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INVESTIGATIONS INTO TENSILE STRENGTH OF BANANA FIBRE REINFORCED HYBRID POLYMER MATRIX COMPOSITES

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Abstract:

Natural fibres, such as banana, coir, jute and gongura have been proved to be effective reinforcements in polymer matrix composites. This work aims to design and fabricate the banana fibre reinforced hybrid polymer matrix composites. The authors developed a hybrid polymer by blending natural and synthetic resins. The tensile behavior of fabricated composites is studied. The influences of natural resin and alkaline treatment of fibre on tensile strength are investigated. ANOVA technique is used to find the regression equations for ultimate tensile strength.

1 Introduction

1.1 Manuscript preparation

There has been an increase in attention regarding research into natural fibre reinforced bio-degradable, polymer matrix composites in recent years. This resurgence of interest is due to the increasing cost of plastics and also because of the environmental aspects of using renewable and biodegradable materials [1]. Several researchers in the past have developed composites using banana fibres [2-4]. Venkateshwaran and Elaya Perumal [3] reviewed the various experiments carried out so far in the field of banana fibre polymer composite. A few pieces of literature are reported on banana fibre reinforced epoxy matrix composites. Several investigations have been undertaken in order to examine the potential of natural fibres as reinforcements for composites and in most cases the results have shown that natural fibre composites provide good stiffness but the composites have not yet reached the same level of strength as glass fibre composites [5].

Mechanical and water absorption behavior of Banana/Sisal reinforced composites were studied by Venkateshwaran et al. [6]. It was concluded that Interfacial bonding between fibre and matrix would be improved by chemical treatment/treatment with coupling agent and it would enhance mechanical properties of the composites. Venkateshwaran et al. [7] and Benítez et al. [8] studied effects of alkali treatment on banana fibres for reinforcement in polymer matrix. The study found that alkali treatment played a significant role in improving mechanical properties and in decreasing the moisture absorption rate of both randomly oriented and plain woven composites. This treatment removed substances such as lignin, pectin and hemicellulose from banana fibre so that the pure composition of cellulose was made [8].

Venkateshwaran et al. [9] predicted tensile properties of hybrid-natural fibre composites. The experimental tensile strength and modulus of the hybrid composite were found using the Rule of Hybrid Mixtures (RoHMs) equation. Mechanical properties of banana fibre were studied by Kulkarni et al. [10]. They observed that the failure of banana

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fibre in tension is due to the pull-out of micro fibrils accompanied by tearing of cell walls. The tendency for fibre pull-out decreased with increased testing speeds. Nilza et al. [11] investigated the potentials of banana, coir and bagasse fibres in composites.

This work focuses on the composite with hybrid polymer as matrix and banana fibre as reinforcement. The literature related to hybrid polymer is limited/nil. Hence the investigation into mechanical properties of such composites is taken up in this work. The objective of this work is to fabricate fibre reinforced hybrid polymer matrix composite materials with hand-lay-up technique and to study their tensile behavior.

2 Experimental

The composite samples were prepared using hand-layup techniques. The ratio of General Purpose Resin and Cashew-nut shell Resin (CNSL) was varied in the hybrid matrix of each sample. The matrix (i.e., hybrid polymer) was prepared by blending GP resin with CNSL resin. For each sample the volume concentration of CNSL resin was varied starting from 0 to 30% with an increment of 5%. The fibres were alkali treated at different concentrations of NaOH (5, 10 and 15%) for different time durations (6, 12 and 24 hours) before they were incorporated into the matrix. The tensile test of the samples was done on a Zwick tensile testing machine. The results obtained from the test include load vs deflection graph, maximum stress at fracture, maximum strain at fracture, maximum load at fracture etc.

Samples were fixed properly in the jaws of the Zwick tensile testing machine. Testing Speed was selected as 2 mm/min. Figure 2 and 3 present the testing facility and samples of the test respectively.

Figure 1. Banana fibre composites and mould.

Figure 2. Zwick tensile testing facility.

Figure 3. Broken specimens after tensile test.

3 Results and discussions

Fig. 4 shows the influence of treatment duration on maximum stress of the composites at constant concentration of alkali solution. The duration of treatment indicates the immersion time of banana fibre in NaOH solution which was 6, 12 and 24 hours respectively. Initially there is a slight decrease in strength as the duration increases, but after a critical point an increase in strength has been noticed.

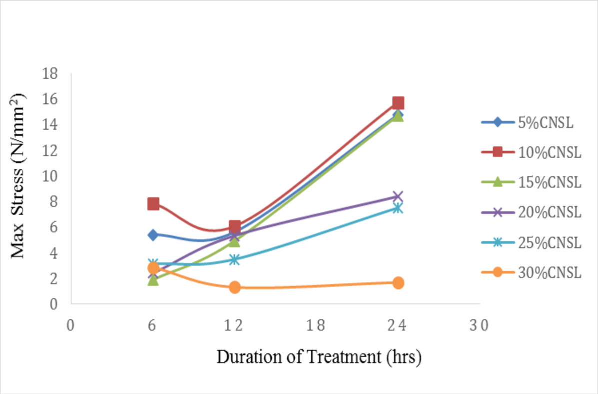

Figure 4. Maximum stress vs hours of treatment (10% NaOH).

Fig. 5 relates maximum strength of composite influenced by the concentration of alkali (NaOH Solution) at constant treatment duration. Three concentrations of the solution, i.e., 5, 10 and 15%, were chosen for this study. It is evident from the graph that the increase in concentration of solution decreases the strength initially, but increases eventually it.

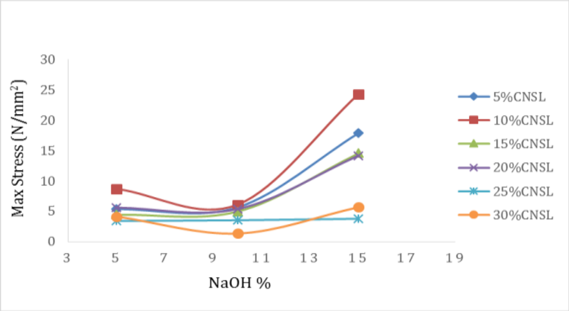

Figure 5. Maximum stress vs NaOH% (12 hours).

3.1 ANOVA Analysis

There are three independent variables in this study i.e., NaOH concentration, duration of treatment and CNSL concentration and two dependent variables i.e., breaking stress and ultimate stress. Minitab software was used to find the influence of the independent variables on each of the dependent variables. Minitab software is based on ANOVA technique and was used to find out the regression equation and plot the contour plot.

Figures 7 and 8 show the contour plots for the breaking and ultimate stresses respectively. The range of x- axis and y-axis from -1 to +1 denotes the levels given for each independent factor while processing is performed in Minitab software. Table 1 shows the low, mid and high levels for each of the three factors. From the contour plots it can be observed that the composite exhibits maximum strength when NaOH concentration (A) is at its maximum, duration of treatment (B) is at its maximum and CNSL concentration (C) at its is minimum.

The Regression equation is obtained through the parametric analysis which indicates the influence of different parameters on the ultimate and breaking stresses of composites.

$$\text{Ultimate Stress} = 5.74638+1.86430\times A+1.57850\times B-3.55660\times C+3.56505\times A^2-0.906955\times B^2-2.65445\times C^2-1.58138\times A\times B-1.56313\times A\times C-0.623625\times B\times C. \quad (1)$$

$$\text{Breaking stress} =4.93335+1.81540\times A+1.29187\times B-3.62890\times C+1.08413\times A^2+0.0617773\times B^2-1.38837\times C^2-1.43337\times A\times B-1.86988\times A\times C-0.588375\times B\times C, \quad (2)$$

where is

A = Level value (-1 to 1) for NaOH concentration,
B = Level value (-1 to 1) for Duration of treatment and
C = Level value (-1 to 1) for CNSL concentration.

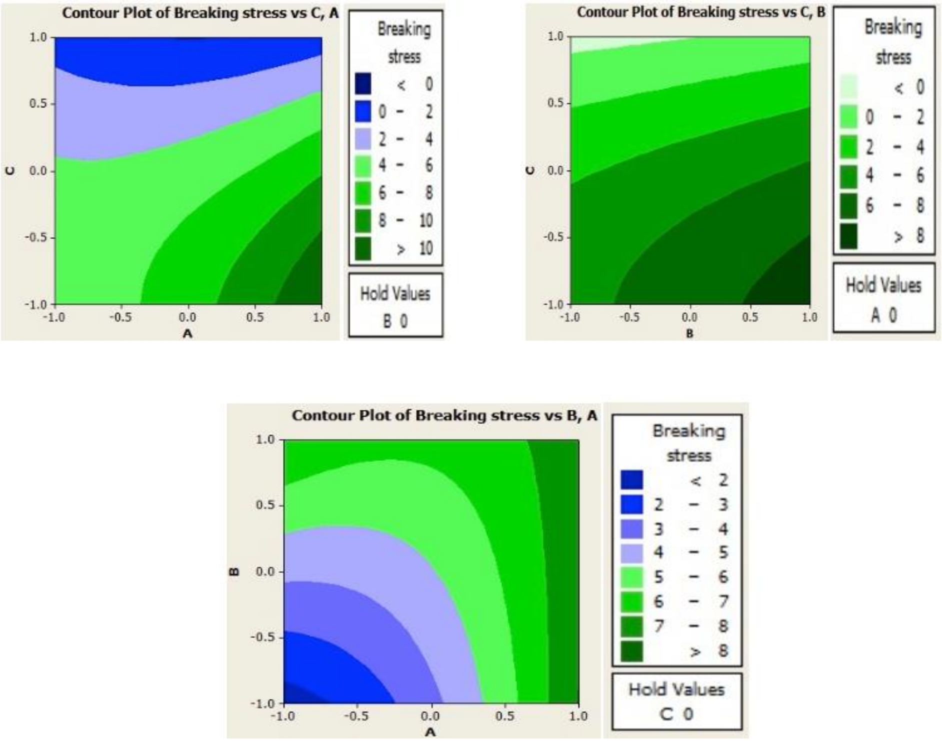

Figure 6. Contour plots for breaking stress.

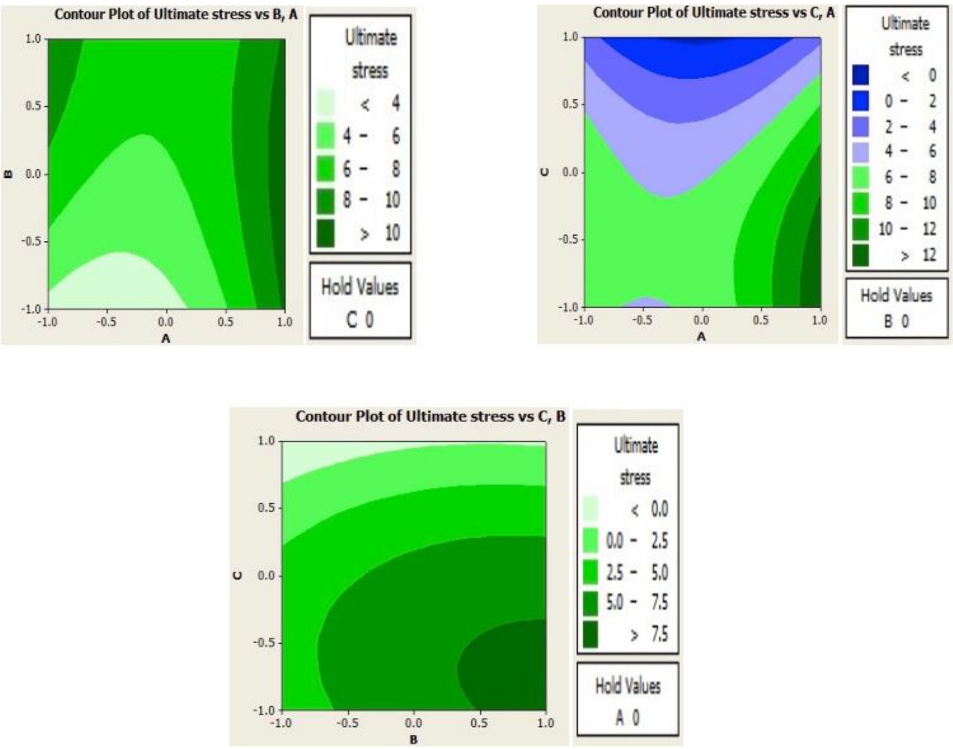

Figure 7. Contour plots for ultimate stress.

Table 1. Values of different levels

Independent factors → Levels ↓	NaOH concentration in % (**A**)	Duration of treatment in hours. (**B**)	CNSL concentration in % (**C**)
Low level (-1)	5	6	5
Mid-level (0)	10	12	20
High level (+1)	15	24	35

Equations (1) and (2) are generalized equations for the ultimate strength and for the breaking stress, respectively. These regression equations help us to find the ultimate and breaking stresses for any value between low level and high level values of the three input parameters (NaOH%, CNSL% and the treatment duration).

The tensile strength of the banana fiber is 54 MPa and has a density of 1350 kg.m^{-3} [9], which makes it suitable for reinforcement of polymeric matrices. The tensile strength of epoxy matrix without reinforcement is between 15-20 MPa [12]. Banana fiber reinforced epoxy composites (which have non-biodegradable matrices) have tensile strengths between 15-30 MPa [7].

The composites tested in this work exhibit tensile strength as high as 25 MPa, as seen in Fig. 5. Hence, the composite has a tensile strength comparable to other banana fiber reinforced composites that are non-biodegradable.

4 Conclusion

The ultimate and failure stresses decrease with increase in the CNSL%. This is the general trend observed in most of the cases. Maximum Strength of natural fibre reinforced composite material initially decreases till a critical point and then increases as duration of treatment and NaOH concentration increase. ANOVA technique was used to find the influence of the independent (NaOH concentration, CNSL concentration and the duration of treatment) variables on each of the dependent variables (ultimate stress and breaking stress) and finally the regression equations for ultimate and breaking stresses were obtained. Though the addition of CNSL decreases the strength, it improves recyclability and bio degradability, which are properties of the natural resin.

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