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Experimental investigation on the effects of process parameters affecting the mechanical properties of Musa Acuminata fibre reinforced thermosetting polymer composites

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ABSTRACT: *Synthetic fibers (such as glass, carbon, ceramic fibers, etc) which were imported at huge cost could be replaced by natural fibers such as flax, hemp, jute, kenaf, etc. which are widely used. In this research work, banana fiber reinforced vinylester matrix composites have been developed by hand lay up molding technique with varying parameters, such as fiber condition (untreated and chemically treated), fiber sizes 10,30 and 50 cm and fiber content (10%, 30% and 50% by weight). The developed banana fiber reinforced composites were then characterized by chemical methods. The results show that tensile strength increases with increase in the fiber size and content; however, after a certain size and fiber content, the tensile strength decreased again. The maximum Tensile strength was 1127N/mm^2 at a fiber length of 2.2cm and volume fraction of 36%. The maximum flexural strength was 67.15N/mm^2 occurring at 10mm fibre length and 50% vol fraction. The minimum creep strength was 2x10^{-4}s^{-1} occurring at 3.2cm fibre length and 30% vol fraction.*

KEYWORDS*: Polymer composite, hydrophilic fiber, hydrophobic polymer, chemical treatment, thermoset, thermoplasts.*

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I. INTRODUCTION

Now-a-days, newer polymer matrix composites reinforced with fibers such as glass, carbon, aramid, etc. are getting a steady expansion in uses because of their favorable mechanical properties. However, they are quite expensive materials. For this, natural fibers such as jute, flax, hemp, etc. can be alternately used to reduce the cost of composites (Mohanty et al., 2004). Moreover, production of environmentally friendly materials is another important issue. Natural fiber composites focus well into this ecological image. The use of natural fibers, derived from annually renewable resources, as reinforced fibers in both thermoplastic and thermoset matrix composites provide positive environmental benefits with respect to ultimate disposability and raw material utilization.

The prominent advantages of natural fibers include acceptable specific strength properties, low cost, low density, high toughness, good thermal properties, and so on, low specific weight, which results in a higher specific strength and stiffness than glass and is a benefit especially in parts designed for bending stiffness. In the fields of automotive industries, reduction of energy consumption in production of motor vehicles and

improvement of their day fuel economy are growing upwards due to accelerating use of natural fiber composites.

In the case of thermoset composites, adhesion between the hydrophilic fiber (such as banana fiber) and hydrophobic matrix (such as vinylester) is poor (Karmaker and Youngquist, 1996). Therefore, the bond between them needs to be improved. This may be improved by alkali treatment. It is believed that the alkali treatment results in an improvement in the interfacial bonding by giving rise to additional sites for mechanical interlocking, hence promoting more matrix/fiber interpenetration at the interface (Gassan and Bledzki, 1997).

In this work, banana reinforced vinylester composite were prepared under various processing parameters using hand lay up molding technique. The goal of this work is to understand the changes of tensile strength under various process parameters.

II. MATERIALS AND METHODS

A. Materials

The composite were produced using 10cm, 30cm and 50 cm for all lengths of fibers with 10%, 30% and 50% (% weight) of banana fiber.

B. Methods

a. **Composite fabrication**

The chopped fibers were sieved with 10cm,30cm, and50 cm sieves for obtaining variation in banana fiber length. The fibers were conditioned at 80^0C for 24 hours to remove moisture and vinylester was also conditioned at the same temperature. Proper proportion of fibers 10,30 and 50% by weight for each of 10, 30 and 50 cm length) and vinylester were properly blended to get a homogeneous mixture for each length type. The mixture was placed in a mold and composite allowed to cure for 5 hours.

b. Tensile test

Tensile testing of the specimens was performed according to ASTM D 638-98 on a universal test machine operated at a crosshead speed 3 mm/min. three test specimens from every composition (combination of predefined fiber length and Weight percentage with vinylester) were tested at the same time and the averages of results were used.

III. RESULTS AND DISCUSSIONS

In this research work, at first selected specimens were observed under metallurgical microscope. Then tensile specimens were prepared according to ASTM specification and were tested using a universal testing machine the Hounsfield tensometers.

A. Tensile strength, flexural strength and creeprate

The typical load-stroke curve obtained from the tensile test is used to predict the failure behavior of the banana fiber reinforced thermoset composite.

The tensile test results have been plotted in as function of fiber length. From these figures, Fig 1, Fig 2, Fig. 3, it is clear that as the fiber length increases, the value of tensile strength increased and then decreases. This observation is true for almost all cases as per these plots, in general, as the fiber percentage increases, the tensile strength also increase and then decreases.

As observed from the curves Fig 1, Fig 2, Fig.3, tensile strength was increased to a maximum at 2 cm fiber length and then dropped. Also, tensile strength was found to increase to a maximum at 30% fiber (by weight) and then decreased. 10% treated fiber composite gave better results than untreated fiber composite.

Fiber length has profound impact on the properties of composites. Besides holding the fibers together, the matrix has the important function of transferring applied load to the fibers. The efficiency of a fiber reinforced composite depends on the fiber-matrix interface and the ability to transfer stress from the matrix to the fiber (Kamani et al. ,1997). In small fiber size (here, 10 cm), tensile strength is low due to the fact that length may not be sufficient enough for proper distribution of load, as proper length is not available for stress distribution, failure occurs easily.

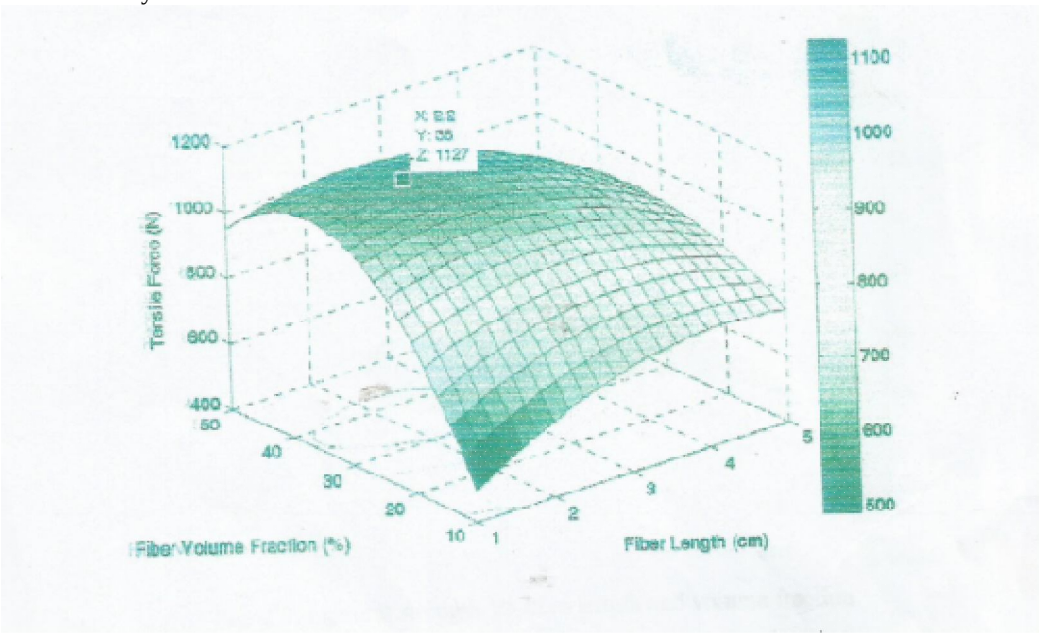

Fig. 1: Tensile strength Vs Fibre length and volume fraction

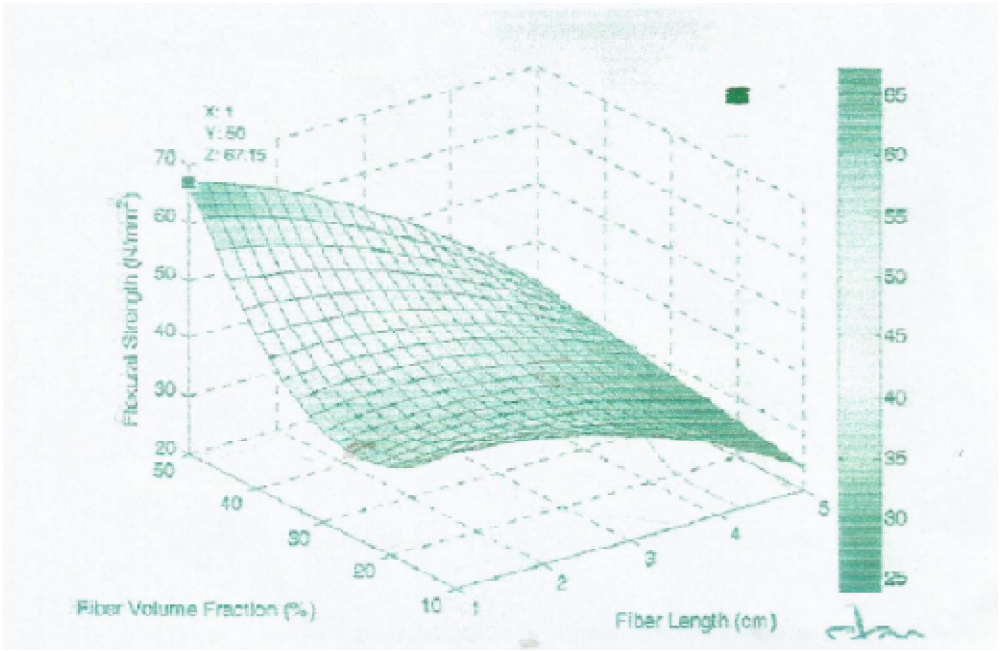

Fig.2: Flexural strength Vs fiber length and volume fraction

On the other hand, for the composites of longer fiber size (here, 50 cm), tensile strengths were decreased compared to 30 cm fiber reinforced composites. The probably reason is that a long fiber may not become

compatible with the matrix properly. Thus improper bonding occurs between the fibers and the matrix. Moreover, fibers may be folded and there is no bonding between the folded and unfolded portion of fiber which resulted in a lower strength. Fiber entanglement may also contribute to reduce the strength (Joseph et al., 2002). For treated fiber composites, the exceptional behavior is probably that 10 cm size of fiber is still not enough to create fiber entanglement or folding inside the matrix.

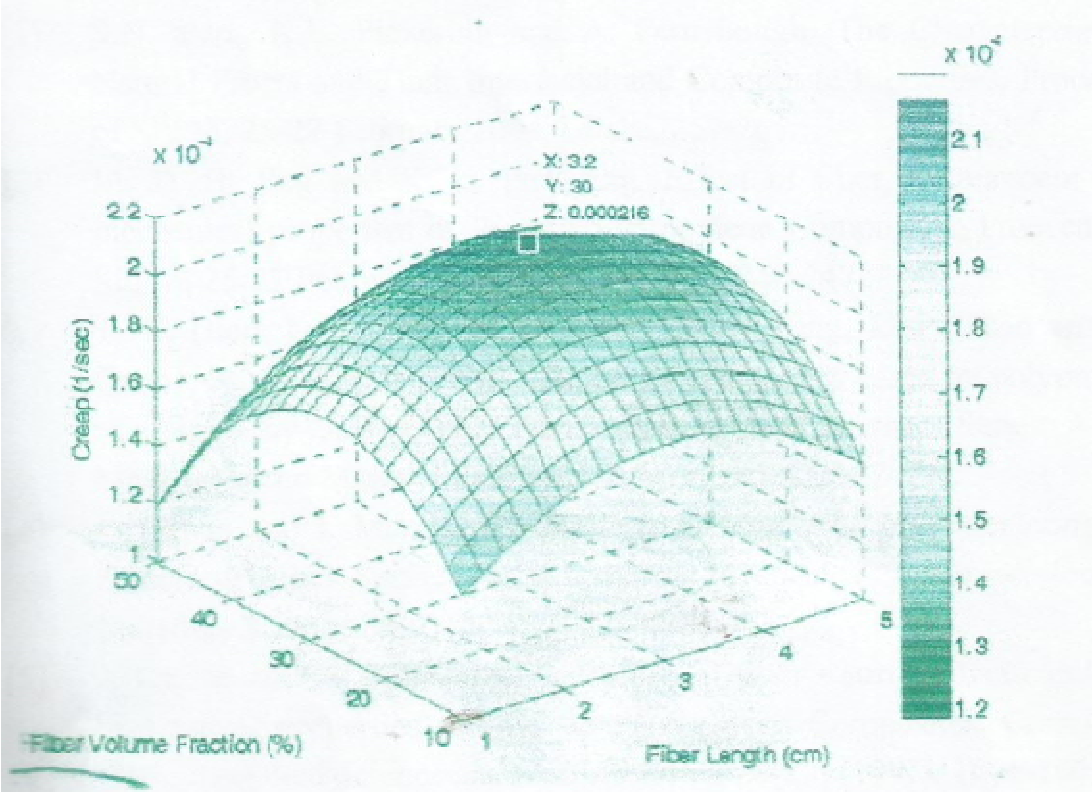

Fig.3: Creep strength Vs fiber length and fiber fraction

In vinylester/banana fiber composites, with the increase of fiber length tensile strength was found to be increased (Joseph et al., 2002). The trend of increase followed by a decrease of tensile strength observed in current work was found in banana/vinylester composite (Jayaraman, [2003).

According to Figures 1,2 and 3 after 30% wt. percent fiber as reinforcement in the composites, tensile strength was decreased with higher percentages of fiber. The incorporation of fibers into thermosets leads to dispersion of fibers due to strong inter fiber hydrogen bonding which holds the fibers together. Improper adhesion hinders the considerable increment of tensile strength. Thus, as fiber percentage increases, gathering of fibers takes pace instead of dispersion and liquid vinylester cannot wet them properly. Since no adhesion is present between the fibers and fibers are also not bonded with matrix, failure occurs before attaining the theoretical strength of composite. Thus high fiber content was limited by the incompatibility issue unless coupling agent is used (Wollerdorfer and Bader , 1998).

It has been reported that initially strength may decrease after a slight increase in strength and then at very high fiber content it may again increase (Wambua et al., 2003).

The tensile strengths of the uncoupled composites have values in close range for all fiber percentage levels (Karmaker and Schneider(1996), Rowell and Stout (1998). Without coupling agent fiber content and fiber length do not have significant effects on composite tensile properties. There exist incompatibilities between the different surface properties of the polar fibers and non-polar vinylester. Due to presence of hydroxyl and other polar groups in various constituents of natural fiber, the moisture uptake is high for dry fibers and these lead to poor wettability with matrix and weak interfacial bonding between the fiber and relatively more hydrophobic matrices. To improve affinity and adhesion between fiber and thermoset, chemical coupling agents can be used so that tensile strength increases (Khan et al., 2001, Sahib and Jog &(1999). As a coupling agent, silane may be used to enhance interfacial adhesion that may react or interact favorably with the hydroxyl group on the fiber surface (Mohanty et al.,2004), Use of coupling agent reduces the number of fiber pull-out (Gassan and Bledzki [2004]).

Alkali treatment generally increases the strength of natural fiber composites (Dieu et al. [2004], Ganan and Mondragon [2000], Razera and Frollini [2004]). A strong sodium hydroxide treatment may remove lignin, hemicelloulose and other alkali soluble compounds from the surface of the fibers to increase the numbers of reactive hydroxyl groups on the fiber surface available for chemical bonding. So, strength should be higher than untreated fiber composites. The probable cause of this phenomenon may be that alkali reacts on the cementing materials of the fiber especially the hemicellulose which leads to the splitting of the fibers into finer filaments. As a result, wetting of fiber as well as bonding of fiber with matrix may improve which consequently make the fiber more brittle. Under stress, these fibers break easily. Therefore, they can not take part in stress transfer mechanism (Ray et al. [2001]). So, high concentration of sodium hydroxide may increase the rate of hemicelluloses dissolution which will finally lead to strength deterioration. Moreover, unnecessary extra time in treatment may also cause increment of hemicelluloses dissolution.

IV. CONCLUSION

From the results of the experimental work we could make the following conclusions

a. In the case of fiber amount, 30 percent fiber (by weight) composites has better tensile strength (figure 1) compared to the other percent fiber content.
b. In the case of fiber length, 30 cm banana fiber composite gave better tensile strength over other fractions.
c. Figure 2 shows that flexural strength increases with an increase in fiber length and fiber volume fraction.
d. The tensile strength increase with fiber volume fraction (fig. 1.0) up to a maximum point of 1127N/mm^2 at a fiber length of 2.2 cm and volume fraction of 36.0%.
e. The creep strength Figure 3 also increase with fiber volume fraction and fiber length up to a point of 0.000216s^{-1} at a fiber length of 3.2 cm and volume fraction of 30%.

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