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Change in Composite Material Behaviour Under Thermal Loading: An Investigation

Satish Birhade[1], Krishan Pandey[2], Bhimrao Pawal[3], Rutuja Bhangale[4], Shanteshwar Dhanure[5]

Lecturer, Department of Mechanical Engineering[1,2,3,4,5]

Pimpri Chinchwad Polytechnic, Pune, Maharashtra, India

Abstract: *Natural fibres are a new generation of reinforcements and supplements for polymer-based products that are made from renewable resources. Due to rising environmental concern, the development of natural fibre composite materials or ecologically friendly composites has become a popular topic recently. Natural fibres are a type of material that can be utilised to substitute synthetic materials and products in order to reduce weight and conserve the environment. Natural fibre reinforced polymer composites and natural-based resins are being widely used to replace conventional synthetic polymer or glass fibre reinforced materials. For its interior components, the automotive and aerospace industries have been actively creating various types of natural fibres, primarily hemp, flax, and sisal, as well as bio resins systems. Natural fibre composites are appealing for a variety of applications due to their high specific characteristics and affordable pricing. The goal of this research is to figure out how thermal loading affects natural fibre reinforced composites. This report is based on a study of composite behaviour at various temperatures.*

Keywords: Natural Fibers, Composites, Thermal Loading, Tensile Test, Bending Test, etc.

I. INTRODUCTION

Composite materials are gaining popularity due to their increased specific strength, stiffness, and fatigue resistance. Composite materials are made up of two or more constituents and contain two or more physical phases that can be separated. Composites are made up of reinforcement, which has a high load bearing ability, and matrix, which has a lower load carrying capacity. It provides desired strength for structural load reinforcement. The matrix or binder (organic or inorganic) maintains its position by reinforcement. Individual constituents have their own properties, but when combined, they produce greater and improved traits.

Natural fibre composites are not new to us; Egyptians were known to use natural fibres in a variety of purposes. Due of their non-conductive nature, wood cotton fibre composites were a hot issue in the twentieth century for electrical applications. These are now employed in automotive and aviation applications where moisture is a secondary consideration. Flax fibre reinforced polyolefin, for example, is widely employed in the automotive industry today, but it is primarily used as a filler material in frames and other non-structural parts. Natural fibres can be employed in structural applications; however, there are some constraints in terms of the environment. Jute, sisal, pineapple, abaca, and bamboo have all been investigated as reinforcement and fillers in composites. Bamboo stalks have a circular cross section and are hollow on the inside.

The pulp is contained in the outer layer. The green layer has the same hardness as hardwood and has a waxy gloss. Stem is capable of extracting fibres. It's able to withstand tremors. Because of its high aspect ratio and robust mechanical qualities, bamboo fibres can be employed as reinforcement in polymer matrix. Bamboo fibres are becoming increasingly popular as a result of this. Natural fibre composites are becoming more popular by the day. Jute fibres, which were obtained from the local market, were also used as reinforcement in this study. The main focus of this paper is on tensile and bending tests of a hybrid composite at different temperatures. As a result, the study's primary goal is to

a. Investigate the behaviour of composite materials when subjected to separate loads
b. Study the behaviour of composite material under thermal loading

Excavator bucket teeth are typically made of alloy steel, and hard facing of some wear resistant materials can be placed to the material of the bucket tooth to extend its life against abrasive wear.

II. LITERATURE REVIEW

C M. Meenakshi [3] has fabricated three types of composite laminates with Glass, Kenaf and Aloe Vera fibers in Epoxy Resins and studied their mechanical and thermal properties. It is found that by adding natural fiber thermal stability increased.
Hua Hu [7] has studied moisture absorption and microstructure evolution of uncoated and coated short jute fibre reinforced He suggest that reliable measures of isolation from moisture must be taken when such composites are exposed in hygrothermal environment.

Paresh V [2] has investigated the mechanical properties of banana fiber epoxy composites in X and Y direction During hygrothermal aging the tensile strength of banana fiber epoxy composites subjected to reduce by average 13.3217%. The change was depending on how the environment was changing.

Yan Yu [13] focused mainly on has tested 11 bamboo fiber and two wood fiber for mechanical properties and he concluded that bamboo fibersshow excellent mechanical properties.
Deepa. A [3] observed that with increase in %weight gain, micro hardness of specimen decrease. %Age area fraction decremented with time has also been studied.

Komorowski [5] concluded that environmental condition affects the noncritical design condition of no defect. Results of tests on samples exposed either on the ground or taken from structures that were in actual service for several years, show little degradation due to environmental exposure. However, most of these samples were only lightly loaded.

Manjunath Shettar [6] has talked about aging effect on GFRP. Thermal and moisture gradient have great influence in hygrothermal aging. It has been observed that aging for long duration has bad effect on strength as well as thermal stability.

Zulkafli [7] studied tensile, flexural and quasi-static indentations of hybrid banana / glass fibers in different stacking sequences were investigated. Based on the results, the hybrid banana / glass fibers showed better mechanical properties with the incorporation of glass fibers, especially in flexural properties.

Amir Hossein [9] concluded that natural fibers have outstanding mechanical and physical properties such as high strength-to-weight; high stiffness-to-weight, low density, good thermal insulation, and biodegradability. But composites have some limitations regarding mainly moisture absorption, variability, and dimensional stability.

Huang [1] successfully used resin transfer molding to fabricate continuous unidirectional bamboo fiber reinforced epoxy composites. On the other hand, the tensile strength and modulus of bamboo fibers decrease after alkaline treatment. The mechanically extracted BF has the better strength compared to other methods.
Natural fibre reinforced composites will be very important in the future, according to a literature review. However, their behaviour under numerous shifting environmental situations is of primary significance. When composites are exposed to humid conditions for an extended period of time, their tensile strength and durability diminish. Because natural fibres were incorporated, the tensile properties of the developed composites improved. There has been very little research into the effect of thermal loading on hybrid composites

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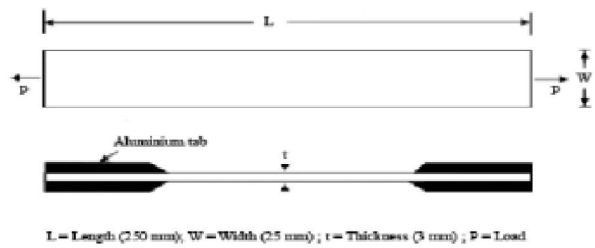
III. MATERIALS AND SPECIMEN

Bamboo fibre and jute fibre reinforced epoxy hybrid composites were used as the materials. The binder is epoxy resin, and the hardener is K-59. The ASTM D3039 standard was used to create the specimen.

Specimen Specification Used for Testing (ASTMD3039)

Sr.No	Specification of theSpecimen	Fortensile testing (mm)	For bending Test (mm)
1	Length	250	250
2	Width	25	25
3	Thickness	3	3



Dimensions of the Tensile Test Specimen (ASTMD3039)

IV. EXPERIMENTAL SETUP AND METHODOLOGY

Oven system has been utilised for various temperature conditions. The test was conducted at a temperature of 28°C and a relative humidity of 65 percent. The test specimens were placed in the chamber once it reached the requisite temperature of 28°C and RH of 65 percent. After the treatment test specimen is taken from the chamber and wiped to remove excess moisture on its surface, the amount of moisture absorbed is calculated using an electronic balance (adjusted to two decimal places) [7]. After that, the specimens were wrapped in aluminium foil to prevent moisture loss or pickup. The percent moisture uptake was calculated using the formula below:

$$w_e\,(t) = 100\times (w_t - w_o) / w_{o,}$$

Where, $w_e$is water absorption percentage, w_t is weight after time t, and w_o is the initial weight of the sample

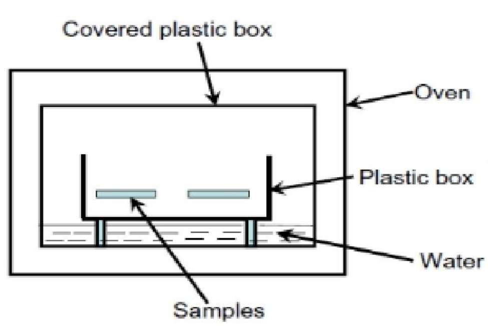


Figure 2: Thermal Treatment Setup

To get the result for large range of temperatures, finite element analysis has been performed on test specimen in ANSYS 19.

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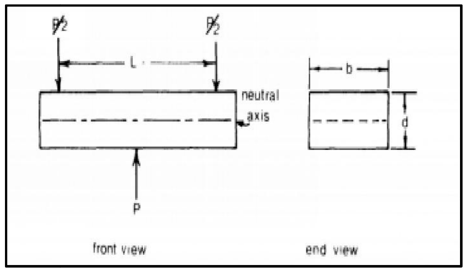
V. PREDICTION OF BEHAVIOUR UNDER THERMAL LOADING



ANSYS 19 was used to simulate tensile testing. The test speed for ASTM D3039 can be determined based on the material. 2 mm/min (0.05 in/min) is a common test speed for standard test specimens.
Extensometers and strain gauges can be used to determine elongation. The rules of mixture are used to calculate the Young's modulus.

$$E_c = E_f V_f + E_m V_m$$

Where,
Ef is the Young's modulus of the fiber, Ec is the Young's modulus of the composite along the fiber direction, Em is the Young's modulus of the matrix, Vm is matrix volume fraction and V f is fiber volume fraction.The abovefig 3 shows the behavior of composite under tensile loading at various temperatures.

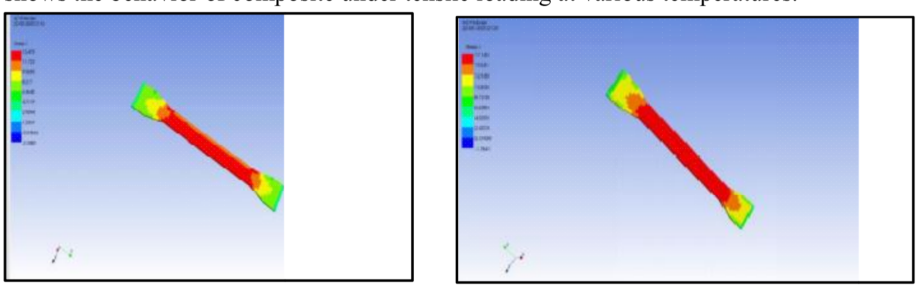


Figure 3: Tensile Test Performed

A bend test is used to determine a material's ductility, bend strength, and fracture resistance. The qualities listed above can be used to predict how a material will behave when subjected to a heavy load for construction purposes. If a material fails to function in a bending test, it is assumed that it will fail catastrophically in real-world applications under similar conditions. Flexural strength is measured using three-point bending tests.
The flexural stress Qf can be calculated by

$$Q_f = \frac{3FL}{2bh^2}$$

Where,

Qf is the flexural stress, (MPa);
Qf is the flexural stress, (MPa);
F is the load in newton's (N);
L is the span, in millimeters (mm);
h is the thickness of the specimen, (mm);
b is the width of the specimen, in millimeter (mm).

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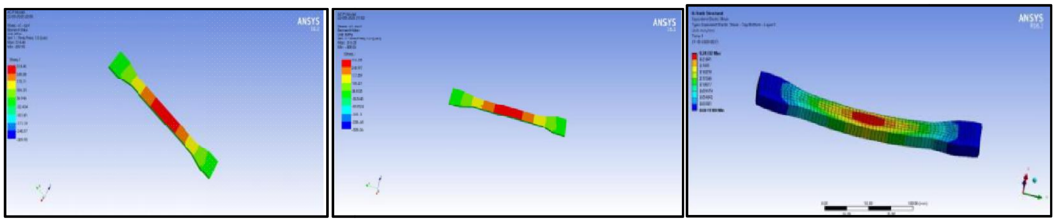

Figure 5: Bend Test Performed

The above figures depict the behaviour of the composite under bending conditions, as well as its deformation pattern.

VI. RESULTS

From the result it has been observed that by adding the natural fiber, tensile properties of neat epoxy-based composite have been improved.

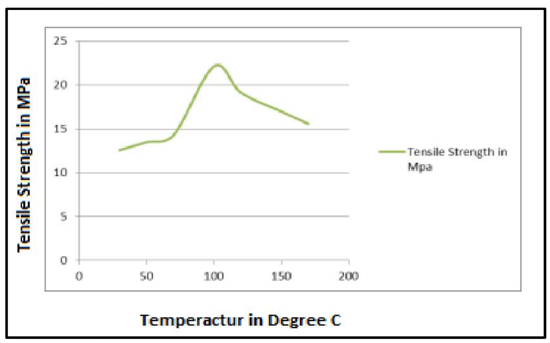

Figure 7: Behaviour of Hybrid Composite during Tensile Test

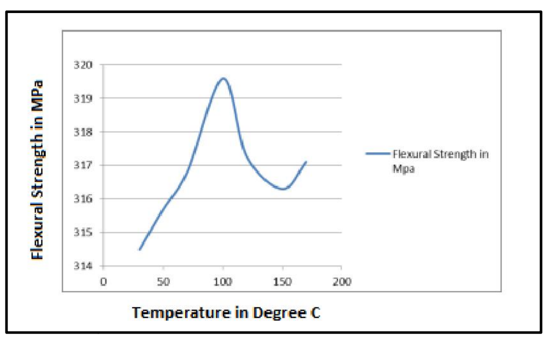

Figure 8: Behavior of Hybrid Composite

The flexural strength of the produced composites increased with increasing temperature until it reached 100^0C, after which it decreased. Above this temperature, the matrix material softens, and the tensile strength decreases. In Figure 8, the flexural strength of the produced composites shows a rise in flexural strength with increasing temperature up to 100°C, then declines with increasing temperature.When compared to the jute fibre composite shown in Figure 9, the hybrid composites had a greater thermal performance. In comparison to jute fibre reinforced composite, hybrid composite has better flexural properties.

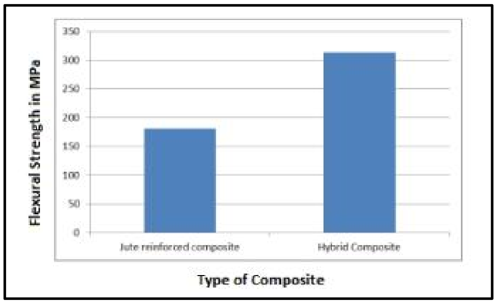

Figure 9: Comparison of Flexural Strength

VII. CONCLUSION

The goal of this research was to anticipate the behaviour of natural fibre composites under combined thermal, tensile, and bending stress. It has been discovered that the advantages of composite materials over conventional materials are mostly due to their higher specific strength, stiffness, and fatigue properties, which boost the usage of natural fibres in structural applications.

Because natural fibres were included into the polymer and bamboo fibre qualities were added, the flexural properties of the hybrid composites improved. The best strength of composites is reached at 100°C, but flexural strength plummets beyond 1000°C.In comparison to a jute fibre reinforced polymer composite, the hybrid composite has better flexural characteristics

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