at ambient temperature than the respective untreated fibers composites. The maximum absorption of steam and water at ambient temperature is observed in untreated hemp fiber composite and minimum absorption of steam and water at ambient temperature is observed in MA treated sisal fiber composite.

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