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Processing and Mechanical Behaviour of Bamboo Fiber Reinforced Polymer Composite Materials

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Abstract: ***The cutting edge dynamic world can't envision its improvement without getting the idea of progression material composite. Different explores are going on in this field to accomplish the ideal standard. Common fiber fortified polymer composite has a tremendous liking to supplant the composite made up of manufactured fiber. This is essentially a direct result of the focal points like light weight, non-poisonous, non-grating, simple accessibility, minimal effort, and biodegradable properties. The manufactured strands have higher part of the arrangement like elasticity and malleable modulus anyway the particular mechanical properties like explicit tractable modulus and other explicit (properties/explicit gravity) of common fiber gives a delightful outcome for composites when contrasted with engineered fiber based composites. The target of the present examination is to research the mechanical conduct of short bamboo fiber strengthened epoxy based composites. Bamboo strands with various length and substance are fortified in epoxy sap to create composite materials. The impact of fiber length and substance on the mechanical conduct of composites is examined.***
Keywords: Bamboo Fiber, Matrix, Reinforcement, Mechanical Behaviour

I. INTRODUCTION

Composite material can be characterized as the material which is made out of at least two particular material on full scale with various properties to shape another material with a property that is totally not quite the same as the individual constituents. The essential period of a composite material is known as a framework having a ceaseless character. As such, framework is a material which goes about as a fastener and holds the filaments in the ideal position accordingly moving the outer burden to fortification. These networks are viewed as not so much hard but rather more flexible. The composite material comprises of a network alongside a fiber with some filler material. The strengthened material can be either engineered or common filaments. In the interest of expanding ecological security, a few common strands strengthened polymer composites (NFPCs) are brought into the aggressive market. NFPCs give a wide scope of focal points over engineered fiber based composites. These focal points incorporate high solidarity to weight proportion, high quality at raised temperatures, high wet blanket protections and high strength [1]. These points of interest can likewise be as their light weight, high solidness and plan adaptability. In NFPCs, the utilized lattices are either thermoset or thermoplastic. Polyester, Epoxy and phenolic sap are the regularly utilized thermoset framework though polypropylenes, polyethylene and elastomers involve the enormous scale position in thermoplastic network.

Composite materials can be arranged in view of the sorts of lattice utilized as:-

A. The Ceramic Matrix Composites (CMC)
B. The Metal Matrix Composites (MMC)
C. The Polymer Matrix Composites (PMC)

Among various types of composites, PMC is the most typically used composites, on account of its various positive conditions, for instance, essential gathering rule, insignificant exertion and high caliber. PMCs have two sorts of polymer that have been used as lattice. These are thermoplastics and thermosetting polymer. Thermoplastic polymer is that polymer which are more than once pacified and improved by warming. A couple of instances of thermoplastics are PVC, LDPE and HDPE.
Thermosetting polymer is the polymer which has hard and solidified cross-associated materials. They are not decrease and pliant when they are warmed. Epoxy is the most by and large used thermosetting polymer.
Starting late, the ordinary strands are getting eagerness as stronghold in polymer composites rapidly. The typical fiber used as stronghold from amazingly antiquated as man used grass and straw from beginning of improvement in reinforcing the hinders that are used to impact mud to divider. There are various focal points of typical fiber over standard invigorating material as needs be as

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low thickness, negligible exertion, updated imperativeness recovery, extraordinary warm properties, satisfactory specific quality and biodegradable [1].

These strands are adequately and copiously available, biodegradable and these central focuses make ordinary fiber surely understood over made fiber, for instance, glass fiber, carbon and other man-made fibers. Ordinary strands are typically happening materials involving cellulose fibrils embedded in lignin arrange.

The structure of some usually utilized common strands is appeared in Table 1, based on the wellspring of beginning, regular filaments are portrayed into three orders they are

1) *Mineral Fibers:* Mineral fibers are the for the most part happening fiber or conceivably adjusted strands obtain from minerals. It has various portrayals they are taking after: Asbestos is the essential by and large happening mineral fiber. The Variations in mineral fiber are the anthophyllite, amphiboles and serpentine. The Ceramic strands are aluminum oxide, glass fibers, boron carbide and silicon carbide. Metal strands merge aluminums fibers.
2) *Creature Fibers:* Animal fiber for the most part incorporates proteins; depictions mohair, fleece, silk, alpaca. Animal hairs are the strands got from animals for example horse hair, Sheep's wool, goat hair, alpaca hair, and so on. Silk fiber is the fibers gathered from dried spit of startling little creatures for the term of the period of planning of spreads. Avian fibers are the strands from flying creatures. Depictions silk from silk worms.
3) *Plant Fibers:* Plant strands are for the most part contains cellulose: portrayals cotton, flax, jute, ramie, sisal and hemp. Cellulose fibers are utilized as a bit of the produce of paper and material. The plan of these strands is as taking after: Seed fibers are the strands obtain from the seed case and seed for example kapok and cotton. Leaf fibers are the strands get from the leaves for example agave and sisal. Skin strands are the fibers are get from the skin or bast joining the stem of the plant [2].

Type of Fiber	Lignin (%Wt.)	Hemi-Cellulose (%Wt.)	Cellulose (%Wt.)	Moisture (%Wt.)	Pectin (%Wt.)	Waxes (%Wt.)
Cotton	-	5.75	86 to 91	7.86 to 8.6	0 to 1	0.7
Bamboo	33	0.6	60.9	-	-	-
Flax	2.3	18.7 to 20.7	72	8 to 13	2.4	1.8
Kenaf	8 to 14	21.6	46 to 48	-	3 to 6	-
Jute	13 to 14	13.7 to 20.5	61.5 to 71.6	12.6 to 14.5	0.3	0.6
Hemp	3.8 to 5.8	17.8 to 20.5	70.5 to 74.6	6.3 to 13	0.8	0.9
Ramie	0.7 to 0.8	13.2 to 16.8	68.7 to 77	7.6 to 17.5	1.8	0.4
Coir	401 to 46	0.16 to 0.26	32.5 to 43.7	9	4 to 5	-
Sisal	11 to 15	11 to 15	66.5 to 78.7	10.3 to 22.5	10.6	3
Banana	6	11	63.5 to 64.7	11 to 13	-	-

This strands having higher adaptability than different fibers. In like way, these strands are utilized as a bit of solid yarn, surface, bundling, and paper. By and by a-days, the standard fiber braced polymer composites applications are generally found in vehicle adventures and building industry and where the dimensional security and burden passing on quality under saturated and warm steadfastness conditions is basic. For example, flax fiber based polyolefin are commonly used as a piece of vehicle industry.

In the present investigation, epoxy is as the lattice material. By and large, epoxy has a lustrous appearance with exemplary focal points like great attachment to different materials, great mechanical properties, great electrical protecting properties, great natural and concoction protections and so on [1]. There are various filaments given naturally to the human humankind. In light of the wellspring of source, this normal fiber can be characterized into three classes, for example, creature fiber, vegetable fiber and mineral filaments. The point by point characterization of regular strands is done underneath in the Figure 1.1.

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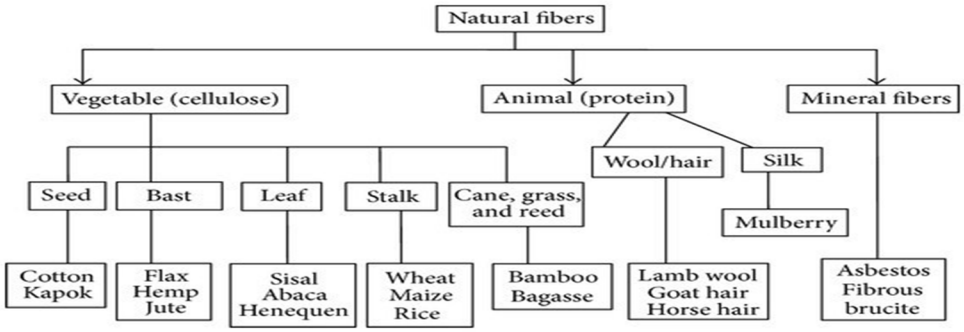

Figure 1.1 Classification of natural fibers based on source of origin

Here, the fiber goes about as a fortification in non-basic inside [3]. Characteristic fiber fortified polymer composites utilized for auxiliary applications, however then for the most part with engineered thermoset grid material which restrict the natural advantages [4, 5]. Properties of few natural fibers are presented in Table 1.1.

Table 1.1 Properties of Natural fibers [3]

Fiber Name	Density (g/cm^3)	Tensile Strength (MPa)	Young's Modulus (GPa)
Sisal	1.4-1.6	508-856	9.5-29
Banana	1.32	528–758	8.3
Cotton	1.6-1.7	288–801	5.6–14
Flax	1.5-1.6	346-1831	28-81
Hemp	1.6	551-1111	59-71
Jute	1.36–1.47	394–801	11–56
Kenaf	46-58	931	21.6
Ramie	1.6	401–939	45–129
E Glass	2.6-2.56	2001-3001	71
Abacca	1.16	401	13
Alfa	0.88	351	13
Bamboo	0.7-1.2	141-231	12-18
Coir	1.3	176	5-7
Pineapple	0.9-1.7	401-628	1.45
Nettle	--	651	39

The main objective of present work is to determine the mechanical properties of bamboo fiber reinforced epoxy composite materials. The effect of bamboo fiber stacking and the length on mechanical properties like strength, rigidity, flexural quality, affect quality and hardness of composites.

II. LITERATURE SURVEY

Hair is a proteinaceous fiber with a firmly various leveled association of subunits, from the α-keratin chains, by means of middle of the road fibers to the fiber [6]. The uncommon properties of human hair, for example, its extraordinary substance piece, moderate corruption rate, high rigidity, warm protection, flexible recuperation, flaky surface, and one of a kind associations with water and oils, has prompted numerous different employments. Volkin et al. [7] distinguished and portrayed the procedures prompting obliteration of cystine deposits. They analyzed proteins from various species, including those of thermophilic microorganisms living close to the breaking point of water.

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Thompson [8] produced a hair-based composite material by controlling a majority of trim lengths of hair to shape a web or tangle of hair, and consolidating said web or tangle of hair with an auxiliary added substance to frame said composite material. Jain et al. [9] examined on hair fiber fortified concrete and presumed that there is colossal augmentation in properties of cement as per the rates of hairs by weight of in concrete. The expansion of human hairs to the solid enhances different properties of solid like elasticity, compressive quality, restricting properties, miniaturized scale breaking control and furthermore increments spalling obstruction. Subsequently human hairs are in relative wealth in nature and are non-degradable gives another time in field of FRC.

Hu et al. [10] considered on Protein-based composite biomaterials which can be framed into an extensive variety of biomaterials with tunable properties, including control of cell reactions. They gave new biomaterials which is an essential need in the field of biomedical science, with guide pertinence to tissue recovery, nano prescription, and ailment medications. Human hair is considered as a waste material in many parts of the world and it is found in civil waste streams which cause various environmental issues. Gupta [11] considered on Human Hair "Waste" and Its Utilization. Through this it has been reasoned that the human hair has countless in regions going from agribusiness to drug to designing ventures. Hernandez et al. [12] contemplated on keratin which is a fiber which is found in hair and quills.

Keratin fiber has a various leveled structure with an exceedingly requested adaptation, is independent from anyone else a biocomposite, result of an expansive development of creature species. Through this it has been reasoned that the keratin strands from chicken quills demonstrates an eco-accommodating material which can be connected in the advancement of green composites. Babu et al. [13] examined on bio-based polymers and presumed that it has generally expanded the consideration because of natural concerns and the acknowledgment that worldwide oil assets are limited.

III. MATERIALS AND METHODOLOGY

The materials that are used in the present work of study are:

A. Epoxy Resin (Matrix)
B. Short Bamboo Fiber (reinforcement)
C. Hardener

1) Preparation of Composites: Dry bamboo fibers were collected from the local market, Srikakulam in the form of long strip with an average width of 15mm. The bamboo fibers were then further left to be died for a week. After a week, the bamboo fibers of three different lengths i.e. 5mm, 10mm and 15mm and a width of approx. 5mm were cut manually. Epoxy Resin and the hardener (HY 951) were supplied by Ciba Geigy India Pvt Ltd. A wooden mould tray having a dimension of 200 × 200 × 40 mm^3 was used for composite fabrication process. Composites with three different wt.% (15wt.%, , 30wt.% and 45wt.%) of fiber with length of 5mm, 10mm and 15mm was taken for the preparation of the composites. The weighed epoxy and hardener is first manually stirred as 10:1 ratio with a glass tube followed with an addition of weighed fiber. The bamboo fiber and epoxy resin is thoroughly stirred to make sure there is no air bubble trapped in the solution. The solution was then poured on a relieving sheet which was already placed in a wooden mould tray. The solution was uniformly distributed over the inner surface of the mould and then closed by another relieving sheet on its top. The mould was then closed and a constant dead load of 50 kg was put on the mould for the purpose of curing to enhance the solution to take the desired shape of mould. The load was left for 24 hours and then released. The composite thus obtained was further allowed to be cured in air for another 24 hours. Figure 3.1 shows the fabricated short bamboo fiber reinforced composite. The various composition of short bamboo fiber reinforced epoxy based composites and their designation is presented below in Table 3.1.

Figure 3.1 Short bamboo fibers

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Table 3.1 Composition of fiber reinforced composite materials

Composites	Composition
C-1	Epoxy (90wt%) + Bamboo fiber of length 5mm (15wt%)
C-2	Epoxy (80wt%) + Bamboo fiber of length 5mm (30wt%)
C-3	Epoxy (70wt%) + Bamboo fiber of length 5mm (45wt%)
C-4	Epoxy (90wt%) + Bamboo fiber of length 10mm (15wt%)
C-5	Epoxy (80wt%) + Bamboo fiber of length 10mm (30wt%)
C-6	Epoxy (70wt%) + Bamboo fiber of length 10mm (45wt%)
C-7	Epoxy (90wt%) + Bamboo fiber of length 15mm (15wt%)
C-8	Epoxy (80wt%) + Bamboo fiber of length 15mm (30wt%)
C-9	Epoxy (70wt%) + Bamboo fiber of length 15mm (45wt%)

2) *Mechanical Testing of Composites:* After the creation of bamboo strengthened epoxy based polymer composite, the example of suitable measurement were set up to complete different tests like rigidity test, flexural quality test, miniaturized scale hardness test and Impact test under ASTM guidelines. The elasticity and flexural quality test were done utilizing howl machine (Figure 3.2.a). Both of these tests are completed on level example. A uniaxial burden is connected to the example in both the bearing of the example, at long last prompting the disappointment of the example after extreme pressure. The ASTM standard test technique for elastic properties of composites has the assignment D 3039-76. Small scale hardness test was completed by utilizing the instrument named LECO hardness analyzer. The test is normally known as Vicker's Micro hardness test. The example utilized for this situation is likewise of level shape. A precious stone indenter of right pyramid shape with a square base and an edge of 1360 between two inverse appearances are constrained into the material under a heap, F kgf. Effect quality of a material is characterized as the property of a material by temperance of which the material contradicts it crack under pressure connected at rapid. Effect quality of a polymer composite material is completely identified with its sturdiness in general.

Fig: 3.2 a. Experimental set up of tensile test b. Specimen for tensile test

c. Loading arrangement for flexural test d. Experimental setup of impact test

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IV. RESULTS & DISCUSSION

The test results of mechanical behaviour for Bamboo fiber reinforced polymer composites with their different compositions are described bellow:-

A. Mechanical Behaviour of Composites

Mechanical properties of short bamboo fibeer reinforced epoxy based composites such as tensile strength, flexural strength, impact strength and hardness number with their different composition are tabulated below.

1) *Effect of Fiber Length on Tensile Strength of Composites:* The tensile strength of a composite material is defined as the resistance offered by the material to get broken under tension. The effect of fiber loading and fiber length on tensile strength of composite is show below in Figure 4.1.

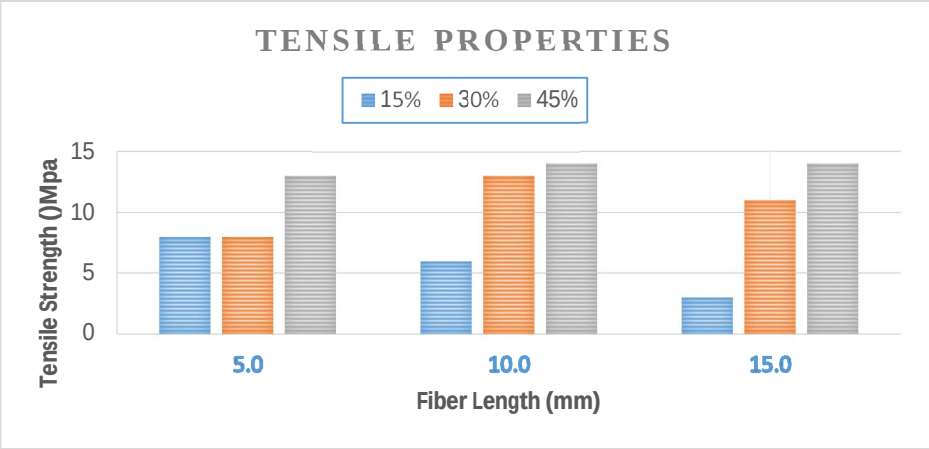

Figure 4.1. Tensile Properties of Bamboo fiber reinforced composites

Elasticity for this situation fluctuates with shifting structure and it is discovered that the quality continues expanding with expanding level of fiber in the composite for every length of fiber. The tractable properties estimated in the present work are very much contrasted and different before agents [12], however the strategy for extraction of bamboo fiber is unique. The tractable modulus shows the overall solidness of a material and would thus be able to be acquired from pressure strain graph [19]. Ideal estimation of rigidity for the composite is observed to be at 45% fiber stacking for every length of fiber. The most elevated an incentive for rigidity is for 45% fiber stacking for a fiber length of 15 mm.

2) *Effect of Fiber Length on Flexural Strength Of Composites:* The flexural strength is stated as the ability of a composite by virtue of which it opposes the deformation likely to be imparted to it under the application of load. The effect of short bamboo fiber loading and fiber length on flexural strength of composites is shown in Figure 4.2.

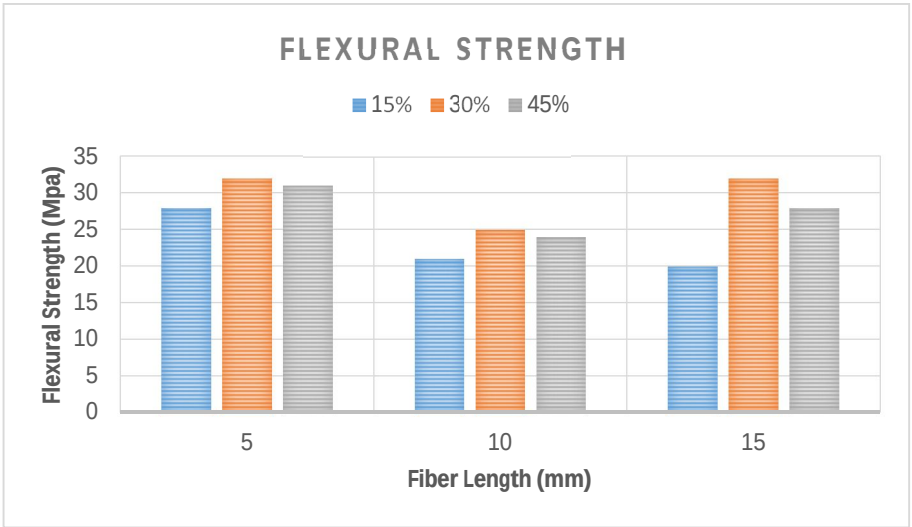

Figure 4.2 Flexural Properties of Bamboo Fiber reinforced composites

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3) *Effect Of Fiber Length On Impact Strength Of Composites:* The impact strength refers to a shock absorbing capacity of composite material. This is entirely related to a toughness of the composite material. The effect of short bamboo fiber loading and fiber length on impact strength of composites is shown below in Figure 4.3.

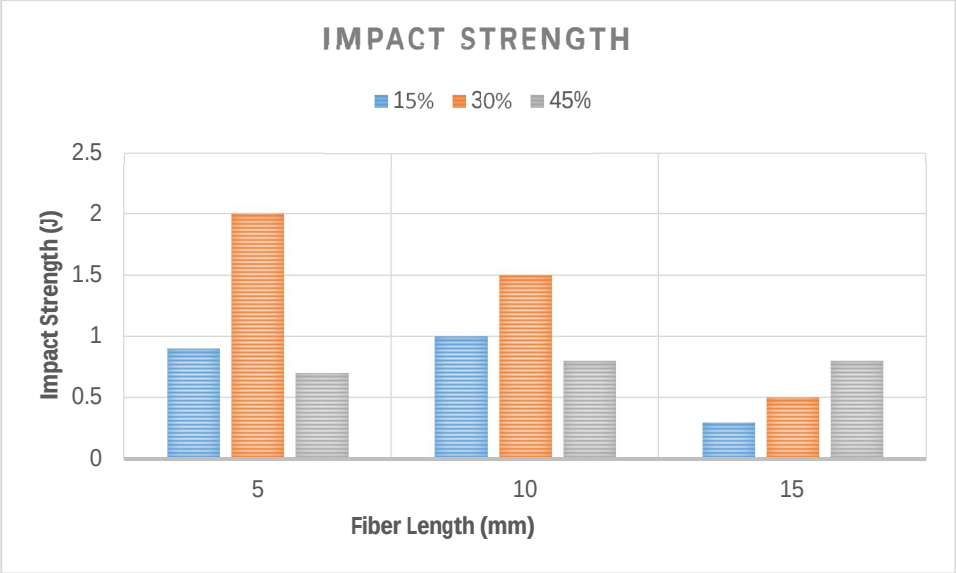

Figure 4.3 Impact Properties of Bamboo Fiber reinforced composites

The diminishing in effect quality or littler variety in quality might be expected to prompt microspaces between the fiber and network polymer, and subsequently causes various smaller scale breaks when effect happens, which incite split proliferation effectively and decline the effect quality of the composites [12, 13].

By and large the effect quality of composite materials increments with the expanding fiber content anyway the lower estimations of effect quality at higher arrangement of fiber might be a direct result of inappropriate attachment between the lattice and the filaments. Higher substance of filaments in composite requires higher framework material however it isn't probably going to be so. Thus all things considered, lattice can't move burden to its filaments.

4) *Effect of fiber Length on Hardness of Composite:* The surface hardness of composite material is at some point a matter of concern when the composite material so created is experienced for space application. For a given work, the composite material was exposed to Vicker's Hardness test and the accompanying perceptions were made (Figure 4.4). From the above figure, it is inferred that the hardness of a short bamboo fiber epoxy based composite increments with the expanding fiber substance and fiber length in a specific way and after that it gradually drops down.

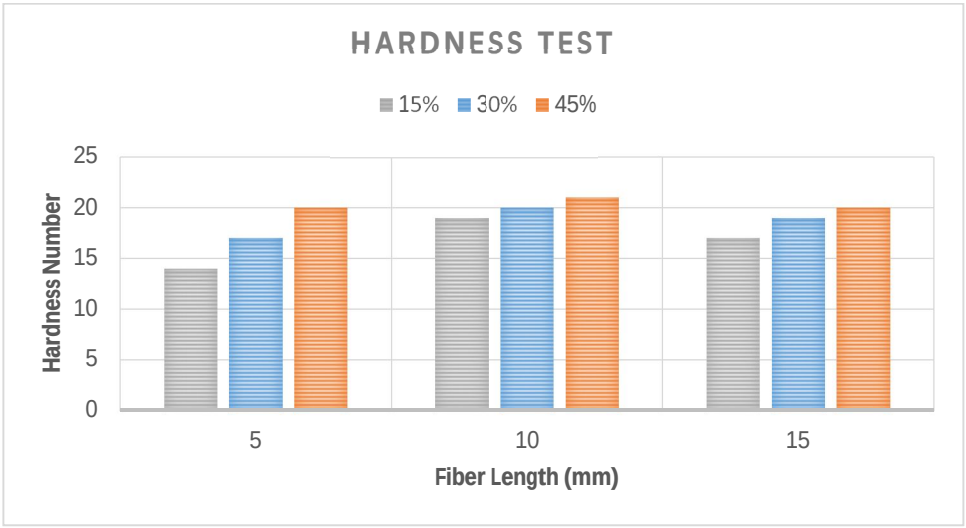

Figure 4.4 Hardness Properties for Bamboo Fiber reinforced composites

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V. CONCLUSIONS

Short bamboo fiber strengthened epoxy based polymer composite was created and its mechanical conduct was examined. The ends drawn from this test examination are as per the following:

A. Epoxy based composite material strengthened with short bamboo filaments have been effectively manufactured.
B. It has been investigated that the mechanical properties of the composites, for example, elasticity, flexural quality, sway quality and hardness are exceptionally impacted by the size of the strands utilized.
C. Excess of strands in composite materials break down the mechanical properties of the composite on account of absence of appropriate holding between the network and fiber around their interface. This makes the interruption in exchange of burden the holding filaments. Lower estimations of effect quality and flexural quality at higher sythesis of bamboo strands might be a direct result of this reason.
D. The present investigation uncovers that effect quality, rigidity and flexural quality increments with expanding substance of fiber in composite materials.

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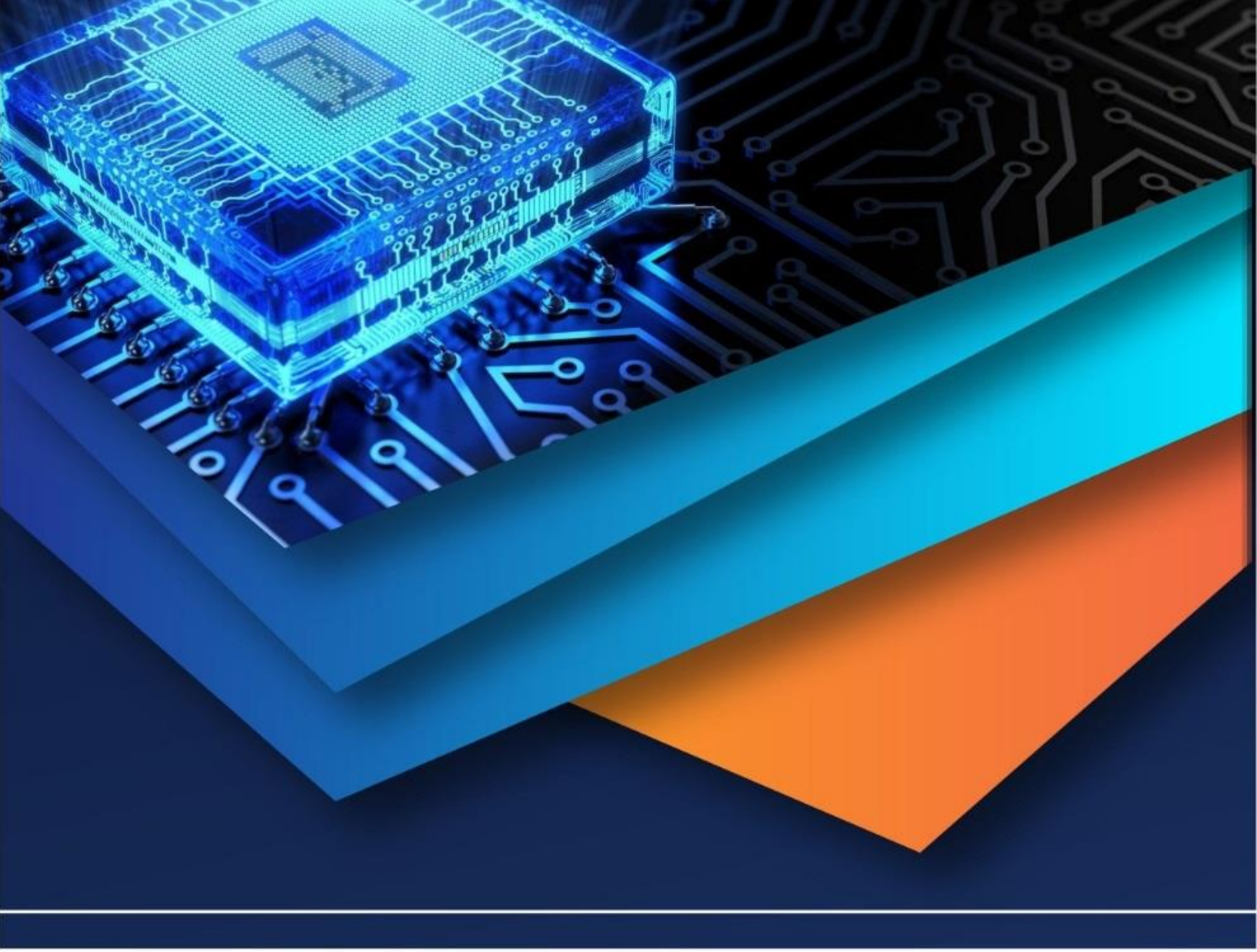

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