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Development of Biodegradable Type Jute and PLA Based Composite for Replacement of PVC Insulation from Electrical Wires

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Abstract: ***The present work has been undertaken with an objective to develop the biodegradable type composite using Polylactic acid as well as natural fibres (chemically treated jute) as a replacement of PVC insulation from the electrical wires and cables. Further, in the present work a separate study has been carried out for finding out the mechanical as well as thermal behaviour of the composite. Crystalline cellulose was extracted from jute by hydrolysis with 40% H_2SO_4 to get mixture of PLA CC was cellulose derived from local source and bleached jute fiber by acid hydrolysis to remove the amorphous regions The diameter gradually became thinner from cutting to top portions. Thus the middle portion of jute fiber would be the better choice while being used as composites.***

Keywords: Composite, Polylactic acid, Biodegradable material Thermal conductivity, Insulation

I. INTERODUCTION

In the recent years, cellulosic fiber materials have grown to be more attractive to the material engineering sectors., material have become alternatives to conventional materials. This is due to their environmentally friendly nature and derived from plants. If the cellulose resources can be fully utilized, much energy can be saved and the environmental pollution can be decreased.[1] A broad variety of natural fibers are now a day's available that can be used as filler in green composites due to their better physic-chemical and physic-mechanical properties. In recent times the natural fibers have found new field of application as reinforcement in composites for replacing the man-made synthetic fibers such as carbon. Jute is a natural biodegradable fiber, largely produced in India, China, and Bangladesh. Jute fibers are durable with many advantages, which include low cost, low density, and light weight, Therefore, it is important to develop new products from jute. The advancement in the field of material science led to many new and advanced materials. [4]

Composites are one of them, which are adopted in various engineering applications. Such authors stated many properties about polymer fibers composite which make them suitable for a many of applications such as aerospace structures, automotive parts, and marine structures. The extensive use of composites in these industries is due to their combined properties of resilience, creep resistance, high strength and stiffness to weight ratios, corrosion resistance, and good damping properties. [3]

A. Jute

Jute is one of the most affordable natural fibers and is second only to cotton in amount produced and variety of uses of vegetable fibers. Jute is a long, soft, shiny vegetable fiber that can be spun into coarse, strong threads. It is produced primarily from plants, which was once classified with the family Tiliaceae, and more recently with Malvaceae. The primary source of the fiber is Corchorus olitorius, but it is considered inferior to Corchorus capsularis. [6] "Jute" is the name of the plant or fiber that is used to make burlap, hessian or gunny cloth. The industrial term for jute fiber is raw jute. The fibers are off-white to brown. Jute is also called the golden fiber for its color and high cash value. [2]

B. Polylactic acid

Poly(lacticacid) or polylactic acid or polylactide (PLA) is a biodegradable and bioactive thermoplastic aliphatic polyester derived from renewable resources, such as corn starch (in the United States and Canada), tapioca roots, chips or starch (mostly in Asia),or sugarcane (in the rest of the world). [3] In 2010, PLA had the second highest consumption volume of any bio plastic of the world, Polylactic acid (PLA) are the most widely studied materials for the regeneration of damaged tissues, acting as artificial supports for cell growth. PLA is mainly used in biomedical applications is the first commodity plastic produced from fully renewable resources. PLA can therefore vary from being an amorphous polymer to semi crystalline or highly crystalline material. [3]

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C. Composite

Considering the huge benefits of environmentally friendly materials, the use of natural/bio fiber reinforced composites has rapidly expanded due to the availability of such renewable resources, for use as reinforcing composites with other synthetic and biodegradable polymer matrices (bio composite) and the low cost and high specific properties of these natural fibers provide significant performance with advantages and economic benefits when their composite with biodegradable polymers. [4] To produce fully renewable and biodegradable composites, both the polymer and fibers have to be derived from renewable resources, where the amorphous regions are removed by acid hydrolysis, can be a very promising cellulosic reinforcement for polymers. Native cellulose is one of the strongest and stiffest natural fibers available. [7]

II. METHODOLOGY FOR MAKING COMPOSITE OF JUTE AND PLA

A. Experimental setup and producer for Composite Development

For making composite a hollow cylindrical pipe will be used, which has one side open to feed the PLA and jute and other side is placed on the steel sheet as shown in the fig.

Fig.1 Mould for strength test

Fig.2 Mould for Lee's disc apparatus

As the inside diameter of the cylinder/mould is 27 mm so the jute fibers of 27 mm length are chopped. Then these fibers are placed transversally in the mould then PLA powder is placed on it. Due to voids present between the jute fibers, the PLA powder moves up to the bottom of the mould and fill the cylinder completely. Then the mould is placed on the microwave oven which has 200˚C temperature for 30 minute. By using the above method 15 different samples for different weight of jute and PLA have been prepared for optimization of maximum density.

For the measurement of the thermal conductivity of the composite Lee's disc method has been used. As per the requirement of the apparatus a circular disc of composite having maximum density has been prepared. For this purpose a different mould has been fabricated having diameter115mm.

B. Selection of optimum value of jute

Many experiments have been conducted for the development of the composite. As the composite made will be sold in the market on the weight basis so the composites developed for different jute and PLA ratios are optimized for the maximum density. To finding the optimum value of jute in the composite initial samples are prepared for fixed amount of Polylactic acid and having different weights of jute fibre. Due to this reason initially the weight of polylactic acid (PLA) has been taken as 10.234 gm. For 10.234 gm of PLA different quantity of jute (0.6 gm, 0.7 gm, 0.8gm, 0.9gm, 1gm, 1.2gm) have been added. The density for the different samples have been measured and presented in the following table.

Table1: Density of composite with varying jute

S.N	Weight (gm)	Diameter (mm)	Height (mm)	Volume (cm^3)	Density (Kg/m^3)
1.	10.04	27.26	23.08	13.4703	743.85
2.	10.38	27.74	26.02	15.8344	655.53
3.	9.830	27.56	27.14	16.1904	607.052
4.	9.660	28.86	26.8	17.53	551.055
5.	10.480	28.06	31.3	19.3557	541.06

C. Selection of optimum value of PLA

From previous section it is evident that for 0.622 gm wight of jute the density of the composite is found maximum. Now for this quantity of the jute, the quantity of PLA in the composite has been varied.

For this purpose quantity of polylactic acid (PLA) has been taken as 8 gm, 9 gm, 10gm, 11gm, and 12 gm, for the quantity of jute as 0.622 gm.

Table.2: Density of composite with varying PLA

S.N	Weight (gm)	Diameter (mm)	Height (mm)	Volume (cm^3)	Density $\left({}^{Kg}/_{m^3}\right)$
1.	8.370	28.16	22.10	13.7641	608.10
2.	9.436	27.90	24.70	15.10006	624.10
3.	11.240	28.60	27.80	17.8594	629.36
4.	12.190	28.86	29.40	19.23223	633.80

III. TESTING ON PLA BASED COMPOSITE MATERIAL

The jute based polylactic acid composite; compressive strength is comparatively low so it is measured by an arrangement in which composite is placed over a flat surface. The other end of the composite is loaded by the different weights. For applying the weight on the composite a steel pan has been used.

A. Compressive and tensile strength test

Test will be started by applying load on the upper steel pan which has weight of 250 gm. The pan is loaded gradually by applying weights of 1, 2, 5 kg. There has been no deformation observed up-to the 19 Kg of applied load on the test sample. However, for 19.2 Kg load, slight surface defects and hair cracks have been observed. Further increase of load i.e. 19.3 Kg leads the clear fracture at the middle portion of the composite.

Fig.3 Composite after compressive test

Fig.4 Arrangement of tensile test

In this arrangement a four point holder with four nuts is used to hold the composite from one side and other side is hold by a screw clamp. The nylon rope is used for holding the weight. From the above arrangement the tensile strength of composite is measured.

B. Thermal Conductivity

Thermal conductivity of composite has been measured using Lee's disc apparatus. The apparatus consists of following

Lee's disc apparatus, Bad conductor in the form of thin disc, Steam generator, two thermometers of 110 ˚C range, Stop watch, Screw gauge and Rough balance sheet.

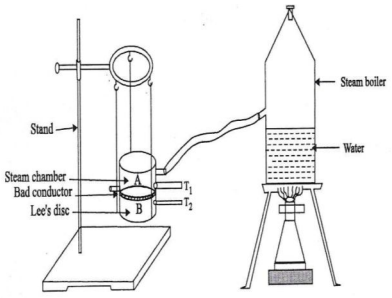

Fig.5 Block Diagram of Lee's disc apparatus

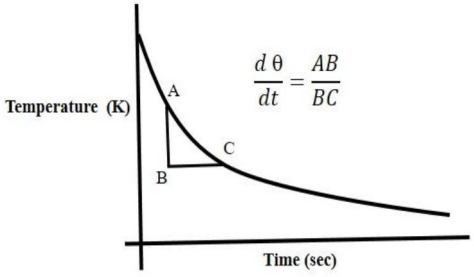

Fig.6 Cooling Curve

The thermal conductivity of bad conductivity

$$K = \frac{MS\left(\frac{d\theta}{dt}\right)d(r+2h)}{\pi r^2(\theta_1-\theta_2)(2r+2h)} \text{ W/m-K}$$

Rate of cooling at $\theta_2 = \left(\frac{d\theta}{dt}\right)_{\theta=\theta_2}$

Table.3: Properties of sample

S.N.	Properties	Unit	Sample1	Sample 2	Sample 3
1	M	Kg	0.850	0.850	0.850
4	θ_1	K	372	372	372
5	θ_2	K	356	349	354
6	r	m	57.7 $x10^{-3}$	57.7 $x10^{-3}$	57.7 $x10^{-3}$
7	h	m	11.27 $x10^{-3}$	11.27 $x10^{-3}$	11.27 $x10^{-3}$
8	d	m	4.03 $x10^{-3}$	8.06 $x10^{-3}$	6.12 $x10^{-3}$

So thermal conductivity of composite is

$$K = \frac{427.0536 \times 0.014 \times 4.03X10^{-3} \times 80.24 \times 10^{-3}}{0.01459 \times 14 \times 137.94 \times 10^{-3}}$$

K = 0.09981 W/m-K

So thermal conductivity of composite

$$K = \frac{427.0536 \times 0.0103 \times 8.06\ X\ 10^{-3} \times 80.24 \times 10^{-3}}{0.010459 \times 23 \times 137.94 \times 10^{-3}}$$

K = 0.0857 W/m-K

So thermal conductivity of composite

$$K = \frac{427.0536 \times 0.0115 \times 6.12\ X\ 10^{-3} \times 80.24 \times 10^{-3}}{0.01459 \times 18 \times 137.94 \times 10^{-3}}$$

K = 0.0928 W/m-K

IV. RESULT AND DISCUSSIONS

A. Composite Develop

1) Selection of optimum value of jute: In Develop process we will discuses to how to find the good strength by fixing the quantity of one and varying the quantity of other. First varying the quantity of jute and fixe the quantity of PLA, this way we have found the sample and calculate its density is in the table.1, According to table plot a graph is in below

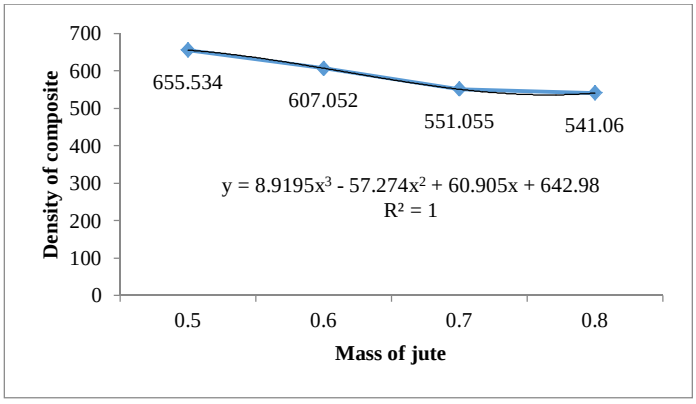

Fig.7 Jute mass and their relative density curve

This graph curve show density will be decreases with the increase the quantity of jute in regular manner, so find the maximum density optimize the curve equation by maxima minima principal. Where we obtained the density is maximum when the jute quantity is 0.622 gm and minimum with3.65gm

2) Selection of optimum value of PLA: Secondly varying the quantity of PLA and fixe the quantity of jute which we obtained for maximum density in above, this way we have found the sample and calculate its density is in the table.2, According to table plot a graph is in below

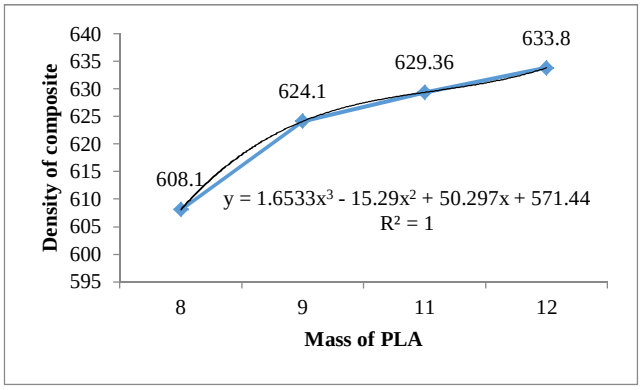

Fig.8 PLA mass and their relative density curve

This graph a curve is formed which show density will be increases with the increase the quantity of PLA in regular manner, so find the maximum density optimize the curve equation by maxima minima principal, a complex value is found. This is optimizing by the minimax fractional programming and partial sworn optimization.

B. Compressive strength

Compressive strength of the jute fiber and PLA composite is finding by the manual load applying on the composite of Volume 18.629 cm^3 and 18.509 cm^3 the composite have no shown any cursing evidence on applying the load 19.550 Kg by applying another 50 gm it will be cursed the fig show the cursing failure of the composite so composite compressive strength is less than the 19.5 Kg.

C. Tensile strength

Tensile strength of jute fiber composite will be find by above discussed method in which we have seen that the there will be no deformation on the composite by applying load on 35 Kg, and we are not able to apply more load because of lack of instrument. So the composite tensile strength is greater than 35 Kg.

D. Thermal Conductivity

Thermal conductivity of bad conductor will be measured by the lees disc apparatus have required a cooling curve is below, three samples are taken to calculate the thermal conductivity of composite.

Cooling curve of the sample are follows:

1) Sample 1

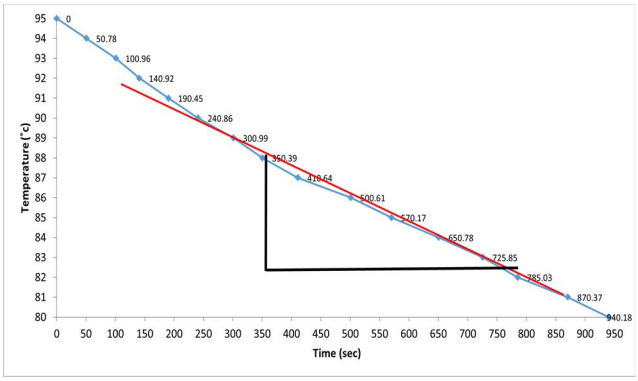

Fig.9 Cooling curve of sample 1

The above curve is in between time and temperature which show the cooling with respect to time, red line show tangent at θ_2 is 85˚c. For this cooling condition thermal conductivity of the bed conductor is 0.09931 W/m-K which is good for the Jute and PLA composite because it is below the thermal conductivity of the pure PLA and above the thermal conductivity of the jute fiber.

2) Sample 2

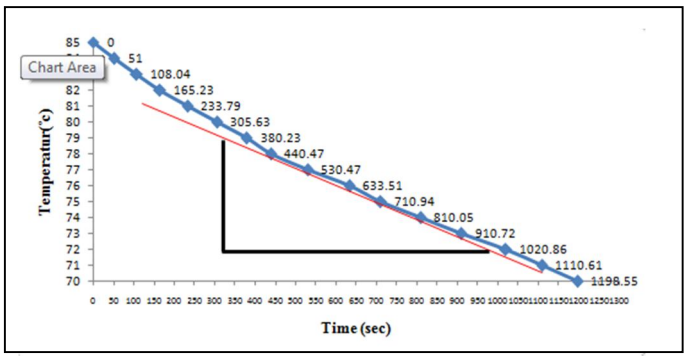

Fig.10 Cooling curve of sample 2

The above curve is in between time and temperature which show cooling with respect to time, red line show tangent at θ_2 is76˚c. For this cooling condition thermal conductivity of the bed conductor is 0.0857 W/m-K which is good for the Jute and PLA composite because it is below the thermal conductivity of the pure PLA and above the thermal conductivity of the jute fiber.

Sample 3

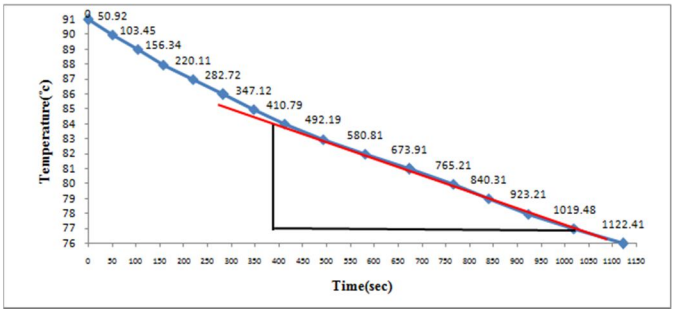

Fig.11 s curve of sample 3

The above curve is in between time and temperature which show cooling with respect to time, red line show the tangent at θ_2 is 81˚c. For this cooling condition thermal conductivity of the bed conductor is 0.0928 W/m-K which is good for the Jute and PLA composite because it is below the thermal conductivity of the pure PLA and above the thermal conductivity of the jute fiber .So from the above three experimental average is 0.0926 W/m-K, so thermal conductivity of composite material is 0.0926 W/m-K which is good for the poly jute composite. Because of the thermal conductivity of PLA is 0.13 W/m-K and jute is 0.04 W/m-K.

V. CONCLUSION

Jute based composites represent an important alternative to composites based on synthetic polymers, which are nowadays produced in mass in our society. The use of Jute composites instead of synthetic polymers would reduce waste and pollution and ensures a renewable supply of raw materials. PLA and jute fibers, both are biodegradable (approximately within a year). However, a separate study is required for the estimation of biodegradation time of the composite developed in the present research. Jute fiber reinforced polymer composites led to the following conclusions

A. Development of PLA and jute based composites has been done successfully
B. It has been observed that the increase in the weight of the jute decreases the overall density of the composite which also indicates increase in the porosity if the composite.
C. Due to heating in the oven the moisture of the jute evaporates which lead the reduction in the weight of the jute in the composite.
D. It has been noticed that the mechanical properties of the composites such as compressive strength and tensile strength of the composites are greatly influenced by the weight and the direction of placement of the jute fiber (longitudinal or transverse).

E. The fracture surface study of the PLA and jute based composite shows that due to the poor interfacial bonding, this composite has lower values of the mechanical properties.

F. Thermal conductivity of the composite is found as 0.09913 which is lower than the thermal conductivity of PVC which indicates that it has better insulating properties than the PVC.

G. The jute fiber based composite is bio-degradable composite whereas PVC is as non-degradable. So for reducing the impact on the environment this composite will definitely be a better option.

H. Some country has ban the poly material because of this degradable period is long ,they only allow 50% bio degradable material mixed polymer so it is a good choice for use the jute base PLA composite.

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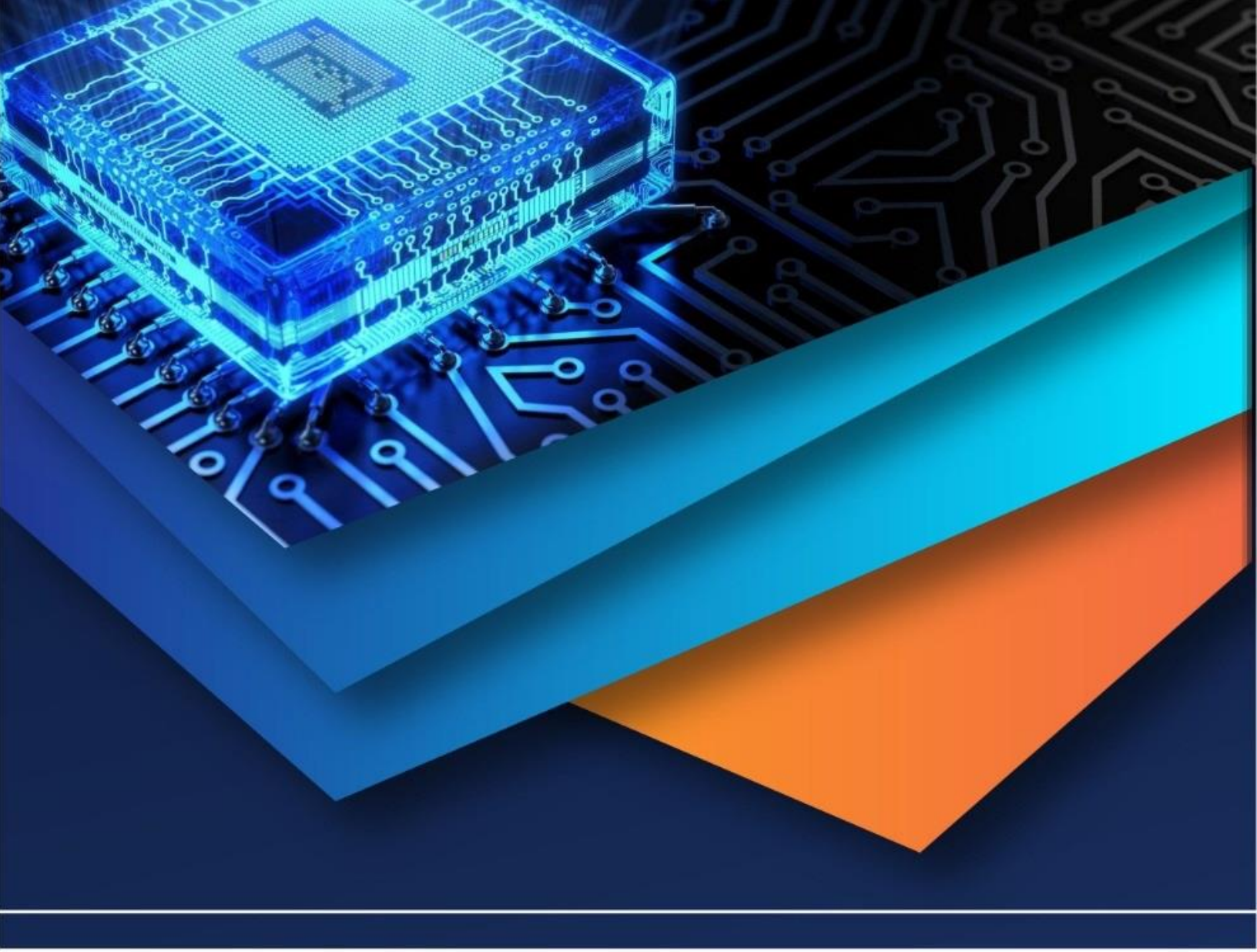

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