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Prediction of Hygric Strain Coefficients for Natural Composites

S. Madhusudan[1], T. Rama Krishna[2], J. Madhukiran[3] and K. Sunil Ratna Kumar[4]

[1,2,4]Dept. of Mech. Engg, Sir C.R Reddy College of Engg, Eluru - 534 007, India
[3]Dept. of Mech. Engg, AKRG College of Engg, Nallajarla-534112, India
E-mail: [1]madhusudan_sunanda@rediffmail.com, [2]ramatadivaka@yahoo.com,
[3]jamimadhukiran@gmail.com, [4]kskumar@gmail.com

Abstract—*Hygric strain behaviour of natural composites was found out experimentally. Natural composites are prepared using banana/pineapple fibers by reinforcing them in epoxy matrix. A separate test setup has been designed for determination of hygric strain in moisture environment. Specimen deflections were measured periodically with respect to time. Coefficient of hygric strains (β) are determined from moisture concentration (C) and hygric strains. Using mathematical equations coefficient of hygric strains are also predicted. For comparison purpose glass fiber reinforced composites are also fabricated under similar processing conditions. Results show that both predicted and experimental values are in good agreement.*

Keywords*: Polymer matrix composites, Natural composites, Deflection, Hygric strain, Moisture concentration, Coefficient of hygric expansion.*

1. INTRODUCTION

Composites consist of two or more chemically distinct materials, namely matrix and reinforcement. Usually matrix is major portion whereas reinforcement is a minor portion. Based on matrix, composites are classified as metal matrix, polymer matrix and ceramic matrix composites. Fiber reinforced, particle reinforced and laminated composites are classifications based on reinforcement. In general, fibers are the principal load bearing agents, while the matrix keeps the fibers in desired orientation and location. In addition, matrix acts as load transfer medium and protects from the environmental damage [1-5]. The fibers are basically of two types, namely synthetic and natural. Jute, Hemp, Ramie, Sisal, Cotton, Kapok, Kenaf, Flax, Pineapple and Banana etc. are some examples of natural fibers. Glass, carbon, aramid and nylon etc are few examples under synthetic fibers. Natural fibers, as reinforcement have recently attracted the attention of researchers because of their advantages over synthetic fibers. Natural fibers are environmental friendly, biodegradable, renewable and available in plenty. Plant fibers with their low cost and high performance contribute to economic interest of industry to a maximum extent. Many investigations have been made on the potential use of natural fibers as reinforcement materials and several cases the results have shown that the natural fiber composites own good stiffness but the composites do not reach the same level of strength as the glass fiber composite [6]. On the other hand, moisture absorption, quality variations and low thermal stability are some of the disadvantages of the plant fibers. Hybrid composites are made by combining two or more different types of fibers in a common matrix. Research studies show that enough work has been done on hybridization of natural fibers with glass fibers to improve the properties [7-11]. N.Venkateswaran, et.al carried out their work on Mechanical and water absorption behaviour of banana/sisal reinforced hybrid composites [12].

With this background in the present work an attempt has been made to fabricate pineapple, banana natural fiber composites and studying their hygric expansion behaviour when exposed to moisture environment. The results are compared with that of glass composite.

2. EXPERIMENTAL

2.1. Fabrication of composite

A teak mould of 350 x 330 x 5 mm was prepared for the fabrication of composites. All the composites are fabricated using hand layup technique.

Fig. 1: Obtained composites- Glass, Banana and Pineapple specimens.

The total fiber volume fraction banana, pineapple and glass fibers of the composite were fixed at 0.4 V_f. The moulds are cleaned and dried before applying epoxy. Remover is coated on the top and bottom surfaces of mould. Banana, pineapple and glass fibers were placed individually in the mould before applying epoxy or releasing agent. After placing fibers uniformly, they were compressed with the help of bottom and top plates for few minutes to ensure good quality of the composite. The epoxy mixed with hardener is then poured uniformly over the fibers and compressed. The curing time was maintained for 24 h. Fig. 1 shows the obtained samples after fabrication.

2.2 Testing

2.2.1 Deflection measurement

The obtained ASTM standard (AS4/3501-6) specimens are used for moisture absorption test. The specimens were then bent into parabolic shape in order to accommodate into the set-up, Fig. 2 [13]. The test was conducted for four months duration and readings are noted at an interval of one month. The deflection changes i.e change in specimen length is measured and there by corresponding hygric strain is evaluated. The initial deflection of the specimen was observed as 14.50 mm.

2.2.2 Moisture concentration estimation

Specimens are exposed to the moisture environment are removed periodically from the water bath and weighed on an analytical balance to determine the relative weight gain, M.

Fig. 2 : Sample under testing for hygric strain measurement.

The average moisture concentration 'C' representing the relative volume occupied by water is related to the weight gain as

$$C = V_w/V_c = \frac{W_w/\rho_w}{W_c/\rho_c} = \rho_c / \rho_w (M) \qquad [13]$$

Where V_w, V_c = volumes of water and composite, respectively
W_w, W_c = weights of water and composite, respectively
ρ_w, ρ_c = Densities of water and composite, respectively
and 'M' is the relative weight gain.

3. RESULTS AND DISCUSSIONS

Table 1 and Table 2 shows the summary results of deflections and moisture concentrations obtained on periodic basis. Based on the results obtained, trends are plotted between moisture concentration, 'C' and deflection.

Table 1: Summary results of deflections for different composites.

Composite type	Deflections (mm)			
	Month-1	Month-2	Month-3	Month-4
Banana	0.06	0.1	0.12	0.14
Pineapple	0.07	0.12	0.15	0.17
Glass	0	0.035	0.05	0.08

Table 2: Summary results of Moisture concentrations for different composites.

Type of composite	Moisture concentration, C			
	Month-1	Month-2	Month-3	Month-4
Banana	6.523	6.61	6.71	6.8
Pineapple	6.644	6.666	6.761	6.99
Glass	6.75	7.81	7.97	8.4

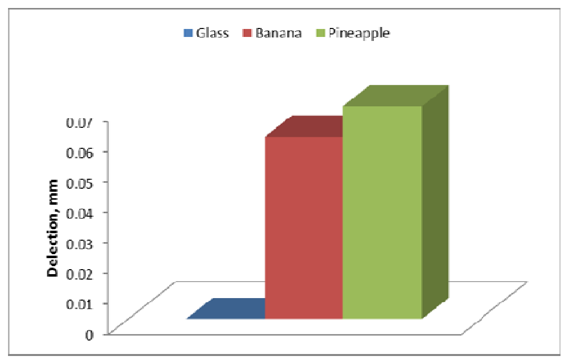

Fig. 3: Deflections observed for glass, banana and pineapple composites after first month.

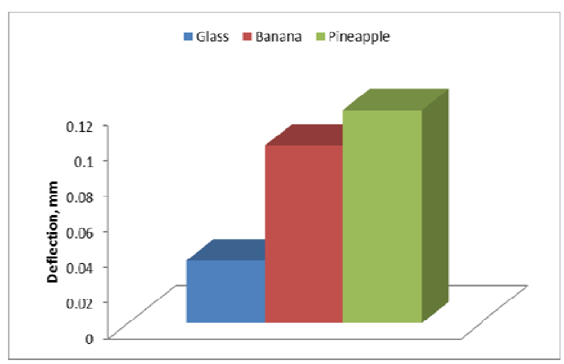

Fig. 4: Deflections observed for glass, banana and pineapple composites after second month

Fig. 3 shows the deflection trends for three composite specimens after one month. Glass fiber has shown zero deflection, whereas both the natural composites have shown deflections. Pineapple fiber composite resulted in higher deflection as compared to banana fiber composite. The higher deflection for pineapple composite can be attributed to the higher moisture absorbing capability for pineapple fiber as compared to banana fiber composite.

Fig. 4 shows the deflection trends for three composite specimens after second month. Higher deflection values can be observed for all composites as compared to first month. This is true because more is the time of immersion, higher is the chance of absorbing moisture. Increasing trend of deflections can be observed for glass, banana and for pineapple composites respectively. The rate of increment of deflections is higher for pineapple moderate for banana and least for glass fiber reinforced composites.

Fig. 5 shows the deflection trends for three composite specimens after third month. In this case also natural fiber reinforced composites has shown higher deflection values as compared to glass fiber reinforced composite. More deflection for pineapple fiber composite is due to more absorbing capability of moisture as compared to banana fiber composite. The deflections for all composites are increased compared to second month.

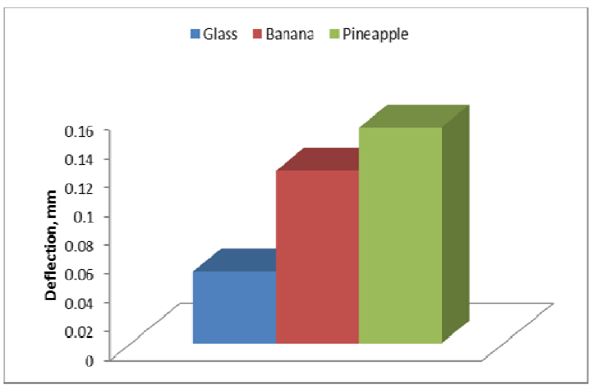

Fig. 5: Deflections observed for glass, banana and pineapple composites after third month.

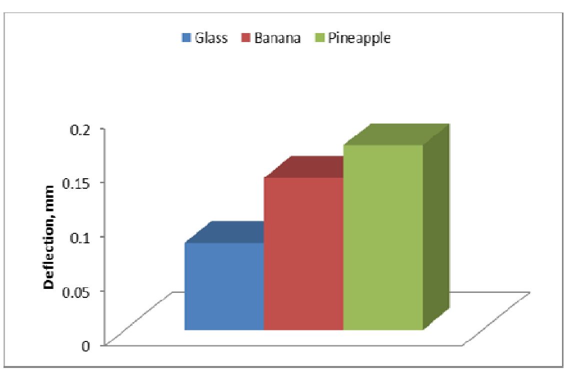

Fig. 6: Deflections observed for glass, banana and pineapple composites after fourth month.

Fig. 6 shows the deflection trends for three composite specimens after fourth month. The deflection trends are increased as compared to third month. There may be two reasons for higher deflections. One may be because of more time of immersion more is the bulging and hence more deflection. Secondly there is always a possibility of presence of voids or cracks obtained during manufacturing. The presence of these obviously makes the composite to absorb more moisture during the exposure time.

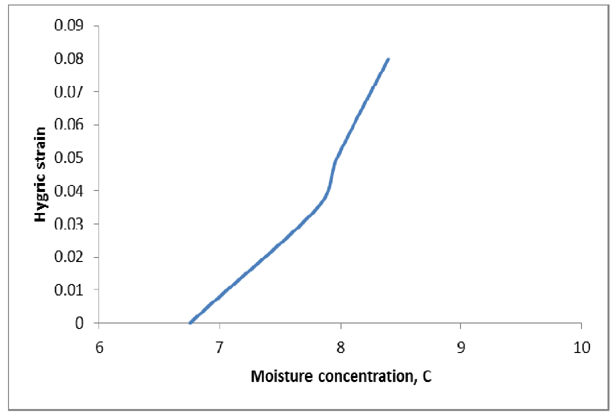

Fig. 7: Hygric strains for glass fiber composites as function of moisture concentration.

Fig. 7 plotted between measured hygric strain versus average moisture concentration for glass fiber composite. The slopes of these curves yield the coefficient of moisture expansion ($\beta = 0.2$). As the measured hygric strains are less of glass fiber composite and the ability of absorbing moisture in to the specimen through weight gain i.e moisture concentration is also low, and hence the obtained coefficient of moisture expansion is a minimum value.

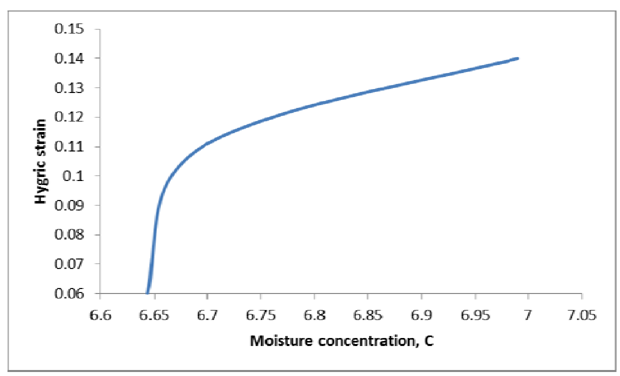

Fig. 8: Hygric strains for banana fiber composites as function of moisture concentration.

Fig. 8 shows the plot between the measured hygric strain versus average moisture concentration for banana fiber composite. The coefficient of hygric expansion obtained from the slope is 0.28. There is no significant difference in the case of hygric strain as well as moisture concentration during initial periods. Upon further exposure to the moisture, the values are comparable. The increase in slope and also the hygric expansion coefficient is due to absorbing capability of banana fiber.

Fig. 9 shows the plot between the measured hygric strain versus average moisture concentration for pineapple fiber composite. The coefficient of moisture expansion obtained from the above graph is 0.31. As explained earlier, the ability of moisture absorption is higher the observed hygric strains as well as moisture concentration also higher. This results in achieving the highest coefficient of moisture expansion.

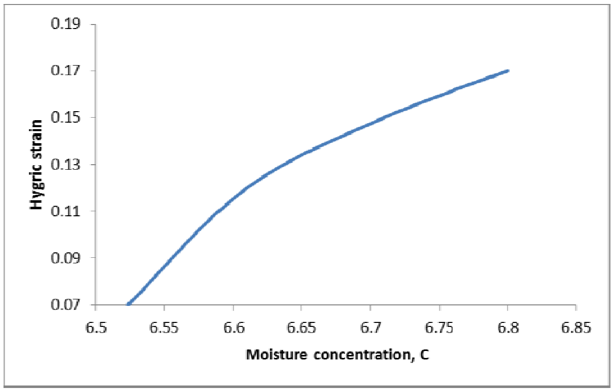

Fig. 9: Hygric strains for pineapple fiber composites as function of moisture concentration.

The obtained values are validated through theoritical analysis using the following formula [14].

$\beta_T = \rho_c/\rho_m\,[1+\nu_m]\,\beta_m$ [14]

Where β_T = Transverse coefficient of moisture expansion
β_m = Moisture expansion coefficient of matrix
ν_m = Poisson's ratio of matrix
ρ_c = Density of composite material
ρ_m = Density of matrix material

Table 3 shows the summary of coefficient of hygric expansion, β values for banana, pineapple and glass composites.

Table 3: Summary of experimental and predicted values of coefficient of hygric expansion

Coefficient of hygric expansion, β	Type of composite		
	Banana	Glass	Pineapple
Experimental	0.28	0.2	0.31
Predicted	0.322	0.2	0.343

Fig. 10 shows the comparison between predicted and experimental hygric expansion coefficient values for banana and pineapple composites. Predicted values are bit higher as compared to experimental values. In both cases pineapple composite exhibited higher coefficient values as compared to banana composite. The reason for higher value in case of pineapple composite might be due to higher ability of absorbing water. The reason for lower experimental values can be explained in two ways. One may be due to effect of manufacturing process parameters that leads to formation of voids, cracks and other defects.

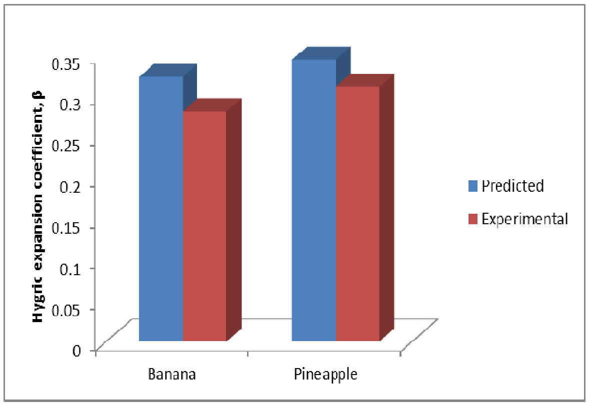

Fig. 10: Predicted and experimental hygric expansion coefficients for Banana and Pineapple composites.

Secondly, there is always a possibility of environmental conditions which may be realistic, due to which the values are lower.

Fig. 11 shows summary graph showing the predicted and experimental coefficient of hygric strain values for banana, pineapple and glass composites. It is true that natural composites due to high moisture expansion capability absorbing more water as compared to glass composite. It can be also observed that both predicted and experimental values for glass composite are in close agreement whereas both banana and pineapple composites has shown less experimental value as compared to predicted values. Manufacturing defects, experimental errors may be reason for the above deviations.

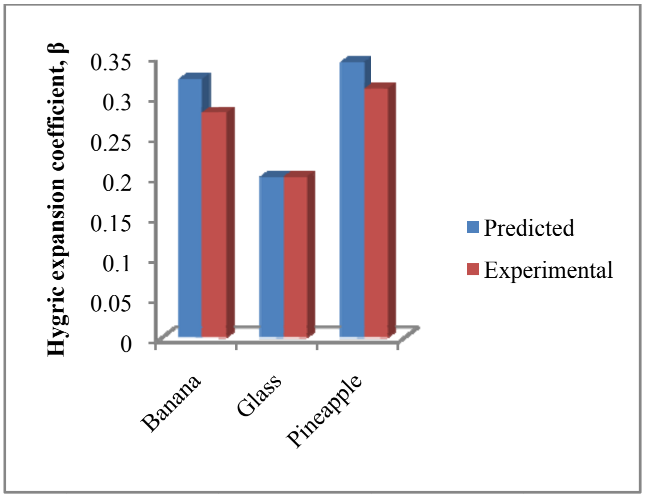

Fig. 11: Predicted and experimental hygric expansion coefficients for Banana, Glass and Pineapple composites.

4. CONCLUSIONS

1. Hand layup technique has been used successfully used for the fabrication of Pineapple, banana and glass fiber composites.

2. All the composites subjected to moisture test exhibited hygric strain.
3. Pure pineapple composite exhibited higher coefficient of hygric expansion.
4. Pure banana composite exhibited lower coefficient of hygric expansion.
5. As expected the coefficient of hygric expansion of glass composite is much lower as compared to banana and pineapple composites.

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