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Mechanical Properties of Reinforced Banana Fibre/ Bio-Fibre Hybrid Polymer Composites on Review

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Abstract: ***Last few decades have seen fibre reinforced composite materials being used predominantly in various applications. This review paper discusses about the flexural properties of banana fibre with bio-fibres, which are reinforced hybrid polymer composites. Banana fiber is a lingo-cellulosic fiber, which is obtained from the pseudo-stem of banana plant. Banana fibre is the best fibre with relatively good mechanical properties. Banana fiber has good specific strength properties comparable to those of conventional material, like glass fiber. This material has a lower density than glass fibers. Flexural strength of reinforced composite materials is an important factor in the manufacturing of aircraft structures and woven or braided composites. These are used for a wide variety of cross-sectional forms such as stiffeners, truss members, rotor blade, automobile body parts, spares, etc. and they reduce the fabrication cost and weight. A composite material is made by combining two or more materials of banana fibre or bio-fibres with suitable binders or resin. Reinforcement with natural fibre in composites has recently gained attention due to low cost, low density, eco-friendliness, acceptable specific properties, ease of separation, enhanced energy recovery, Co_2 neutrality, biodegradability and recyclable nature.***

The importance of this review could be attributed to the significant aspects of natural fiber based hybrid composites. The properties of these composite were influenced by the one or more factors such as variation in fiber volume/ weight fraction, variation in stacking sequence of fiber layers, fiber treatment, environmental conditions for the improvement of the mechanical properties such as flexural, tensile and impact properties of the fibres as well as the hybrid composites.

Keywords: Flexural properties, Natural fibers, Banana &Bio-fibres, Hybrid composites.etc.

I. INTRODUCTION

Banana is one of the rhizomatous plants and currently grown in 129 countries around the world. India is the largest producer of banana in the world with an estimated annual output of 13.5 million tons, of which 80% is generated from six states, namely, Tamilnadu, Maharashtra, Karnataka, Kerala, Andhra Pradesh and Gujarat. Annually about 1.5 million tons of dry banana fibres could be produced from the outer sheath of pseudo-stem. Different parts of banana trees serve different needs, including fruits as food sources, leaves as food wrapping, and stems for fiber and paper pulp. The abundant availability of natural fibre in India, has been investigated for their use in plastics, including banana fibre , sisal, coir, paper-mulberry, raphia, flax, hemp, jute, kenaf, ramie, papyrus, straw, wood fiber, oil palm, empty fruit bunch, rice husks, wheat, barley, cane (sugar and bamboo), grass reeds, water pennywort, kapok , pineapple leaf fiber and oats and those could be alternately used to reduce the cost of the composites and weight.

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. Natural fiber composites gained attention due to low cost, low density, eco-friendliness, acceptable specific properties, ease of separation, enhanced energy recovery, C02 neutrality, biodegradability and recyclable nature.

The prominent advantages of natural fibers include acceptable specific strength properties, high toughness, good thermal properties, and eco-friendliness. In the fields of automotive industries, reduction of energy consumption in production of motor vehicles and improvement of their day to day fuel economy are growing upwards due to accelerated use of natural fiber composites.

Synthetic polymer composite materials are widely used in many industrial areas to meet light-weight and high strength requirements. However, with the increasing amount of synthetic polymer materials present worldwide, environmental issues such as disposal treatment, waste disposal services, and incineration pollution demand immediate solutions. Compared with synthetic fibers, the advantages of used natural fibers in composites are their low cost, low density, unlimited availability, biodegradability, renewability, eco-friendliness and recyclability. Natural fibres have a good potential for chemical treatment due to the presence of hydroxyl groups in lignin and cellulose.

Composite is a combination of at least two different materials. when compared to their essential components composites offer superior properties like high flexural, tensile and impact strength. Three dimensional effects are obtained with a combination of components. None of the components can show this desired property alone. The desired properties of matrix element are work environment, strength, high stiffness, heat resistance, chemical resistance and insulation. Reaction of hydroxyl groups can change the surface energy, surface conditions and the polarity of the natural fibres. Different surface treatment methods such as mercerization (alkali treatment), isocyanate treatment, acrylation, benzoylation, latex coating, permanganate treatment, acetylation, silane treatment and peroxide treatment have been applied on the fibre to improve its strength, size and its shape and the fibre-matrix adhesion.

A. Flexural Strength (ASTM D-790)

Flexural strength, also known as bend strength, or fracture strength a mechanical parameter for brittle material, is defined as a material's ability to resist deformation under load. The transverse bending test was most frequently employed, in which a rod specimen having either a circular or rectangular cross section , the bent until fracture using a three point flexural test technique. The flexural strength represents the highest stress experienced within the material at its moment of rupture. Its unit measured in terms of stress. While bending, at the edge of the object on the inside of the bend (concave face) the stress would be at its maximum compressive stress value. At the outside of the bend (convex face) the stress would be at its maximum tensile value. These inner and outer edges of the beam or rod are known as the 'extreme fibers'. Most materials fail under tensile stress before they were failed under compressive stress, so the maximum tensile stress value that could be sustained before the beam or rod were failed its flexural strength.

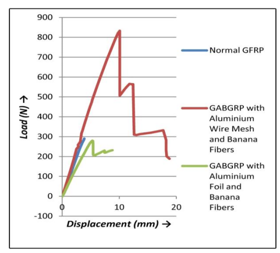

Figure.1 Flexural testing of the specimen (ASTM D 790). Figure 2. Load vs. displacement graphs for flexural test (ASTM D 790)

(Ref:- A Thirumurugan et.al (2016), Investigations on Aluminum wire mesh, Banana Fiber and Glass Fiber Reinforced Hybrid Composites , IJST, vol.9(42) , November 2016)

B. Tensile Test (ASTM D-638)

The ability to resist failure under tensile stress is one of the most important and widely measured properties of materials used in structural applications. The force per unit area in MPa, required to break a material in such a manner is the ultimate tensile strength or tensile strength. Tensile properties indicate how the material will react to forces being applied in tension. A tensile test is a fundamental mechanical test, where a carefully prepared specimen is loaded in a very controlled manner, measure the applied load in various zone, the elongation of the specimen or changing in length and changing in area. Tensile tests are used to determine the modulus of elasticity, elastic limit, elongation, proportional limit, and reduction in area, tensile strength, yield point, yield strength and other tensile properties.

Fig-2: Experimental set up for Tensile Test machine

C. Charpy Impact (ASTM D-256)

The charpy impact test, also known as the charpy v-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of toughness of specimen materials and acts as a tool for study temperature-dependent ductile-brittle transition. It is widely applied in industry, since it is easy to conduct and results can be obtained quickly. A major disadvantage is that results are comparative. The apparatus consists of a pendulum axe (hammer) swinging at a notched specimen. The energy transferred to the material can be inferred by comparing the difference in the height of the hammer before and after the impact .The notch in the specimen and size of the specimen affects the results of the impact test. Thus it is necessary for the notch to be of regular dimensions and geometry. Since the dimensions determine whether or not the materials in plane strain. Impact strength = E/t×1000 , 'E'- Energy used to break (J) , 't' – Thickness in mm

Fig- 3. Experimental set up for Impact Test Machine

II. LITERATURE REVIEW ON FLEXURAL STRENGTH

S. M. Sapuan et al (1).In this paper, the experiments of tensile and flexural (three-point bending) tests were carried out using natural fibre with composite materials (Banana or Musaceae /epoxy). As for the case of three-point bending (flexural), the maximum load applied was 36 N to get the deflection of woven banana fibre specimen beam of 0.5 mm. The maximum stress and Young's modulus in x-direction was recorded to be 26 MN/m^2 and 2 GN/m^2, respectively. Maximum flexural strength was 35 MPa on load of 36.25N (of size L=10cm, b=2.5cm, t=0.5cm) and tensile strength was 26 MPa..

Hetal Shah. et al (2). In their research work, the tensile test and flexural test were conducted according to ASTM standard testing methods D638 and D790 respectively. Flexural strength of silane treated & untreated WBF/UPR composite was 58 MPa & 70 MPa . Tensile strength was 39 MPa for the untreated composite, it was 45 MPa for the composites treated with Vinyl triethoxy silane. The higher flexural strength was due to good bonding between fibre and matrix. The improved fiber–matrix interaction after silane treatment was evident from the enhanced tensile and flexural properties.

Sevgi Hoyur. et al (3) . In this study, in the dimensions of 40x40x100 mm of bio-composite profiles were produced using the banana fibers, glass ropes and polyester resin as filling material through molding process. The surfaces of the profiles were applied glass fibers by lay-up method. The test results showed that the highest and lowest bending strengths (Flexural Strengths) for a single layer specimen were found to be 13 MPa and 8 MPa, respectively. While, the highest and lowest bending strengths for the double layer specimens were found to be 18 MPa and 16 MPa, respectively.

Madhukiran. J et.al (4). Work has been carried out to investigate the flexural properties of composites made by reinforcing banana and pineapple fibers into epoxy resin matrix. The flexural strength of various composites with varying weight fractions and it can be observed that pure banana and pure pineapple composites shows a flexural strength of 213 Mpa and 137 Mpa respectively. The flexural strengths of the hybrid composites of banana/pineapple with weight fractions of 15/25 and 20/20 were found to be 192 Mpa and 223Mpa respectively. However the flexural strength of the hybrid composite of banana/pineapple with 25/15 weight fraction was found to be 278 Mpa which was higher among the others . The banana/pineapple hybrid composite with weight fraction of 25/15 shows maximum flexural strength and maximum flexural modulus.

T. Hariprasad et. al (5).

An investigation has been undertaken on banana-coir, for flexural strength, also known as the modulus of rupture or bend strength, or fracture strength, as a mechanical parameter for brittle materials. The flexural strength of untreated specimen of banana fibre hybrid composites as per ASTM D 790 standards with the fiber weight fraction of 20% has been used, flexural strength (untreated specimen) was 36 MPa. And flexural strength (alkali treated) was 20 MPa. and flexural Modulus was 4890 MPa. An alkali-treated banana-coir epoxy hybrid composite has greater tensile strength and impact strength than an untreated banana-coir epoxy hybrid composite. Tensile strength of alkali treated was 16 MPa and untreated was 13 MPa.

R. Sakthivel et al (6). In this project, natural fiber and glass hybrid composites were fabricated by using epoxy resin combination of hand lay-up method and cold press method. Specimen was cut from the fabricated laminate according to the ASTM standard for different experiments for tensile test, flexural test, and impact test. In this hybrid composite laminates banana-glass-banana (BGB) and glass-banana-glass (GBG) exhibit higher mechanical properties due to chemical treatment to natural fibers. The tensile strength (50×12.50 ×4 mm specimen size) was 54 MPa, flexural strength (100× 27× 4 mm size) was 163 MPa and Impact strength was 10 J/mm^2. Chemical treatments like NaOH will increases the flexural strength was 163 MPa of the fiber up to 20-30% and removes the moisture content of the fiber.

J. Santhosh et al (7).

In this paper both treated and untreated banana fiber are taken for the development of the hybrid composite material. The flexural test was performed by the three point bending method according to ASTM D 790 and cross head speed of 1 mm/min., five specimens were tested, and the average flexural strength was calculated. The flexural properties of untreated/alkali treated banana fiber/epoxy composites at 30% fiber loadings are calculated. It was observed that the flexural strength and modulus of alkali treated banana fiber /epoxy composite has high flexural strength. The maximum Flexural strength, Tensile strength and Impact strength of the composite was 51MPa, 22 Mpa and 8 KJ/ m^2 respectively.

Lina Herrera-Estrada et al (8). In this work, Flexural tests show that banana fiber/eco-polyester composites have a higher flexural strength and modulus, due to improved fiber/matrix interaction. The resulting banana fiber/epoxy composites were found to yield a flexural strength of 35MPa and compressive strength of 122 MPa when alkaline pretreated, with improved environmental exposure resistance. While the non alkaline pretreated banana fiber/polyester composites were found to yield a flexural strength of 40 MPa and compressive strength of 123 MPa, with higher hydrothermal resistance than pretreated fiber composites with the same matrix. In flexural testing of the specimens, Banana fiber/ eco-polyester composites presented a flexural modulus of 2549 MPa; whereas, banana fiber/ epoxy composites presented a modulus 4% smaller than the banana fiber/eco-polyester composite.

Siddanagouda B Biradar et al (9). Investigation was done to study the bending properties of Banana fibre reinforced epoxy composite for treated and untreated fibres. Surface treatment was done on the fibres by applying a thin layer of coating with acetate. Fibres are also treated with sodium hydroxide (NaOH) and potassium permanganate ($KMnO_4$) which is reinforced in epoxy composite. From the results obtained; Resin has less load carrying capacity as compared to the fiber reinforced material. As the number of fibers increase load carrying capacity of the material would also be increased.

P Surya Nagendra et al (10). In this work, three point bending test was performed in accordance with ASTM D790M test method. The percentage tensile strength, % elongation, flexural strength and modulus of the composite were analyzed. The Young's modulus increases as the nanofibre was increased and reached a maximum of 334 MPa at 2% banana nanofiber, then falls to 233 MPa at 8% banana nanofiber. The maximum Flexural strength was 130 MPa, Tensile strength was 164 MPa and the impact strength reaches maximum value of 3 KJ/mm^2 of 4 wt.% BNF. The flexural strength of the composite increased with increasing up to 8 % nanofibres content the composite becomes stiffer and harder, and thus there was an increase in hardness with increasing nanofibre content. The impact strength of base epoxy composite was 2 KJ/mm^2. The impact strength reaches maximum value of 3 KJ/mm^2 of 4wt.% BNF, thus showing an improvement of 38%. Later, the impact strength was found decreased by a further reinforcement of 6 wt. % and 8 wt. % BNF content.

A.K. Chaitanya et al (11). The main objective of this project was investigated the effect of NaOH solution on the mechanical properties of banana fiber in polyester composites. Hand layup method was adopted and the respective tests were conducted by results of the mean tensile strength of NaOH treatment of banana fiber polyester composites was increased to 88 Mpa at volume fraction of fiber 27% than that of 77 Mpa without NaOH treatment at volume fraction of fiber 20%. The mean bending strength of NaOH treatment of banana fiber polyester composites was increased to 266 Mpa at volume fraction of fiber 24% than that of 153MPa without NaOH treatment at volume fraction of fiber 17%. The mean impact strength of NaOH treatment of banana fiber polyester composites was increased to 0.34 J/mm at volume fraction of fiber 26% than that of 0.235 J/mm without NaOH treatment at volume fraction of fiber 23%.

G. S. Divya et al (12). This review article aims, in the improvement of mechanical properties of natural fiber reinforced thermoset composites are suitable chosen and used in automobile sector, industries, aerospace, sports, and also in medical fields for making the components required.. Flexural strength of Banana fibre Polypropylene reinforced composite was 38Mpa, Flexural strength of Natural Fibre Composites (epoxy Banana fibre) was 53MPa, Flexural modulus of thermoset based Polypropylene banana fibre (treated) was 1650 MPa and Flexural Modulus of epoxy Banana fibre reinforced composites was 563MPa. Tensile Strength of NFC (Natural Fibre Composites) of the epoxy Banana fibre reinforced composites was 23 MPa and of polypropylene treated Banana fibre composites was 24 MPa. The young's Modulus of epoxy banana fibre reinforced composites was 1390 MPa and of polypropylene banana fibre (treated) composites was 560MPa.

Narra Ravi Kumar et al (13). In this project work, the composite samples were prepared by mixing of fibers in proper proportions (0, 5, 7.5, 10, 12.5 and 15%) by weight, glass fiber (2.5% of fiber weight) and polypropylene pellets were properly mixed to get a homogeneous mixture. Three point bend tests were performed in accordance with ASTM D790M to measure the flexural properties. The specimens were prepared to dimensions of 64 x 12 x 9 mm. from the results 7.5% fiber weight fraction composites exhibited maximum tensile strength and maximum flexural strength was observed for 10% fiber weight fraction composites. Tensile and Flexural Modulus values increased with increase in fiber weight fraction and higher values were observed in 15% fiber weight fraction composites.

H.Venkatasubramanian. et al (14) This work deals with fabrication and investigation of mechanical properties of natural fibers such as abaca and banana fiber and compares with the hybrid natural fiber composite. Tensile, flexural and impact strength of the composites are investigated in the process of mechanical characterization. Hand lay-up technique was used to manufacture the composite and the fiber content was varied through volume fraction of upto 0.5. Glass fiber on top and bottom layers of the laminate improves its surface finish and adds up strength and Abaca-Glass-Banana Hybrid Composite was found to better Flexural strength and Impact value.

R. Sakthivel, et al (15). In the project natural fiber and glass hybrid composites were fabricated by using epoxy resin combination of hand lay-up method and cold press method. The hybrid composite material shows the highest mechanical properties. From its results, maximum Tensile strength was 54 MPa (on size of (L) 50mm×(b)12.50mm ×(t)4mm), Maximum Flexural strength was 163 MPa (on size of 100 mm× 27mm × 4 mm) and Impact strength was 11 J/ mm^2 (on size of (b)10mm and(t) 3.4mm) on 40% of weight fraction of fibre.

Idicula et al (16). The study on sisal and banana hybrid composites has reported that the mechanical properties were higher. The polyester resin with curing agents methyl ethyl ketone peroxide and catalyst cobalt naphthenate. Where the resins had the following characteristics of tensile strength was 33 MPa, Flexural Strength was 70 MPa, and Impact strength was 9 kJ/m^2. The surface area of banana fiber was higher than sisal because of the diameter of banana fiber was less than that of sisal and volume ratio of banana and sisal 3:1. Flexural and impact properties were higher in bi-layer composites. Tensile strength was maximum in banana/sisal/banana composite. The maximum Flexural modulus was 2991 MPa.

Venkateswaran N et al (17). In this work, has evaluated the mechanical behavior of the banana/sisal fibre composites. In comparing the banana epoxy fiber composites it has found that the optimum length was 15 mm and weight percentage was 16%. When the banana fiber was compared to banana/sisal hybrid composite reinforced with epoxy resin there was an increase of about 16 % , 4% , 35% in tensile , flexural and impact strength of the composite under same length and weight percentage. The flexural strength was 57 Mpa of fibre ratio of banana / sisal on 100/0, 58 Mpa on ratio of 75/25, 59 MPa on ratio of 50/50, 60 MPa on ratio of 25/75 and 62 MPa on ratio of 0/100.

Thiruchitrambalam et al (18). Investigated the woven mat of banana/kenaf fiber polyester based reinforced hybrid composite. It was prepared with 10% alkaline and 10 % sodium Laulryl sulphate-treated fibers. The maximum tensile and flexural strength was found at 40% volume fraction of woven hybrid fiber composites. It was found that the sodium lauryl sulphate given higher property value than alkali treatment. For first test : Flexural strength was 37 MPa, on 11cm untreated fibre length and was 39 MPa on 15cm alkali treated fibre length. For second test :Flexural strength was 43 MPa on 15cm untreated fibre length and was 45MPa on 17 cm alkali treated fibre length. And for third test : Flexural strength was 39 MPa on 13 cm untreated fibre length and was 42 MPa on 16 cm alkali treated fibre length.

Boopalan et al (19). This work, investigated the mechanical properties of jute and banana fiber reinforced epoxy fiber composites. The maximum values which are obtained for tensile strength, flexural strength and impact strength was 18 MPa, 59 MPa and 18kJ/m2 respectively. When the reinforcement in 50/50 volumetric weight the tensile, flexural and impact strength was maximum. When the addition of banana fiber results in 17% increase in tensile strength, 4 % increase in flexural and 35 % increase in impact strength.

A. Thirumurugan et al (20). The investigation conducted on Glass-Aluminum Foil/Wire Mesh- Banana Fibre-Glass Hybrid Composites, it has been inferred that the GABGRP (with Al wire mesh) hybrid composite has the highest flexural strength among its counter parts. In Tensile test, the specimen size of 175 x 25mm×4mm(ASTM D3039) of load of GFRP was 19430 KN. In Flexural test, the specimen size of 125 x 25mm ×4mm (ASTM D790) of load of GFRP was 270 KN. In Impact (Drop Test) 60 x 60mm (ASTM D3029) of load of GABGRP was 835 KN.

S P Jagadish et al (21). In this work, Coated composites were succeed, thrive, with the aid of four different natural fibers such as jute, hemp, banana and sisal with bi-directional orientation in which a Vacuum Bag technique procedure was used to consolidate four dissimilar, materials in a hybrid Natural fibre polymer composite. Characterization was carried out by Epoxy resin with each of 4% of above Natural fibers were placed layer by layer or ply in the form of orthotropic and filled with variying amount of AL_2O_3 . The curing time was around 24 hours at normal room temperature. Maximum Tensile strength was 43 MPa on 16% & 24% of Banana fibre volume fraction and Maximum Flexural strength was 84 MPa on 16% & 24% of Banana fibre volume fraction.

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IV. CONCLUSION

This review concludes that, the flexural strength of banana fibre with bio-fibres (natural fibres) composites have many advantages. It will be of no use if the composites are not fabricated without surface modification of the fibers, good selection of fiber, and the matrix and proper combination of the constituents such as weight fraction, size, and orientation of the fibers. The flexural strength was increased by increasing the weight fraction or volume fraction of the banana fibre or bio-fibres in the composites. The flexural strength was maximum in the direction of fibre length or longitudinal direction than the transverse direction while in bending. If alkali is treated with banana fibre or bio fibre, it will improve the surface finish, then it helps to improve the tensile properties and flexural properties of the composites. The reinforcement of the fibre and its volume fraction with the resin matrix has better flexural strength of hybrid composites. The high flexural strength occurs on banana fibre with bio fibre reinforced hybrid composites of sandwiched fibre matrix while on flexural testing.

A. Sample Conclusions

(flexural strength-ASTM D 790 & Tensile strength-ASTM D 638)

Composites	flexural strength	Tensile strength
1.Banana or Musaceae/epoxy	35 MPa	26 MPa
2. Banana-coir / epoxy	32 MPa	16 MPa
3.Banana-glass-banana	163 MPa	54 MPa
4.Natural Fibre Composites (epoxy Banana fibre)	53 MPa	23 MPa
5. Alkali treated banana fiber /epoxy	51 MPa	22MPa
6. Sisal / banana hybrid	70 MPa	33MPa
7. Woven mat of banana/kenaf fiber polyester	59 MPa	18MPa
8.Jute, hemp, banana and sisal with bi-directional orientation of hybrid polymer composite	84 MPa	43MPa

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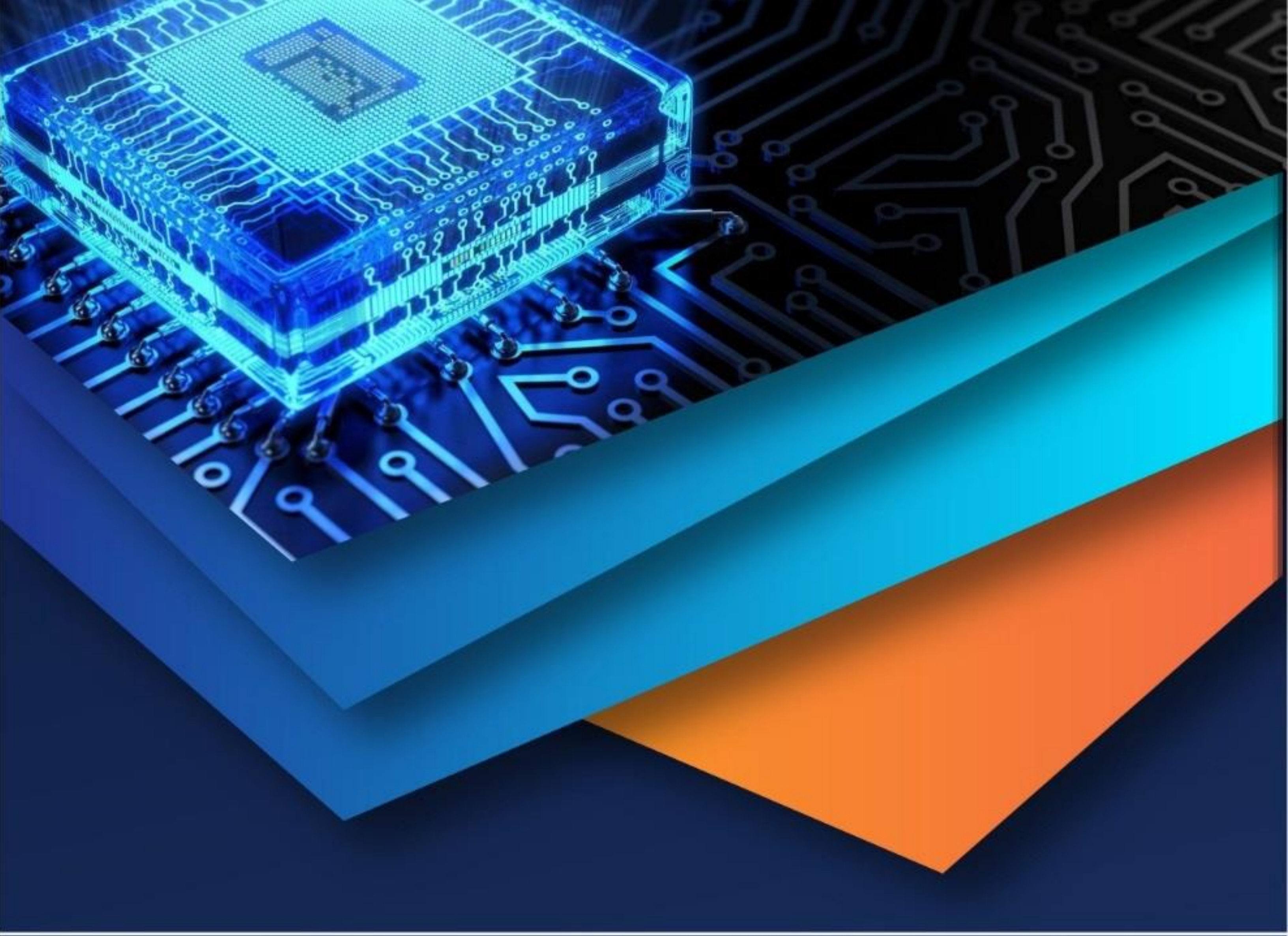

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