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Experimental Investigation of Mechanical Properties of Flax Fibres Reinforced Composites with Epoxy

A.Mohamed Abdul Ajeez[1], T. Pushpaganeshan[2]
[1,2] Mechanical Engineering, Dhanalakshmi Srinivasan College of Engineering and technology

Abstract*: The term Natural Fiber Reinforced composites is now being applied to a surprising range of materials derived wholly or in part from renewable resources. Keeping up with the developments in technology, it is necessary to stop developing materials, which are environmentally insecure. This concept of renewable materials has now become of key importance due to the need to protect our environment. Bio-fibres like flax, coir, bamboo, jute, cotton and so on are now finding applications in a wide range of industries. The field of bio-mass based research has experienced an explosion of interest, mainly with regard to its comparable properties to synthetic fibers within polymer composites. The major area of increasing usage of these composites is the automotive industry, mainly in interior applications. Some of the potential applications of natural fiber reinforced composites are door and instrument panels, package trays, glove boxes, arm rests, and seat backs
Keywords: Epoxy Resin, Fiber, Bamboo, Flax, Coir, Jute

I. INTRODUCTION

Natural fibers like flax, bamboo, coir, jute, hemp, sisal, and banana in their natural form as well as several waste cellulosic products such as wood flour, shell flour and pulp have been used as reinforcing agents of different polymer composites. Several researchers have reported the behavior of natural fibers and their composites by incorporating the fiber in different matrices before and after chemical treatments. The mechanical properties of natural fiber reinforced polymer composites can, in fact, be further enhanced by chemically promoting a good adhesion between the matrix and the fiber. Other advantages of utilizing bio-based fibers are related to their cycle of production which is eco-friendly that is inexpensive and their ease of processing which demands minor requirements in equipment and safer handling and working conditions with respect to synthetic fibers. In any case, the most attractive feature coming from the employment of bio-fibers is the extremely positive environmental impact, due to the fact that bio-fibers are produced from a renewable resource and are biodegradable. Also, bio based composites can be easily recycled and avoiding damping at the end of their life cycle. Therefore, natural fibers represent an interesting alternative as substitutes for traditional synthetic fibers like glass and carbon. Even though, a very large amount of research work has been published on various bio-based natural fibers and their composites, an attempt has been made in the present research to introduce a new bio-based natural fiber as one of the flax fiber and its use as reinforcement in the manufacture of new composite material for the light weight structures.

The objective of this research work is to study the fiber extracted from "Linum usitatissimum" by natural method and the use of these fibers as reinforcement in Epoxy matrix. Flax fiber reinforced composites at various percentage volume of fiber were fabricated, tested and characterized to study their mechanical characteristics. Many fiber-reinforced composite materials offer a combination of strength and modulus that are either comparable to or better than many pure materials with low specific mass and reduced energy consumption.

A. Problem Identification

In current Industrial Processes, the reinforced composites were majorly identified for synthetic fibers. In addition to it, natural fibers such as cotton and jute were also used as an alternative for fiber reinforcement. In case of unavailability or difficulties in attaining fibers from different places, it is convenient if another type of strong fiber is introduced. From flax as a thrice better than cotton we prefer it for reinforcement with epoxy resin.

B. Problem Definition

To increase the mechanical properties of Fiber reinforced composite and to add substitute for fiber requirement through flax fiber.

II. MERITS OF COMPOSITES

Advantages of composites over their conventional counterparts are the ability to meet diverse design requirements with significant weight savings as well as strength to weight ratio. Some advantages of composite materials over conventional ones are as follows.

A. Tensile strength of composites is four to six times greater than that of steel or aluminum (depending upon the reinforcements).
B. Improved torsional stiffness and impact properties.
C. 30% - 40% lighter, for example any particular aluminum structures designed to the same functional requirements.
D. Lower embedded energy compared to other structural metallic materials like steel, aluminum, etc.
E. Composites are more versatile than metals and can be tailored to meet performance needs and complex design requirements.
F. Long life offer excellent fatigue, impact, environmental resistance and reduced maintenance.
G. Composites exhibit excellent corrosion resistance and fire retardant.
H. Improved appearance with smooth surfaces and readily incorporable integral decorative are other characteristics of composites.
I. Composites parts can eliminate joints/ fasteners, providing part simplification and integral design compared to conventional metallic parts.
J. Composite parts provide low coefficient of thermal expansion and offers better fatigue resistance.
K. Composites gives potentially lower component costs such as maintenance costs, quality assurance costs, scrap rate.

A. Demerits of Plywood

When wood veneer is glued together to create plywood, it can end up with voids in the layers. These voids are spaces where the plywood didn’t adhere. These voids reduce the ability of the nail to hold properly in the plywood.

Plywood is made up of various sheets of wood glued together. This leads to splintering at the edges.

Plywood bends or sags when longer pieces are used. It is not considered suitable for applications which require large pieces of wood, such as frost doors, benches or any other situation where long panels are required.

The adhesive used to hold the plies together may be ecologically damaging. One important aspect is that it is important to check which chemical glue has been used for sticking the veneers together. Urea formaldehyde adhesives which are used prior to phenolic resins are not considered very safe for use, and can also pollute the environment.

The process used to make plywood is more costly, especially compared to standard particle board. Plywood does contain more material and it is heavier, which makes up part of the increased cost.

B. Classifications of Composite according to the Fibre Placement

1) Continuous fibre composites
2) Woven fibre composites
3) Chopped fibre composites
4) Hybrid fibre composites

III. LITERATURE SURVEY

The chapter outlines some of the recent reports published in literature on composites. As a result of the increasing demand for environmentally friendly materials and the desire to reduce the cost of traditional fibres (i.e.) carbon, glass, aramid, jute, hemp etc. reinforced petroleum based composites, new bio based composites have been developed. The evolution of composite materials has replaced most of the conventional materials of construction in automobile, aviation industry etc. fibre reinforced composite have been widely successful in hundreds of applications where there was a need for high strength materials. There are thousands of custom formulations which offer FRPs a wide variety of tensile and flexural strengths.

Researchers have begun to focus attention on NFC (i.e. bio – composites), which are composed of natural or synthetic resins, reinforced with natural fibres. Natural fibres exhibit many advantageous properties: they are low density material yielding relatively lightweight composites with high specific properties. These fibres also over significant cost advantages and ease of processing along with being a highly renewable resource, in turn reducing the dependency on foreign and domestic petroleum oil. Recent advances in the use of natural fibre when compared with traditional materials such as metals, the combination of high strength and lower weight has made FRP an extremely popular choice for improving a product design and performance.

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IV. THEORY

A. Reviews on Composites

Natural fibres have been used as reinforcing materials for over 3000 years, in combination with polymeric materials. The study of fibre reinforced plastics began in 1908 with cellulosic materials in phenolics, later extending to urea and melamine and reaching commodity status with glass fibres reinforced plastics (Jawaid et al 2011). However, glass fibres do have some disadvantages; they are non-renewable and give problem with respect to ultimate disposal as they cannot be thermally recycled by incineration and are left behind as a residue. They are also very abrasive which leads to an increased wear of processing equipment such as extruder and moulds. With respect to health they cause skin irritations during handling of fibre products during processing of fibre reinforced parts. Nowadays, there is a growing interest in the development of new materials which ensure optimal utilisation of natural resources, and particularly of renewable resources. Increased pressure from environmental activists and stringent laws has resulted in renewed interest in sustainable composites focusing on renewable raw materials. In this context, there is a growing interest in use of natural fibres such as flax, straw, hemp, ramie and jute etc as reinforcements in composites. Natural fibres can be considered as naturally occurring composites consisting mainly of cellulose fibrils embedded in lignin matrix. These cellulose fibrils are aligned along the length of the fibre, irrespective of its origin. It appears that such an alignment renders maximum tensile and flexural strengths, in addition to providing rigidity in that direction (Satyanarayana et al 1990). These fibres can be found in great amount in nature and are already harvested in many countries of the world. Their primary advantage is their renewal time. Although these fibres are abundantly available in developing countries such as India and Bangladesh, most application is still rather conventional such as matting, carpet backing, packing materials and ropes etc. The natural fibres are categorised into three groups: vegetable, animal hair and mineral fibres (John and Thomas 2008).

The possible advantages of natural fibres composites are:

1) renewable, bio degradable
2) Co2 neutral when incinerated,
3) Lower pollution level during production,
4) Lower cost,
5) Lower density,
6) Healthier in use and
7) Less abrasive to the processing tools.

The theoretical mechanical properties of cellulose reinforced composites are impressive because of the strength and stiffness of crystalline cellulose (Duchemin et al 2009). Of the natural fibres, bast fibres, defined as fibres obtained from the outer cell layers of the stems of various plants are more likely to be adopted as reinforcements over the other cellulosic fibres because of their specific mechanical properties and low density (Summerscales et al 2010). This combination of interesting mechanical properties together with their environmentally friendly character has triggered extensive research activates by research institutions, academicians and automobile industry, as environment friendly alternative for the use of glass fibres.

The flax fibre bundles are glued together by pectin interface. The technical fibres are isolated by the partial separation of these fibre bundles. The bulk of the fibre essentially consists of secondary cell wall layer. The elementary fibres are not circular but polyhedron with five to seven sides to improve the packing in the technical fibre. The elementary fibres are single plant cells, made up of cellulose $(C_6H_{10}O_5)_n$. assembled into bundles of 10-40 fibres maintained together by pectin. Most of elementary fibres consist of highly crystalline, oriented cellulose fibrils spirally wound in a matrix of amorphous hemicelluloses and lignin. The fibrils in the cell wall are oriented at an angle of about $\pm 10^{\circ}$ to the fibre axis and give the fibre its high tensile strength. The fibre has a hollow space called the lumen which is filled with cytoplasm during cell life and disappears when the plant dies (Baley 2002).

Kromer et al (2009) have studied the physical properties of flax fibres for non-textile applications and have summarised the sampling procedure and the existing methods for measuring geometrical, gravimetrical and mechanical properties of flax fibre, including ring plate test of natural fibre reinforced plastic.

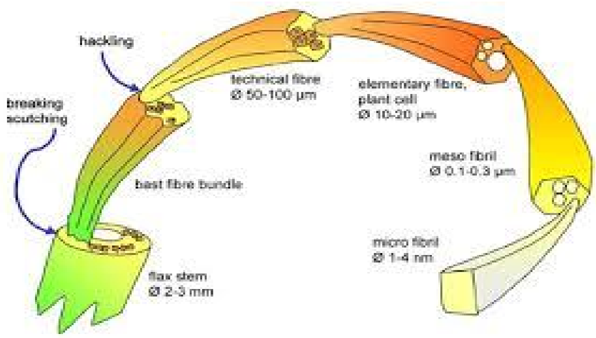

Fig. 1- Schematic picture of technical and elementary flax fibre cells

B. Characterization of Flax Fibres

The morphological structure of multicellular flax fibres makes them analogous to the modern reinforced rigid matrix composites. Smeder Bo et al (1996) in their study on market opinion in applications considered interesting for flax fibres have reported that the industrial interest is different between the applications, but the main function of interest is reinforcement. Further, it has been reported that the most important fibre property of flax when selecting for development for technical uses was consider to be the fibre length. The cell wall of flax is made up of number of layers, the so-called primary cell wall, the first layer deposited during cell development and the secondary cell wall (S). The principal components of the flax fibre cell walls are cellulose, hemicelluloses and lignin with pectin binder. Cellulose attains its highest concentration in the S2 layer. The S2 layer is usually by far the thickest layer and dominates the properties of the fibres. Typical compositions of flax fibres reported by several authors are in the range given in Table 2.1. Various parameters such as the species, variety of plant, weathering conditions, soil quality, retting process and measurement conditions etc all accounts for the varying compositions.

Composition of flax fibre

Cellulose (%)	64.1-73.8
Hemicellulose (%)	11-16.7
Pectin (%)	1.8
Lignin (%)	2.0-2.9
Water soluble substances (%)	3.9
Wax (%)	1.5
Water (%)	7.9-10

C. Report

1) Prepare load vs displacement diagram for each sample
2) Prepare stress vs strain diagram for each sample

Fig. - Flexural test Machine

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D. Impact Test

Notched-bar impact test of metals provides information on failure mode under high velocity loading conditions leading to sudden fracture where a sharp stress raiser (notch) is present. It measures the amount of energy absorbed during fracture of a specimen. This absorbed energy is a measure of a given material's notch toughness and acts as a tool to study temperature-dependent ductile-brittle transition.

E. Test Report

The reading is automated and gives the hardness in HRR scale.

Fig.7 - Hardness test - brinell

Fibre used - Flax fibre with density of 1.45 Kg/m^3

Fig.8 Non continuous Flax fibre

Fig-Epoxy Resin

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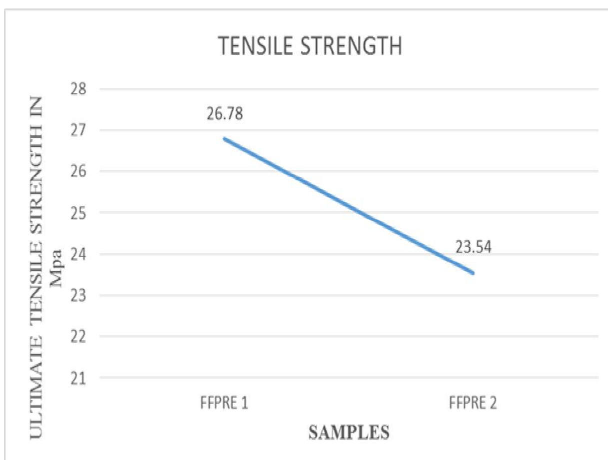
V. RESULTS & CONCLUSION

A. Results

Fig:Flax Epoxy ASTM standard

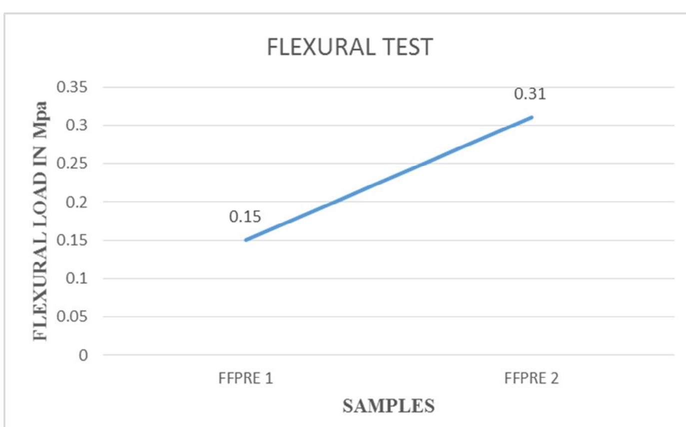
B. Tensile Test

The test is carried out with 4 specimen of each sample and average value is plotted in the above graph. The Ultimate Tensile strength for the Composite fibre is obtained as 26.78 MPa and 23.54 MPa for the samples 1 and 2 respectively. The tensile strength of flax/Epoxy composites at different percentage of flax fibre are depicted in the graph. It is clear that the tensile strength of the composites decreases with increasing percentage of flax fibre. By addition of 5% fibre, the strength was found to be decreased to 6.4% for sample 2 when compared to sample 1.



Graph.1

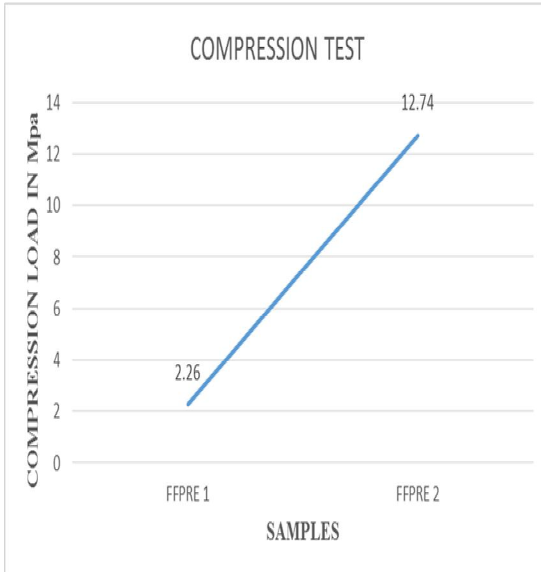
1) Flexural Load Test:



Graph.2

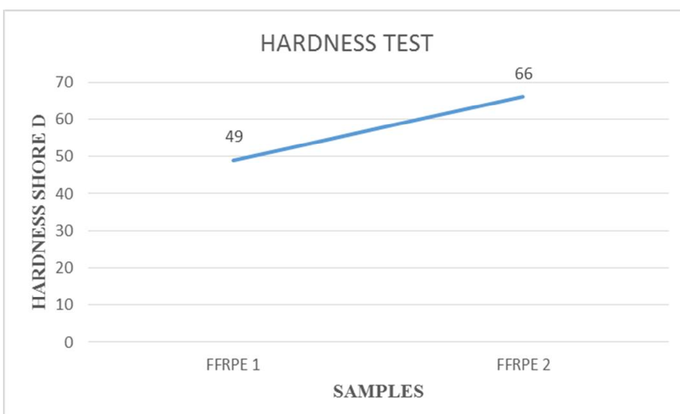
The test is carried out with 4 specimens of each samples and the average value is plotted in the above graph. It is evident that 10% flax fiber reinforced polyester composites showed the maximum flexural strength of 1150 MPa over 60 MPa showed by 5% treated flax reinforced epoxy composites. The maximum force resisted by the flax polyester composite before failure was 2.48KN .The 10% flax fiber reinforced polyester composites were found to have 90 % increase in the flexural strength than the 5 % reinforced epoxy composites.

2) Compression Test:



The test is carried out with 4 specimens of each sample and average value of the overall test is plotted in the above graph. The Compression load for the Composite fibre reinforcement is obtained as 2.26 KN and 12.74 KN for the samples 1 and 2 respectively. The sample 2 is enhances as better mechanical properties for the composite material. The tests showed that the composites made with fibre resin weight percentage were very good with the impact stress as it showed very better values form the tests performed. The fibre provides strength for the composite material, as the flax fiber percentage in the composite is only 5-10 percentage. The Flax Epoxy composite seems to have a better impact strength than the first sample with 69.86 %. The reason being natural fiber contains higher cellulose content and lower micro fibril angle results in higher work of fracture in impact testing.

3) Hardness Test:



The test is carried out with 4 specimens of each samples and average value is plotted in the above graph. The Hardness for the Composite fibre reinforcement is obtained as 49 and 66 for the samples 1 and 2 respectively. Sample 2 provides better mechanical properties for the composite material compared to sample 1. The results were found to be in close conjunction with each other. In the test conducted the hardness value was found for flax fiber reinforced Epoxy composites. This shows that the changes in resins

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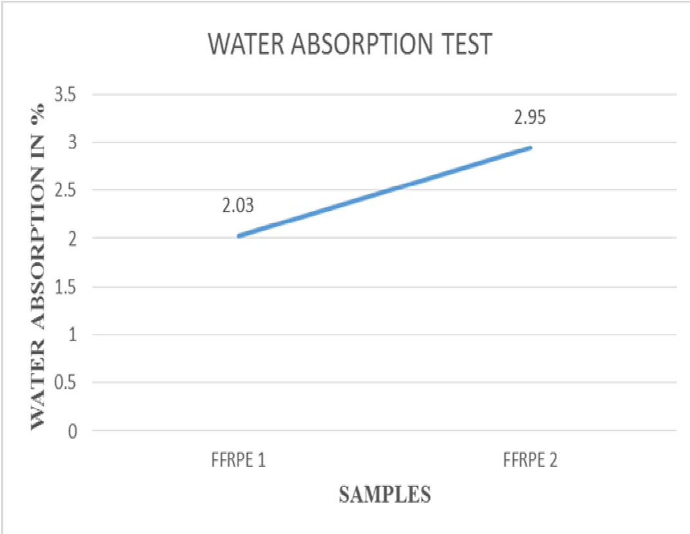
amount have no considerable effect on the hardness of the composite and it mainly depends on the type of fiber used as the reinforcement. The 10% reinforced flax fiber composites showed better results than the 5% reinforced flax fiber composites as the results indicate as in the graph.

4) Water Absorption:



The test is carried out with each sample and average value is plotted in the above graph. The Water absorption for the Composite fibre reinforcement is 2.10% and 2.58% for the samples 1 and 2 respectively. Sample 1 is enhanced with better mechanical properties for less water absorption than sample 2 for the composite materials.

TEST 1 VS TEST 2

S.NO	TYPE OF TEST	SAMPLE FFRE1	SAMPLE FFRE2
1	TENSILE STRENGTH in MPa	26.78	23.54
2	FLEXURAL LOAD in KN	0.15	0.31
3	IMPACT LOAD in KN	2.26	12.74
4	HARDNESS	49	66
5	WATER ABSORPTION in %	2.03	2.95

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C. Conclusion

Flax fibres are cost-effective materials have specific mechanical properties which have potential to replace glass fibres as reinforcement in composite. Their main disadvantage is the variability in their properties. Environmental effects (e.g. high relative humidity) will degrade the tensile properties of flax fibres. A suitable chemical treatment (e.g. Silane) can increase the tensile strength and strain of the flax fibres. The tensile strength and modulus of flax fibres decrease with an increase in fibre length, fibre diameter and gauge length. Flax fibres at the mid-span and tip in the stem with high content of cellulose should be considered as the raw materials. Improving the poor environmental- and dimensional stability of lingo cellulosic materials is an effective way to modify the mechanical properties of these materials. The tensile properties of flax fibres scatter significantly with the change in fibre diameter, gauge length. An appropriate treatment (e.g. Duralin treatment or drying cycle treatment) can be selected to achieve a higher and more uniform strength with less scatter. Flax fibre with thermoplastic, thermoset and biodegradable polymer matrices exhibit promising mechanical properties. A major limitation of using flax fibres as reinforcement in composites is the incompatibility which results in poor fibre/matrix interfacial bonding and thereby reduces the tensile properties. The selection of suitable manufacturing process and physical/chemical modification can improve the mechanical properties of flax composites. Flax composites have the potential to be the next generation materials for structural application for infrastructure, automotive industry and consumer applications. Future work on flax composites should be focused on understanding the environmental assessment, durability, further improving the mechanical properties and moisture resistance. Additionally, novel manufacturing processes and surface modification methods should be further developed.

VI. FUTURE WORK

In this above experiment multiple tasking for the composite may be performed.

A critical issue is that the properties of flax composites are dependent on the properties of the fibre and the adhesion between the fibre and the matrix.

Chemical modifications of the matrix and fibre and use of adhesion promoters can be used in order to improve mechanical properties of natural composites.

Modification relies on chemical and physical techniques, mainly focused ongrafting chemical groups capable of improving the interfacial interactions between filler particles and polymer matrix.

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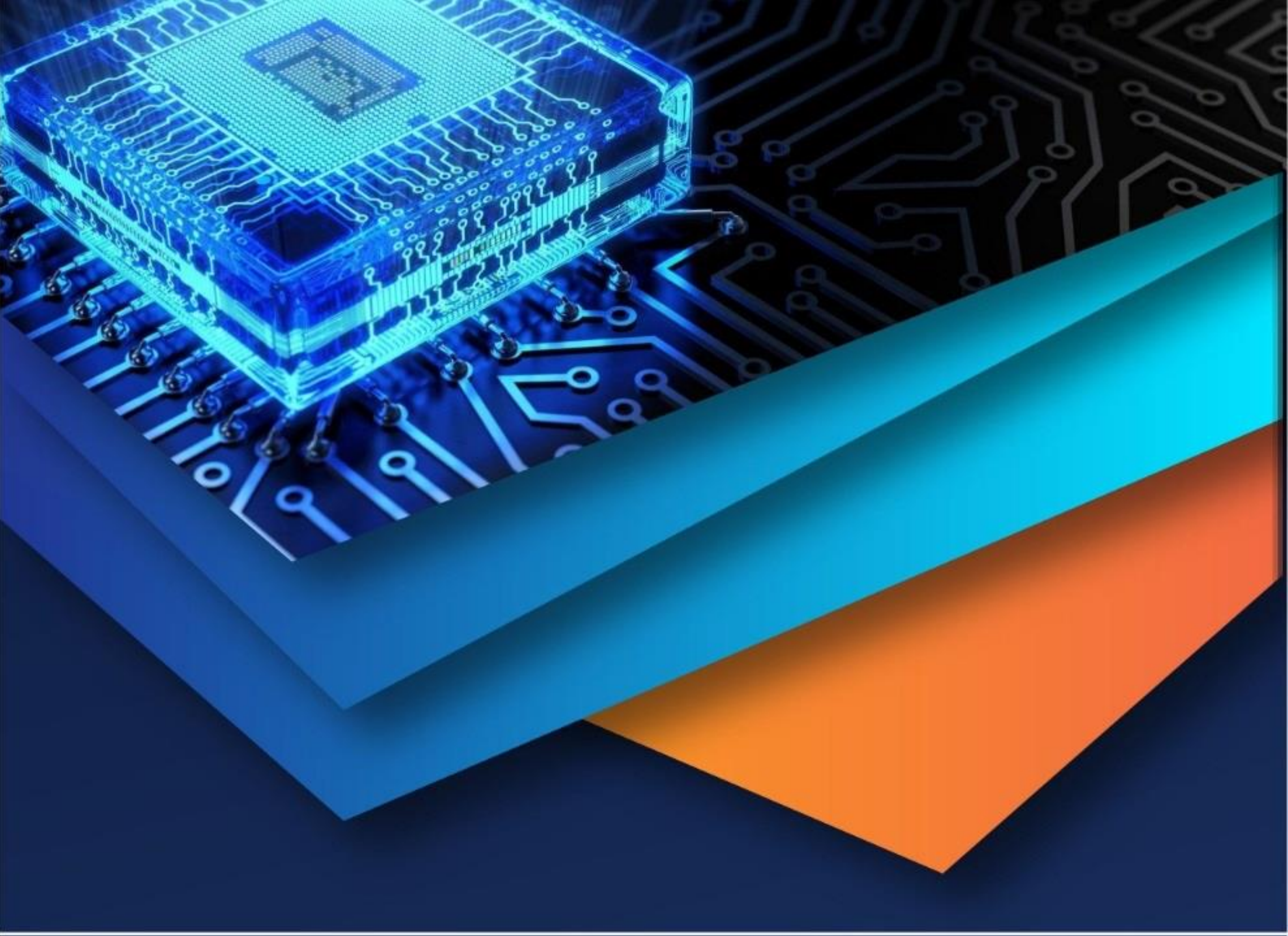

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