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Evaluation on Mechanical Properties of Coated RHA-TIO2-LM24 Aluminium Alloy Composite

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Abstract:** In the present research work, liquid state technique is employed to prepare the LM4/RHA/TiO2 composites containing four different mass proportion of RHA and TiO2. The weight proportion of reinforcements ie RHA-1,3&5 and TiO2 2,5&6 respectively. Hybrid composite with 3% of RHA and 6% of TiO2 showed the maximum Tensile strength of 298.37 N/mm².It is found that there is 37 % increase of tensile strength while addition of RHA and TiO2 to LM 24.The aluminium based particulate reinforced composite, the dislocations are generated during solutionizing due to thermal mismatch between the matrix and the ceramic reinforcement particles. It can be inferred that the tensile strength increased with an increase in the weight percentage of rice husk ash and TiO2. Because, the RHA particles act as barriers to the dislocations when taking up the load applied. It has been observed that with changing rate of TiO2 compressive quality increments from 478.83 to 653.79 MPa. The increase in compressive strength is mainly due to the decrease in the inter-particle spacing between the particulates since RHA and TiO2 are much harder than LM24. The presence of RHA and TiO2 resists deforming stresses and thus enhancing the compressive strength of the composite material. The maximum hardness value obtained for 5 wt.% of RHA and 6 wt.% of TiO2 .ie.117 BHN. It was observed that the hardness of the composite linearly increasing with the increase in weight fraction of the rice husk ash particles. This occurs due to increases in surface area of the matrix and thus the grain sizes are reduced. The presence of such hard surface area offers more resistance to plastic deformation which leads to increase hardness..
***Keywords:** LM4/RHA/TiO2, Tensile testing, Compression, Hardness, Rice husk.*

I. INTRODUCTION

Aluminium alloys have excellent mechanical properties coupled with good corrosion resistance. However, they possess poor wear and seizure resistance. To improve the above said properties, researchers have successfully dispersed various hard and soft reinforcements such as SiO2, SiC, Al2O3, flyash, glass, WC, graphite, mica, and coconut shell char in aluminium alloys by different processing routes. Of all the processing routes, liquid metallurgy method is the most sought after owing to its several advantages such as economical mass production, near net shaped components can be produced. In recent years, aluminium alloy-based metal matrix composites (MMCs) are being explored as candidate materials in several interesting applications such as piston, connecting rod, contactors, where sliding is a key component.

Aluminium alloys (or aluminium alloys; see spelling differences) are alloys in which aluminium (Al) is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon, tin and zinc. There are two principal classifications, namely casting alloys and wrought alloys, both of which are further subdivided into the categories heat-treatable and non-heat-treatable. About 85% of aluminium is used for wrought products, for example rolled plate, foils and extrusions. Cast aluminium alloys yield cost-effective products due to the low melting point, although they generally have lower tensile strengths than wrought alloys. The most important cast aluminium alloy system is Al–Si, where the high levels of silicon (4.0–13%) contribute to give good casting characteristics. Aluminium alloys are widely used in engineering structures and components where light weight or corrosion resistance is required.

Presently, aluminium based reinforced metal matrix composites have huge demand and keen attention by researchers due to its light weight, high strength and high stiffness. Aluminium metal matrix finds a wide range of applications in aerospace, automotive, marine, rail etc. SiC and Al2O3 are the most commonly used ceramic materials for the reinforcement of Aluminium. A perfect replacement of the reinforcement materials SiC and Al2O3 could be Boron Carbide due its high hardness. Nano materials are the cornerstones of nano science and nano technology.

Nano structured science and technology is a broad and interdisciplinary area of research and development activities that has been growing explosively worldwide in past few years. It has the potential for revolutionizing the way in which the material and the products are created. It is already having the significant commercial impact which will assuredly increase in future. Reinforcement of nano materials in the aluminium matrix will increase the mechanical properties of the material considerably.

Aluminium metal matrix can be fabricated through various methods such as liquid stir casting, powder metallurgy, spray deposition etc. Each fabrication method has different unique way for the fabrication. Based on the study of literature, liquid stir casting method is the most economical and suitable method for the fabrication of aluminium metal matrix composites. The reinforcement material binds together with the matrix material to carry the load and distributes the load to the individual reinforcement. The characterization of micro structures of the composite is necessary as the interface between the matrix material and the reinforcement material plays an important role in the metal matrix properties. The mechanical properties of the aluminium metal matrix composites can be increased by decreasing the size of the reinforcement material to nanometre. The objective of this work is to produce Al [LM24]– Risk Husk ash(RHA)/TiO_2 composites with different proportion of RHA and TiO_2 , using liquid stir casting method. The fabricated composites were examined for structural and mechanical properties.

In recent time, commendable work has taken place in the field of Metal Matrix Composites. The results of which have shown us their tremendous capacity in enhancing the favourable properties of aluminium and its alloys. Metal matrixes with the suitable reinforcement have addressed a range of new requirements. A lot of work has been carried out in the field of E-Glass fibres reinforced aluminium matrix composites which makes it very clear that this combination is a very popular one. Al alloy matrix composite with homogeneous distribution of a variety of non-metallic particles and fibres ranging in size from 0.06 μm to 800 μm were racially fabricated, cast and hot extruded. Composites containing hard non-metallic particles such as Ceramic, TiC, Al_2O_3, glass slag exhibited lower wear than the pure matrix alloy. Addition of E-Glass to the composites also gives good mechanical properties.

A lot of research has been done on aluminium alloy 1XXX to aluminum 6XXX based composites but research on LM24 based composites is very rare, also the properties of these composites are still not clear. Against this background, the present research work has been undertaken, with an objective to study the effect of different composition of reinforcement as Rice husk ash and TiO_2on the LM24 based metal matrix composites.

II. MATERIALS AND METHODS

A. Materials.

The reinforcement materials and matrix materials used in the present research are tabulated in table.

Table 2.1: Specifications of the materials used in the project work

Sl No	Materials
01	LM24
02	Rice Husk Ash
03	TiO_2

B. Material Selection.

1) *LM 24:* The selection of material is based on the properties, cost and the area of application where it is needed. In metal matrix composites, mostly pure aluminium are being used for its light weight and good corrosive resistance. Aluminium cast alloys have a great scope and application in the current scenario. Aluminium LM4 is selected as the base material which has high static load that are anticipated and creep extinction at elevated high temperature. This cast alloy conforms to BS 1490:1988 standards which contains silicon as the major constituent.
2) *Rice Husk:* The RHA is obtained from rice husk which is an agricultural waste produced after removing the peels of rice crop. The removed peels are waste material but can be used as a suitable reinforcement particle through processing. The rice husk is organic in nature containing about 70- 90 % of matter in form of cellulose, lignin and minerals like silica, alkalis etc. Figure 1 shows rice husk.

Fig 2.1: Risk Husk

Fig 2.2: Coated Risk Husk ash

C. Titanium Dioxide (TiO2)

Rutile is one of three forms of titanium dioxide (TiO2). It occurs in crystals, often in twins or rosettes, and is typically brownish red, although there are black varieties. Rutile is found in igneous and metamorphic rocks, chiefly in Switzerland, Norway, Brazil, and parts of the United States. Rutile is found naturally occurring in small quantities as impurities in iron oxide, chromium oxide and vanadium oxide. Rutile has a tetrahedral crystal structure (i.e. it has one fourfold axis) with 4/m 2/m 2/m symmetry. Its structure is made up of parallel chains of octahedrons, which are in turn composed of a titanium ion surrounded by six oxygen atoms. The model below shows the structure of the octahedron bases, although includes the unit cell edges.

Fig 2.3 : TiO_2

D. Fabrication Method

In this work composite were fabricated by using Stir Casting Method, the manufacturing process in which a molten/liquid metal is transferred into a mould which consists of void/cavity in desired profile/contour, allowed solidifying where the solidified fragment is called as casting. The furnace is heated up to 8000c. Though the melting point of aluminium LM24 is 6600c, the temperature is raised up to 8000c to handle the temperature from furnace to pouring die and furnace shown in Figure

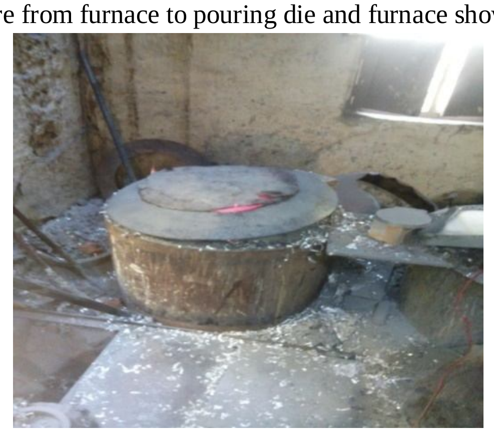

Fig2.4 : Furnance

The employed technique here is the vortex method of stir casting, in which by using a mechanical stirrer the re-enforcement was brought into the vortex of the melt which as in A cylindrical die of 30mm diameter and length of 300mm is used, as the molten metal is poured into it as the temperature of the melt reaches 6600c. After solidification the cast pieces are separated from the die.

III. EXPERIMENTATION

A. Determination Of Mechanical Properties

1) *Tensile Strength:* A computerized universal testing machine was used for the tensile test as per ASTM E8 standard. The specifications of the specimen used in the tensile test are as follows: 12 mm grip diameter, 25 mm grip length, and 31.5mm gauge length, 54 mm length of reduced cross section, inward diameter of 9 mm and over-all span of 104 mm. these dimensions were achieved by machining of the cast specimens. The results of this test help us in better understanding of tensile strength, yield strength, percentage of elongation of the specimen used.

Fig 3.1: Universal Testing Machine.

Fig 3.2: Specimen before testing.

Fig 3.3: Specimen after Testing.

2) *Compression Strength:* A compression test is destructive test in which a material experiences opposing forces that push inward upon the specimen from opposite sides or is otherwise compressed, “squashed”, crushed, or flattened. The test sample is generally placed in between two plates that distribute the applied load across the entire surface area of two opposite faces of the test sample and then the plates are pushed together by a universal test machine causing the sample to flatten. A compressed sample is usually shortened in the direction of the applied forces and expands in the direction perpendicular to the force. A compression test is essentially the opposite of the more common tension test.

Fig 3.4: UTM for Compression.


Fig 3.5: Specimen before testing.


Fig 3.6: Specimen after testing.

3) *Hardness Test:* Hardness is the measure of how resistant solid matter is to various kinds of permanent shape change when a force is applied. Macroscopic hardness is generally characterized by strong intermolecular bonds. There are three types of tests used with accuracy by the metals industry; they are the Brinell hardness test, the Rockwell hardness test, and the Vickers hardness test. But in our present work we considered only Brinell hardness test.


Fig 3.7: Brinel Hardness Testing eqioment.

IV. RESULTS AND DISCUSSION

A. *Tensile Test*

Table 4.1 Tensile Strength of the composite laminates

Sl No	Hybrid Composite	Tensile Strength, PA
1	LM24	224
2	L1R2T	252.19
3	L1R4T	260.01
4	L1R6T	286.13
5	L3R2T	261.42
6	L3R4T	279.47
7	L3R6T	298.37
8	L5R2T	271.26
9	L5R4T	292.85
10	L5R6T	289.68

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Fig 4.1: Tensile Strength of the Composites.

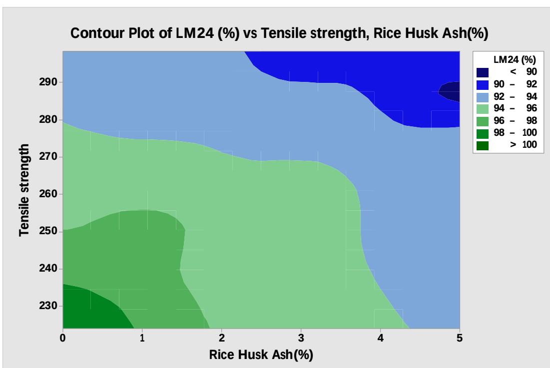

Fig 4.2: Contour plot of Tensile strength LM24 vs Rice husk

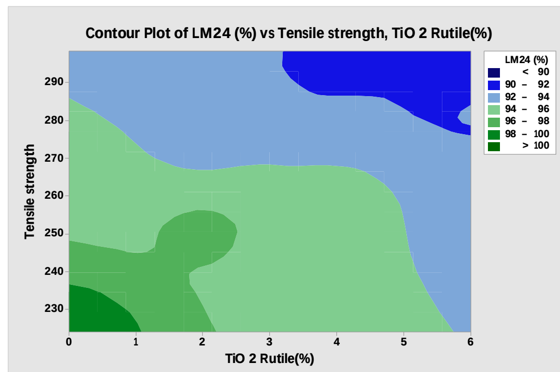

Fig 4.3: Contour plot of Tensile strength LM24 vs TiO2

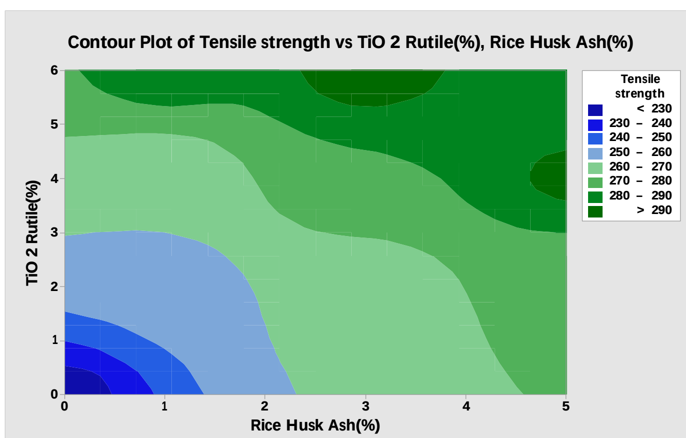

Fig 4.3: Contour plot of Tensile strength RHA vs TiO2.

From the Table 4.1,Hybrid composite with 3% of RHA and 6% of TiO2 showed the maximum Tensile strength of 298.37 N/mm².It is found that there is 37 % increase of tensile strength while addition of RHA and TiO2 to LM 24 .Figure 5.1-5.3 shows effect of reinforcements on tensile strength, intermetallic particles are precipitated which resist the movement of dislocations in a crystal lattice . RHA and TiO2 particles and precipitation of intermetallic increase tensile strength. As the amount of RHA and TiO2 particles and intermetallic put together increase, the tensile strength increase less proportionately. The aluminium based particulate reinforced composite, the dislocations are generated during solutionizing due to thermal mismatch between the matrix and the ceramic reinforcement particles.

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The relation between tensile strength of the fabricated composites with the different weight fractions of rice husk ash and TiO2 particles are shown in figures 5.4 . It can be inferred that the tensile strength increased with an increase in the weight percentage of rice husk ash and TiO2. Because, the RHA particles act as barriers to the dislocations when taking up the load applied. The similar observation was found in Basavarajappa et al., for fly ash particles. The observed improvement in tensile strength of the composite is attributed to the fact that the filler rice husk ash possesses higher strength by offering more resistance. There was a decrease in the tensile strength of the samples with rice husk ash and TiO2 weight fraction 5 and 6 %. It may due to the poor wettability and agglomeration of the reinforcement with the matrix

B. Compression Test

The Compression strength of fabricated composite laminates was estimated on computerized universal testing machine.

Table 4.2 Compression strength of the composite laminates

Sl NO	Hybrid Composite	Compressive Strength, MPa
1	LM24	462.23
2	L1R2T	478.83
3	L1R4T	495.83
4	L1R6T	538.37
5	L3R2T	504.58
6	L3R4T	555.64
7	L3R6T	572.92
8	L5R2T	561.51
9	L5R4T	653.79
10	L5R6T	645.16

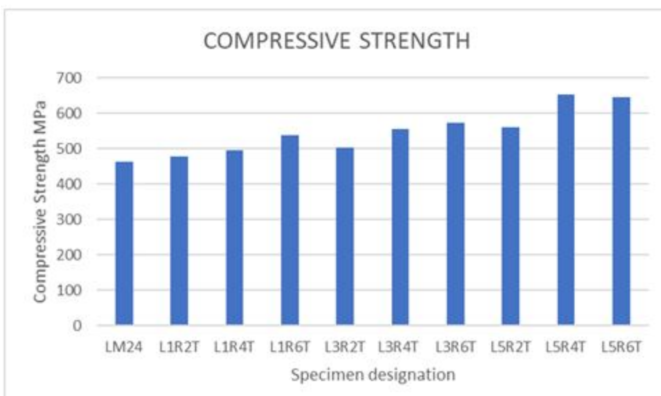

Fig 4.4: Compressive Strength.

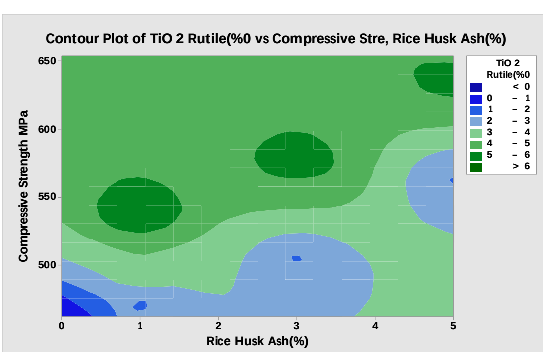

Fig 4.5: Contour plot of Compressive strength RHA vs Rice husk

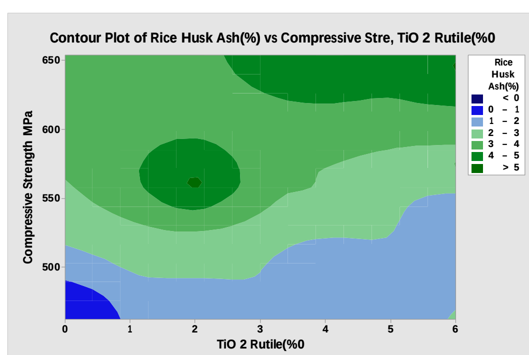

Fig 4.6: Contour plot of Compressive strength RHA vs TiO2.

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It has been observed that with changing rate of TiO2 compressive quality increments from 478.83 to 653.79 MPa. The increase in compressive strength is mainly due to the decrease in the inter-particle spacing between the particulates since RHA and TiO2 are much harder than LM24. The presence of RHA and TiO2 resists deforming stresses and thus enhancing the compressive strength of the composite material. The variations of compressive strength with addition of Rich husk ash due incorporation, it was observed that the compressive strength increases with an increase in the weight percentage of rice husk ash particles. This may be due to the hardening of the base alloy by rice husk ash particles.

C. Hardness

Hardness, which is the resistance of the specimens to deformation, is a measure of their resistance to plastic or permanent deformation. The static indentation test was the test used in the present study to examine the hardness of the specimens in which a ball indenter was forced into the specimens being tested. The hardness is a surface property measured by resistance to abrasion or wear, cutting, machining and crusting. Thus, hardness is surface property measured by resistance to indentation or penetration by some hard body. The test results are tabulated for the as cast conditions. The graph shows the effect of addition of reinforcement on the hardness of the composites Brinell's Hardness Test.

Table 4.3: Results of Hardness.

Sl NO	Hybrid Composite	BHN
1	LM24	84
2	L1R2T	89
3	L1R4T	93
4	L1R6T	95
5	L3R2T	98
6	L3R4T	101
7	L3R6T	104
8	L5R2T	107
9	L5R4T	113
10	L5R6T	117

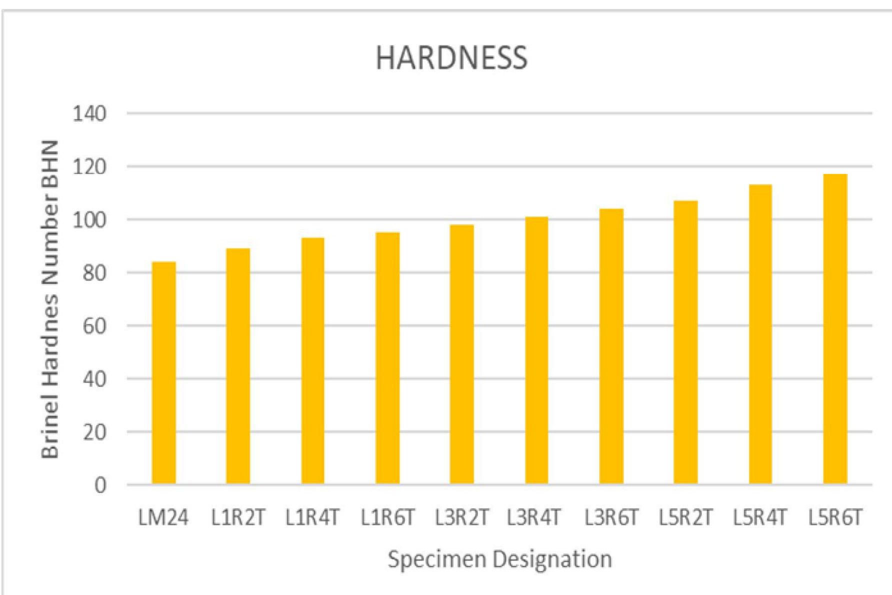

Fig 4.7: Hardness Values.

V. CONCLUSION

In the present research, composite laminates were successfully fabricated by using Stir cast technique and test specimens were prepared to evaluate different mechanical properties as per the ASTM standard by cutting fabricated laminates with the help of band knife cutting machine.

A. Coated RHA and TiO2 reinforced MM24 hybrid composite is manufactured successfully.
B. Hybrid composite with 3% of RHA and 6% of TiO2 showed the maximum Tensile strength of 298.37 N/mm².It is found that there is 37 % increase of tensile strength while addition of RHA and TiO2 to LM 24.
C. The aluminium based particulate reinforced composite, the dislocations are generated during solutionizing due to thermal mismatch between the matrix and the ceramic reinforcement particles.
D. It can be inferred that the tensile strength increased with an increase in the weight percentage of rice husk ash and TiO 2. Because, the RHA particles act as barriers to the dislocations when taking up the load applied.
E. It has been observed that with changing rate of TiO2 compressive quality increments from 478.83 to 653.79 MPa. The increase in compressive strength is mainly due to the decrease in the inter-particle spacing between the particulates since RHA and TiO2 are much harder than LM24. The presence of RHA and TiO2 resists deforming stresses and thus enhancing the compressive strength of the composite material.
F. The maximum hardness value obtained for 5 wt.% of RHA and 6 wt.% of TiO2 .ie.117 BHN.
G. It was observed that the hardness of the composite linearly increasing with the increase in weight fraction of the rice husk ash particles. This occurs due to increases in surface area of the matrix and thus the grain sizes are reduced. The presence of such hard surface area offers more resistance to plastic deformation which leads to increase hardness.

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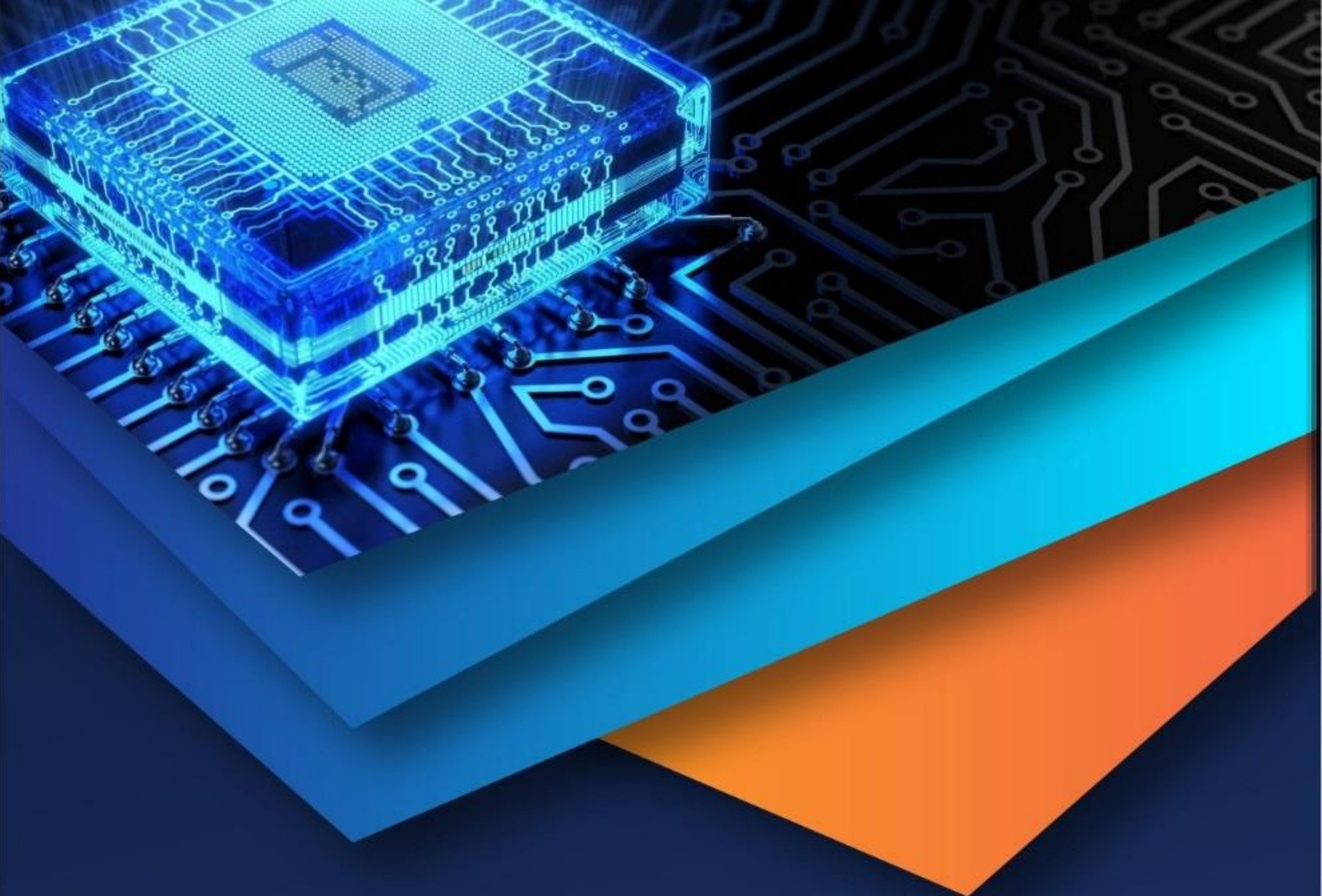

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