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Study of Mechanical and Tribological Properties of Synthetic - Natural Fibers Reinforced Polymer Hybrid Composites for Brake Pad in Automobiles

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Abstract: The hybrid composite materials have wide engineering applications which improves strength, impact resistance, corrosive resistance and more reliable. They form heterogeneous structures which meet the requirements of specific design and function with desired properties, as the incorporation of several different types of fibers into a single matrix has led to the development of Hybrid composites. There is need of natural fibers, which offers cost savings, reduction in density and easy decomposing. Composites with different fiber orientation, matrices and constituents would result in different mechanical properties. Presently the work involves, experimental study, which aims at: The development of Hybrid composites using Hemp cloth, which is a natural reinforcement with S glass fiber as a synthetic reinforcing material with addition of natural filler with varying weight percentage along with the matrix system as epoxy resin will be fabricated using hand layup technique for the development. The developed hybrid composites will be investigated for its Mechanical and Tribological properties. The developed material will be checked for its suitability so that it can be used for brake pad material as a part of automobile application.
Keywords: Epoxy, S-glass, Hemp, Sea Shell, K6 Hardener, Filler, Mechanical tests, Tribological tests

I. INTRODUCTION

Hybrid Composites made of the same reinforcing material system may not give better results as it undergoes different loading conditions during the service life. In order to solve this problem hybrid composites are the best solution for such applications. A hybrid composite is a combination of two or more different types of fiber in which one type of fiber balance the deficiency of another fiber.

The purpose of hybridization is to construct a new material that will retain the advantages of its constituents but not their disadvantages. The concept of hybridization gives flexibility to the design engineer to tailor the material properties according to the requirements, which is one of the major advantages of composites.

The performance of fiber reinforced polymer composites is affected by many factors such as properties of the fibers, orientation of the fibers, content of the fibers, properties of the matrix, fiber-matrix interfaces etc. Increase in volume content of reinforcements can increase the strength and stiffness of a composite to a point. If the volume content of reinforcements is too high then there will not be enough matrix to keep them separate, and they can become tangled. The mechanical properties of fiber reinforced composites are affected by the elastic and strength properties of the matrix, the fibers and the fiber-matrix bond which govern the stress transfer. Similarly, a crucial parameter for the design with composites is the fiber orientation. The arrangement or orientation of the fibers relative to one another within the matrix can affect the performance of a composite. In order to obtain the preferred material properties for a particular application, it is important to know how the material performance changes with the fiber content and fiber orientation under given loading conditions.

Filler is a solid material capable of changing the physical and chemical properties of materials by surface interaction or its lack thereof and by its own physical characteristics.

The braking system is an indispensable component of an automobile, and is composed of many parts including brake pads, master cylinder, wheel cylinders, and a hydraulic control system. The brake pad is an important part of the brake system and consists of steel braking plates with friction materials bound to the surface facing the brake disc. The brake pad generally consists of asbestos fibers embedded in polymeric matrix, along with several other ingredients .The use of asbestos in brake pads has become a source of concern due to its carcinogenic nature and problem of disposal. Industrial and agricultural wastes are currently receiving attention as alterative raw materials to asbestos in the manufacture of brake pads. The use of suitable polymer materials can provide added values and costs associated with disposal.

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II. RELATED WORKS

Prasanna et al. conducted 3 body wear test on hybrid composite consisting of E-glass fiber with basalt fiber in the addition of Sic filler at varying percentage, fabricated by hand layup technique. The 3 body wear test was conducted and the result obtained shows, the presence of sic filler has improved wear resistance. SEM analysis reveals the wear out of fiber with fillers as in [1]. Karthick et al. has studied 3 body wear test investigating on bio composite consisting of PMMA, and Seashell Nano powder in varying percentage, fabricated by stirring and ball milling. The result obtained shows the presence of sea shell powder and can be varied for better wear properties as in [2]. Arunavathi et al. investigated the mechanical property namely tensile strength of jute fibers by humidification and heat treatment. The results obtained shows an increase of 50% in the load bearing capacity by reinforcing jute fiber in a composite hence increasing characteristics such as abrasive wear resistance as in [3]. R.D Hemanth et al. conducted experiments to understand tensile strength test on E-glass fiber with coconut fiber, TETA hardener, fabricated by Hand layup technique. The tensile strength was conducted and the results obtained shows, the E-glass natural fiber composite provides greater value of tensile strength than that of when used a combination of E-glass and polyester fiber as in [4]. Abiodun Ademola et al. has conducted tensile strength test on composite consisting of sea shell (filler), Unsaturated Polyester resin (matrix), Methyl Ethyl Ketone Peroxide (catalyst) and Cobalt Naphthenate (accelerator). The result obtained shows that at 15% concentration of filler (wt. %) in the composite gave the highest ultimate tensile strength and ultimate strain as in [5]. A. Chennakesava Reddy et al. conducted 3-point bend test on composite consisting of Epoxy resin (L12 grade), hardener (K-6), E-glass fiber, fly ash. The results obtained shows flexural strength 81.648MPa to 110.497MPa as in [6]. Shaik Javeed et al. has conducted 3-point bend test on Glass fiber reinforced epoxy composite. The results obtained shows maximum flexural strength @ glass fiber of 30 grams as in [7]. Prem Chand R et al. conducted specific gravity test on composite consisting of hemp fiber, E-glass fiber. The results obtained shows the specific gravity of E-glass is more than that of hemp fiber as in [8]. M. S. EL-Wazerya et al. conducted 3 point bending test, Brinell hardness test and Charpy impact test consisting of Unsaturated Polyester, E glass and MEKP hardener, fabricated using hand layup technique. The results shows that properties of the composite increase with the increase of E glass by fiber weight fraction as in [9]. Parvesh Antil et al. has studied wear properties on pin on disk wear testing machine consisting of Araldite AW106 resin/hardener HV953U is used as matrix and The fiber reinforcement used were E-glass chopped strand mat fibers and S- glass, fabricated using hand layup technique. The results show that the wear property of the produced composite increased exponentially due to the presence of a glass fiber as in [10].

III. MATERIALS AND METHODS

A. Sea Shell Filler

Sea shells were collected from the beach. The shells were cleaned furthermore sun dried for seven days before it was crushed and converted into powder form. The shells were sieved with the help of sieve tester of different sizes of particles at micron level. The shells are compacted and made into small sized particles. Sea shells which were powdered and sieved by using Sieve Analysis method is as shown in Fig. 1.

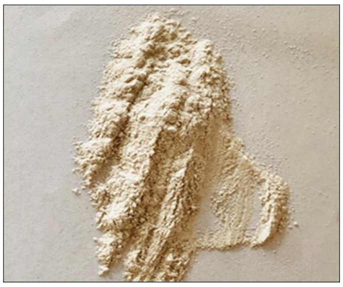

Fig. 1 Sea Shell powder

The chemical analysis were done using a Scanning Electron Microscope (SEM), JSM-IT300 (JEOL, Japan), equipped with a field emission gun (FEG). The EDX quantification provided a rough estimate of the composition of the sea shell powder containing more amounts of calcium present followed by oxygen potassium, silica contents. Fig. 2, shows the SEM area of study to get the EDX Analysis of sea shell powder. The materials inorganic particles presented several shapes and sizes. In general, materials particles had the same appearance, with irregular structure and random form with various perforations. From the SEM images shown in Fig. 3, the particle size were measured and was found to be irregular in shape of the filler and it measured minimum of 300 nm to maximum of 2 microns.

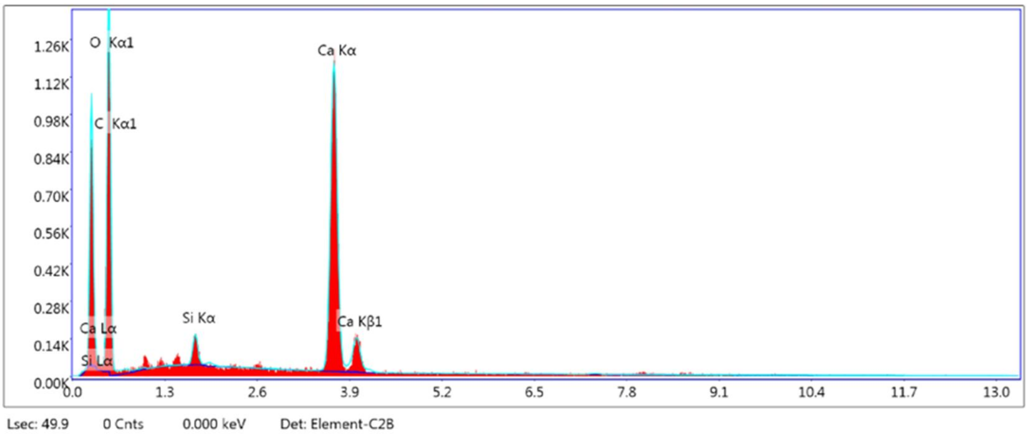

Fig. 2 EDX spectrum: y-axis depicts the number of counts and x-axis the energy of the X-rays of sea shell powder

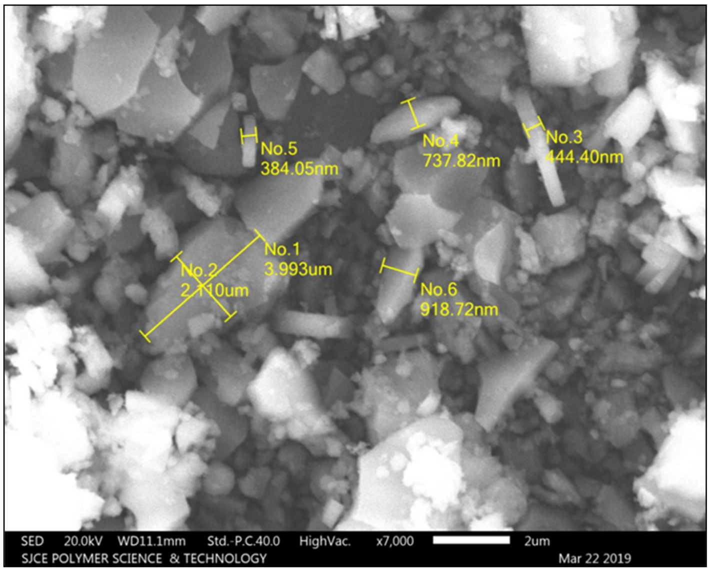

Fig. 3 Typical scanning electron photomicrograph of sea shell powder. Particles can be seen with several shapes and sizes, presenting irregular structure and measurement of the particle size.

B. Matrix & Reinforcement System

The epoxy resin (Lapox L 12) a thermosetting polymer and hardener K-6 was used at right amount along with filler at various proportions. As epoxy is an adaptable resin system, allowing for an extensive range of properties and giving out capabilities. It exhibits low contraction as well as excellent bond to a variety of substrate resources. Reinforcement used were Plain weave woven S-glass fiber made of 193 gsm and hemp fabric has been employed to form material system.

C. Fabrication of Composites

The composite materials are fabricated by hand lay-up process. Hemp and S-glass fibers were cut into the dimensions of length and breadth is of 350×350mm was used to prepare the specimen. The composite specimen consists of 3 layers of S-glass fiber and 5 layers of Hemp fibers for one sample and 5 layers of S-glass and 8 layers of Hemp for another sample. A measured amount of epoxy is taken and mixed with the hardener and Sea shell filler is added into that mixer in a clean bowl. The layers of fibers were fabricated by adding the required amount of epoxy resin. First a release film is placed on a slab then epoxy is coated on the film. The S-glass fiber is first placed then epoxy resin is applied on it. Before the resin gets dried, the second layer Hemp fiber is placed over the glass fiber and this process continues till the required amount of thickness is obtained. Then the release film is placed over the fibers and a dead weight is placed on the composite for equal distribution of matrix. Hand lay-up process is as shown in the Fig 4. Table 1 shows the weight composition of constituents of the respective composite.

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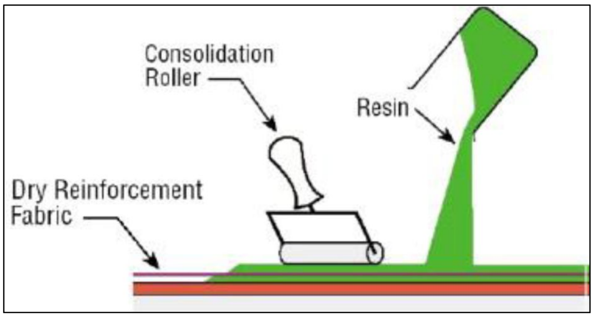

Fig. 4 Hand Lay-up process

TABLE 1
Weight Composition of Constituents of The Respective Composite

Reinforcement Arrangement	Sea shell Weight %	Matrix Weight %	Reinforcement Weight %
Hybrid Composites for Mechanical Testing			
S1:- S:H:H:H:S:H:H:S	5	65	30
S2:- S:H:H:H:S:H:H:S	10	60	30
S3:- S:H:H:H:S:H:H:S	15	55	30
Hybrid Composites for Wear Testing			
S4:- S:S:S:H:H:H:H:S:H:H:H:H:S	5	65	30
S5:- S:S:S:H:H:H:H:S:H:H:H:H:S	10	60	30
S6:- S:S:S:H:H:H:H:S:H:H:H:H:S	15	55	30
Note: S: S-Glass, H: Hemp			

IV. MECHANICAL AND WEAR TESTING

A. Tensile Test

The tensile test is done as per ASTM: D638 standard. A computerized universal testing machine (UTM) is used for testing with a maximum load rating of 200 KN. Hybrid Composite specimens with different compositions are tested. The samples prepared are as shown in Fig. 5.

Fig. 5 Samples for Tensile Test

B. Flexural Test

The flexural test is done in a three point flexural setup as per ASTM: D790 standard. When a load is applied at the middle of the specimen, it bends and fractures. The samples prepared are as shown in Fig. 6.

Fig. 6 Samples for flexural test

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C. Compression Test

The compression test is done as per ASTM: D695 standard. Compressive load tends to squeeze the specimen. Brittle materials are generally weak in tension but strong in compression. But ductile materials are strong in tension, but weak in compression. The samples prepared are as shown in Fig. 7.

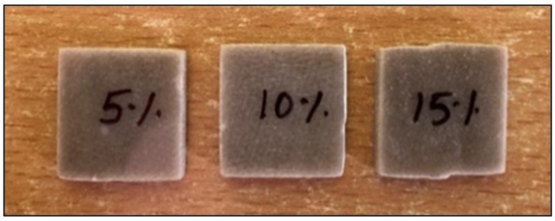

Fig. 7 Samples for Compression Test

D. Impact Test

The impact test is done in a Charpy impact setup as per ASTM: D256 standard. The specimen must be loaded in the testing machine and allows the pendulum until it fractures or breaks. The samples prepared are as shown in Fig. 8.

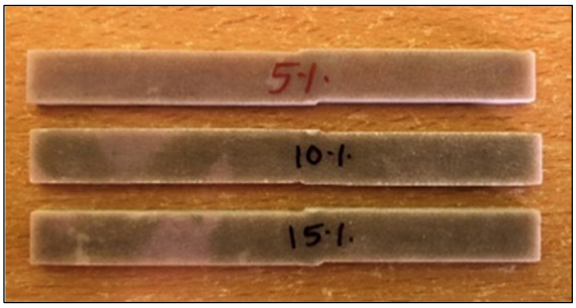

Fig. 8 Samples for Impact Test

E. Rockwell Hardness Test

The Rockwell Hardness Test is done in a hardness test setup as per ASTM: D785 standard. The depth of an indentation determines the hardness values. The samples prepared are as shown in Fig. 9.

Fig. 9 Samples for Hardness Test

F. Specific Gravity Test

Specific gravity test has been done on the specimen using Densimeter equipment and the test is done according to ASTM D792 standard. The samples prepared are as shown in Fig. 10.

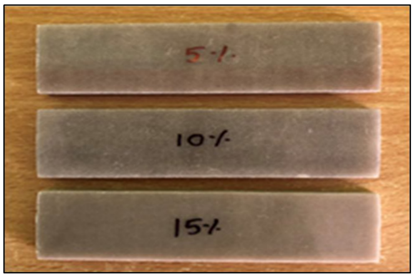

Fig. 10 Samples for Specific gravity test

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G. Two Body Wear Test

Wear is the damaging, gradual removal or deformation of material at solid surfaces. The study of wear and related processes is referred to as Tribology. In two-body abrasion a hard surface rubs against a softer one in which a soft material is ploughed by a relatively hard material. The test is done according to ASTM G99 test standard. The samples prepared are as shown in Fig. 11.

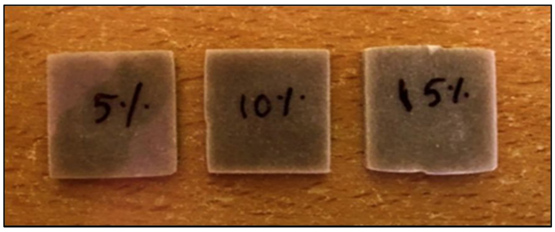

Fig. 11 Samples for Two Body Wear Test

V. RESULTS AND DISCUSSIONS

A. Tensile Test Result

The ultimate tensile stress for 15% sea shell filler in hybrid composites has resulted in 107.28 MPa as shown in the Table 2, when compared with others. Addition of filler has increased the tensile stress, as Calcium Carbonate present in filler has bonded the reinforcements well with epoxy resin.

TABLE 2
Tensile properties of Hybrid Composites

Sl. No.	Sample	Maximum load in kN	Ultimate Tensile Stress in MPa	Young's Modulus in MPa
1.	5%	5.320958993	102.5825909	2534.954707
2.	10%	5.565015974	107.2877574	2589.852372
3.	15%	4.663992954	89.9169646	4044.993645

B. Flexural Test Result

The maximum flexural strength for 15% sea shell filler in hybrid composites has resulted in 225.56 MPa as shown in the Table 3, when compared with others. Addition of filler has increased the flexural stress, as filler breaking with reinforcement has raised the resistance to flexural load.

TABLE 3
Flexural properties of Hybrid Composites

Sl. No.	Sample	Maximum load in N	Maximum Bending Stress in MPa	Young's Modulus of Bending in MPa
1.	5%	383.1669388	225.569234	8372.027463
2.	10%	341.4952479	201.0372338	7762.267221
3.	15%	355.6985192	209.3986573	8673.221437

C. Compression Test Result

The maximum compressive strength for 15% sea shell filler in hybrid composites has resulted in 689.52 MPa as shown in the Table 4, when compared with others. Addition of filler has increased the compressive load, as filler & reinforcement have contributed to resist compressive load.

TABLE 4
Compressive properties of Hybrid Composites

Sl. No.	Sample	Maximum Load in N	Maximum Compressive Stress in MPa
1.	5%	80075	526.52
2.	10%	86880	678.60
3.	15%	89567	689.52

D. Impact Test Result

The impact strength also seems to be higher for 15% sea shell filler in the material system of 62.18 KJ/m^2 as shown in the Table 5, when compared with others.

TABLE 5

IMPACT STRENGTH OF HYBRID COMPOSITES.

Sl. No.	Sample	Charpy Impact Strength (kJ/m^2)
1.	5%	47.04
2.	10%	61.55
3.	15%	62.18

E. Rockwell Hardness Test Result

The Rockwell Hardness Number for 15% sea shell filler in the material system of 6 as shown in the Table 6, when compared with others.

TABLE 6

RHN of Hybrid Composites

Sl. No.	Sample	RHN
1.	5%	79
2.	10%	78
3.	15%	86

F. Specific Gravity Test Result

The density also seems to be higher for 15% sea shell filler in the material system of 1.3698 g/cm^3 as shown in the Table 7, when compared with others.

TABLE 7

Density of Hybrid Composites

Sl. No.	**Sample**	**Density g/cm^3**
1.	5%	1.3095
2.	10%	1.3493
3.	15%	1.3698

G. Two Body Wear Test Result

The two body wear test for 15% sea shell filler in the material system of 1.109×10^{-6} m^3/m of wear rate as shown in the Table 8, when compared with others. The filler has resisted against the abrasion action.

TABLE 8

WEAR TEST VALUES

Sample	Weight loss in gm	Density in g/cm^3	Sliding distance in m	Wear rate m^3/m
5%	0.1881	1.3090	1000	$1.43*10^{-6}$
10%	0.1584	1.3493	1000	$1.1741*10^{-6}$
15%	0.1520	1.3698	1000	$1.109*10^{-6}$
Brake pad	0.3704	2.8	1000	$1.5204*10^{-6}$

VI. FABRICATION OF BRAKE PAD

By referring to the previous results obtained, considering the properties like wear rate, hardness and compressive strength which were important for a brake pad to survive for maximum period. By the results, selecting 15% sea shell composition to fabricate a brake pad. By considering the composition, brake pad has been fabricated by hand lay-up technique.

TABLE 9
WEIGHT COMPOSITION OF CONSTITUENTS OF THE COMPOSITE

Reinforcement Arrangement	Sea shell Weight %	Matrix Weight %	Reinforcement Weight %
S6:- S:S:S:H:H:H:H:H:S:S:H:H:H:H:S	15	55	30
Note: S: S-Glass, H: Hemp			

The composite materials are fabricated by hand layup process. Hemp and S-glass fibers were cut into the dimensions of length and breadth is of 30*20 was used to prepare the specimen. The composite specimen consists of 6 layers of S-glass fiber and 9 layers of Hemp fibers. A measured amount of epoxy is taken and mixed with the hardener and Sea shell filler is added into that mixer in a clean bowl. The layers of fibers were fabricated by adding the required amount of epoxy resin. First a release film is placed on a slab then epoxy is coated on the film. The S-glass fiber is first placed then epoxy resin is applied on it. Before the resin gets dried, the second layer Hemp fiber is placed over the glass fiber and this process continues till the required amount of thickness is obtained. Then a back plate of the brake pad is placed on the layers stacked and then the release film is placed on the completed specimen and a dead weight is place on the completed specimen for uniform distribution. It is cured for 24 hours and then the specimen is removed. After the specimen is removed the brake pad is cut according to the standard shape. This brake pad is used in different automobile applications.

Fig. 12 Fabricated brake pads

VII. CONCLUSIONS

The experimental study on the effect of fibre arrangement on mechanical and Tribological behaviour of S-glass /Hemp reinforced epoxy based hybrid composites with sea shell as a filler leads to the following conclusions:

A. The present investigation revealed that fibre arrangement and sea shell compositions significantly influences the different properties of composites. The maximum impact, hardness, compression, specific gravity is obtained for the 15% sea shell composition. However the maximum tensile and flexural strength is obtained for 10% sea shell composition.
B. In SEM images the particle size were measured and was found to be irregular in shape of the filler and it measured minimum of 300 nm to maximum of 2 microns. Smaller the sea shell particle it fill the voids in the composite and makes it compact and it gives more strength to the composite.
C. In 2-body wear test the results of the different sea shell compositions shows that 15% sea shell composition shows better wear resistance property when compared with the commercial brake pad [11].

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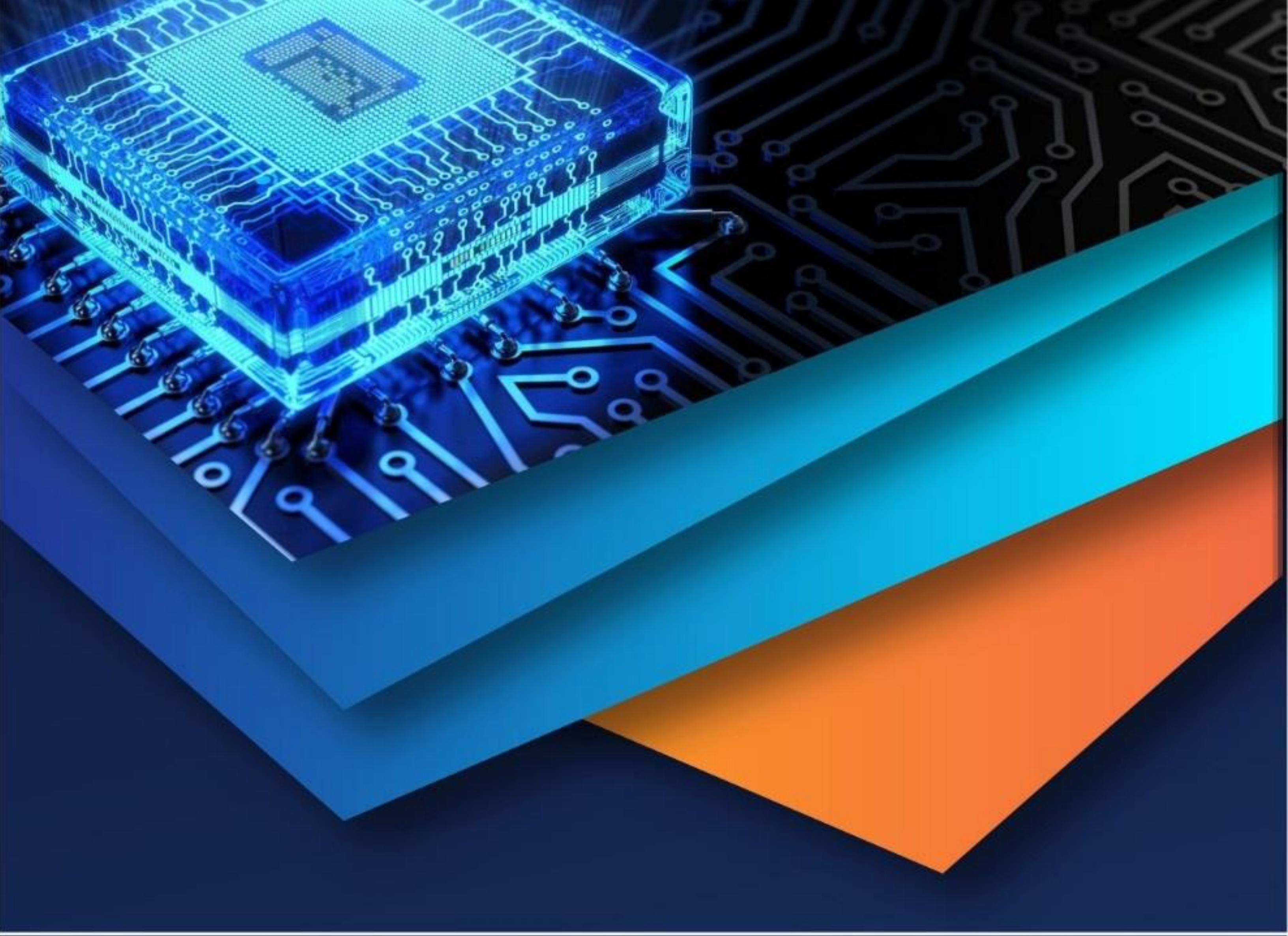

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