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Experimental Study on Mechanical Characteristics of Aluminium Metal Matrix Composite Reinforced with Titanium Oxide (TiO_2) and Graphite (Gr) Particles Processed by Stir Casting Method

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Abstract: ***In recent trend Aluminium based metal matrix composites are most used in mechanical and automobile component design applications because of their excellent mechanical, Tribological and its physical properties. Also, Aluminium metal matrix composites are used for a variety of applications such as military, aerospace, electrical industries, and automotive purposes. The present work concentrates on the experimental study on the effects of TiO_2 and Gr on aluminium alloy. During this investigation, Titanium oxide (TiO_2) and Graphite (Gr) particles was reinforced with aluminium and it was prepared using stir casting technique with various weight percentage combinations of TiO_2 particles 2% by wt., 4% by wt., and 6% by wt. and 3% of Gr constant for all trials. Mechanical parameters were estimated by selecting the standard test methods.***
Keywords: Mechanical properties, Stir casting, Al, TiO_2, Graphite.

I. INTRODUCTION

Composite materials possess good mechanical properties compared to monolithic materials. They are among the most widely used materials due to their adaptability to different situations and relative ease of combining with other materials to serve specific purposes and exhibit desirable properties. They have fabulous high strength, lightweight, chemical and corrosion resistance, and have a low thermal expansion coefficient. They are formed by combining 2 or more materials with quite different properties and do not dissolve or blend. The different materials in the composite work together and exhibit unique properties. In the present world, most of the experimental work on composite materials is focused on their applications in the sectors of aerospace, automobiles, helicopters, spacecraft, etc. Aluminium matrix composites (AMCs) have strong physical and mechanical qualities, making them potential materials for a variety of applications. In comparison to traditional engineering materials, the metallic matrix's stiffness, specific strength, wear, creep and fatigue properties are improved with the addition of reinforcements. By adding desirable single and multiple reinforcement particulates like SiC, Al_2O_3, Gr, TiO_2, B_4C, and fly ash as composites, the composite materials exhibit higher characteristics than the base alloy material.

Mohammad Faisal Ansari, [1] synthesized aluminium metal matrix composites (AMMCs) with different weight percentages of TiO_2 particles by stir casting process. Aluminum-TiO_2 composites reinforced with various weight percentages of (0, 5, 10 and 15 wt. %). The test results show that the mechanical behaviours of the fabricated composites are enhanced by increasing the Titanium dioxide content. The ultimate tensile strength and hardness of the produced composite enhanced with the addition of higher percentage of TiO_2. Vijaykumar S Shet, [2] synthesized aluminium metal matrix composites (AMMCs) with different weight percentages of TiO_2 particles by stir casting process. The extent of incorporation of TiO_2 particles in the composite will be varied from 2-8 wt.% in steps of 2. Microstructure studies, wear properties, hardness of as cast Al 6063 alloy and Al 6063- TiO_2 composites will be evaluated. TiO2 when used as reinforcement have owed to an increase in the micro hardness (VHN), wear resistance and Density of the composite

Siddhesha S, et al [3] in his study showed that the metal matrix composite is prepared with varying the (TiO_2) volume fraction which ranges from 2% to 8%. Metal Matrix Composite is fabricated successfully through stir casting method. The experimental results show that the tensile strength, hardness and impact strength of Metal Matrix Composite are increasing with volume fraction of Titanium dioxide. Raghu S, et al [4]

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Synthesized Titanium oxide nanoparticle reinforced with Al6061 metal matrix composite specimens by high pressure die casting technique by using bottom pouring stir casting technique. The Effect of various Nano Particle Sizes of TiO_2 was evaluated. The Brinell hardness and ultimate tensile strength of the Nano-composites increases with increase in Nano TiO_2 particles.

II. SELECTIONS OF MATERIALS

The matrix material in present study is pure Aluminium, and the reinforcing material selected is Titanium dioxide (TiO_2) and Graphite (Gr) of different composition. The Titanium dioxide is varied by 0%, 2%, 4% and 6% weight of Aluminium and 3%Gr.
Some of the attractive property combinations of Al based matrix composites are: high specific stiffness, strength, thermal conductivity, and low thermal expansion. TiO_2 (rutile) is a soft powder. The reinforced particles size of TiO_2 is 44 microns. The material properties of the Al and titanium dioxide (rutile) are shown in table 2.1.

Table 2.1: Material properties of Al ,Gr and TiO_2

Material	Density (g/cc)	Elastic modulus (GPa)	Melting point(^{o}c)
Pure Al	2.7	70	660.3
TiO_2 (Rutile)	4.23	230-288	1843
Graphite (Gr)	2.26	11.5	3600

III. STIR CASTING

In conventional stir casting method, reinforced particulate is mixed into the aluminium melt by mechanical stirring. Mechanical stirring is the most important element of this process. After the mechanical mixing, the molten metal is directly transferred to a shaped mould prior to complete solidification. The essential thing is to create the good wetting between particulate reinforcement and aluminium melt. The distribution of the reinforcement in the final solid depends on the wetting condition of the reinforcement with the melt, relative density, and rate of solidification etc. Distribution of reinforcement depends on the geometry of the stirrer, melt temperature and the position of the stirrer in the melt.

Figure 3.1: Stir casting setup

A. Preparation of Aluminum, TiO_2 and Gr Composite

The stir casting setup was prepared initially. The Aluminium with 0%, 2%, 4% and 6% of TiO_2 powder and 3% Gr must be constantly maintained in all the trials has to be prepared by stir casting technique where Aluminium is the base material and TiO_2 is the reinforcement material.

1) *Step 1:* Melting of base metal Aluminium in furnace.
2) *Step 2:* One sample metal was prepared without adding TiO_2 and another three different compositions of molten metal were prepared by adding 2%, 4%, 6% TiO_2 and 3% Gr reinforcement material.
3) *Step 3:* Stirring of Al and TiO_2 powder.
4) *Step 4:* Pouring of molten metal mixture into the mould and solidification.

Figure 3.2: Casted MMCs.

IV. EXPERIMENTAL DETAILS

Various tests were conducted on fabricated MMCs samples to analyse the casting performance characteristics of hybrid MMCs. Mechanical properties such as tensile strength and hardness have been determined on fabricated MMCs. The tensile test was conducted on Tensometer and Hardness test carried out on Rockwell hardness testing machine.

A. Tensile Test

Figure 4.1: Tensometer

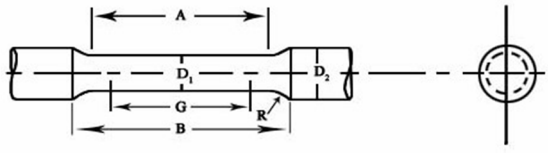

Figure 4.2: specifications of tensile specimen.

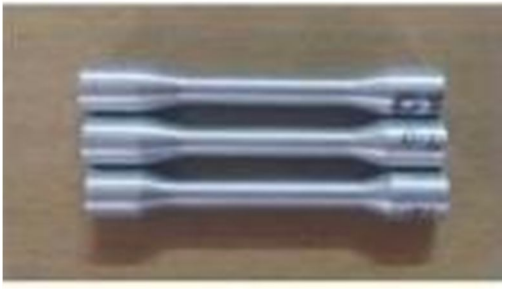

Figure 4.3: tensile test specimen.

Where,
D_1= gauge diameter=9mm
G=gauge length=36mm
R=fillet radius=8mm
A=reduced section=45mm

The metal matrix composites were machined as the required dimensions for the test. The gauge length is an arbitrary length defined along the small diameter portion of the specimen by two indentations so that its increase can be measured during the tests. The larger diameter ends of the specimen are insertion into a Tensometer. Which can apply either controlled loads or controlled deflections to the ends of the specimen, the gauge length portion is mirror polished to eliminate stress concentrations from surface defects. The specimen is stretched slowly in tension until it breaks, while the load and the distance across the gauge length are continuously monitored. The result is a stress strain plot of the material.

B. Hardness Test

Figure 4.4: Rockwell hardness testing machine

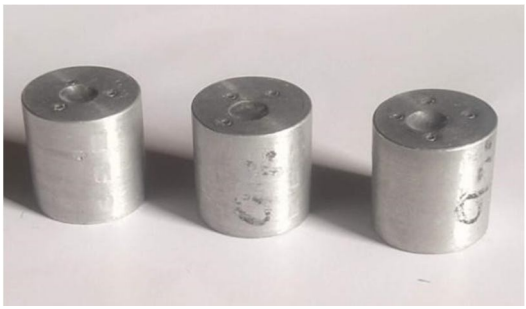

Figure 4.5: Hardness test specimens

V. RESULTS AND DISCUSSION

A. Tensile Test Results

Tensile test has been performed on Tensometer, to examine the composite specimens to find important mechanical properties of Aluminium and different composition of TiO_2 reinforced composite samples. The test results of tensile tests are given in the Table5.1.

Table5.1. Tensile Test Results

Samples	Compositions	Ultimate Tensile Strength (MPa)
1	Al	92.15
2	Al +2%TiO_2 +3% Gr	93.32
3	Al +4% TiO_2 +3% Gr	95.83
4	Al +6% TiO_2 +3% Gr	96.40

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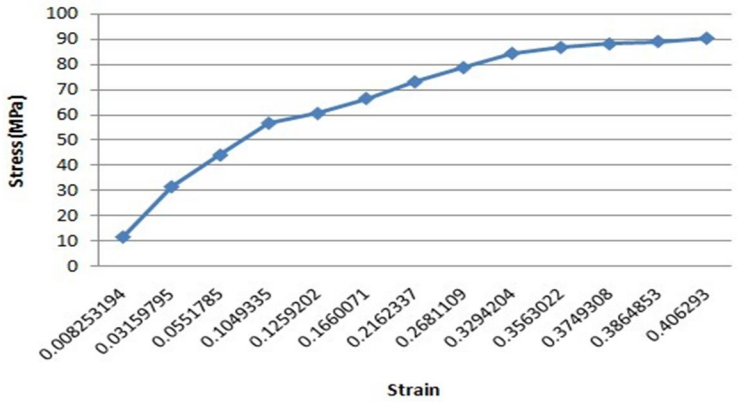

Figure 5.1: Stress and strain diagram for 0% weight composition of TiO_2 and Gr.

For the specimen with Al and 0% weight composition of TiO_2, and Gr the obtained ultimate tensile Strength is 92.15 MPa as shown in the Figure 5.1.

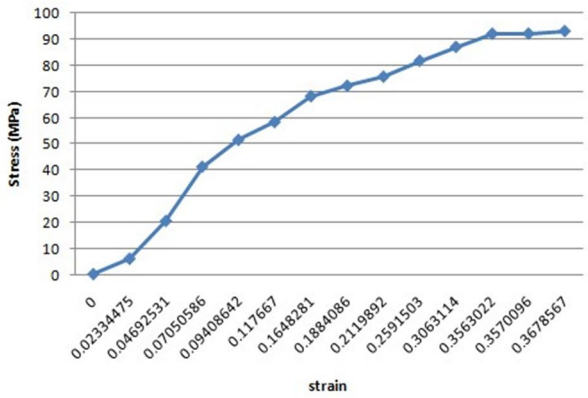

Figure 5.2: Stress and strain diagram for 2% weight composition of TiO_2 and 3% of Gr.

For the specimen with Al, 2% weight composition of TiO_2 the ultimate tensile Strength obtained is 93.13 MPa as shown in the Figure 5.2.

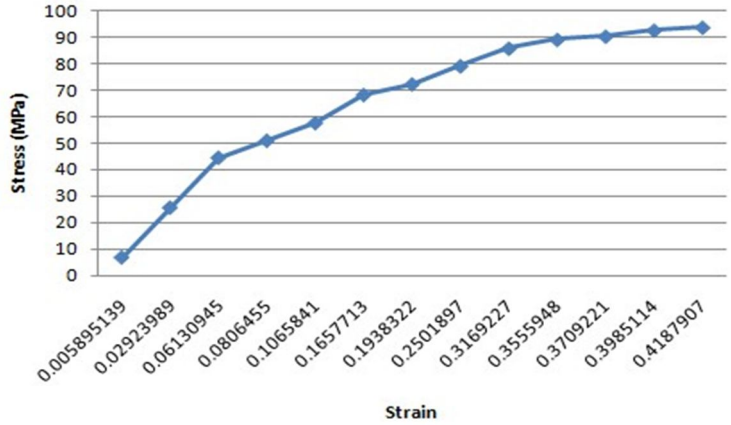

Figure 5.3: Stress and strain diagram for 4% weight composition of $TiO_2$and 3% of Gr.

For the specimen with Al and 6% weight composition of TiO_2 the ultimate tensile Strength obtained is 94.70MPa as shown in the Figure 5.3.

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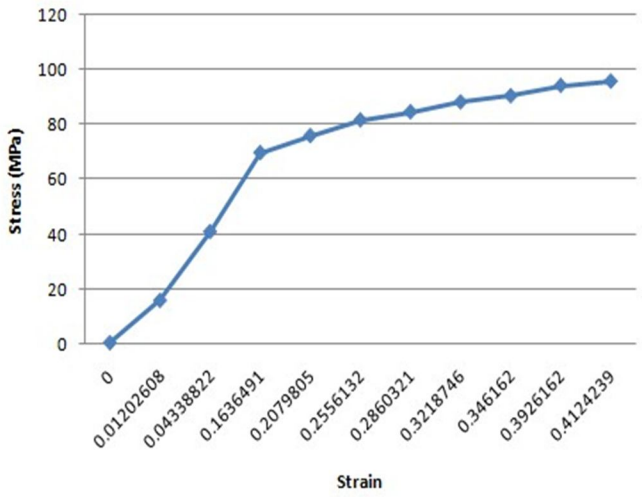

Figure 5.4: Stress and strain diagram for 6% weight composition of TiO_2 and 3% of Gr.

For the specimen with Al and 6% weight composition of TiO_2 the ultimate tensile Strength obtained is 95.3MPa as shown in the Figure 5.4.

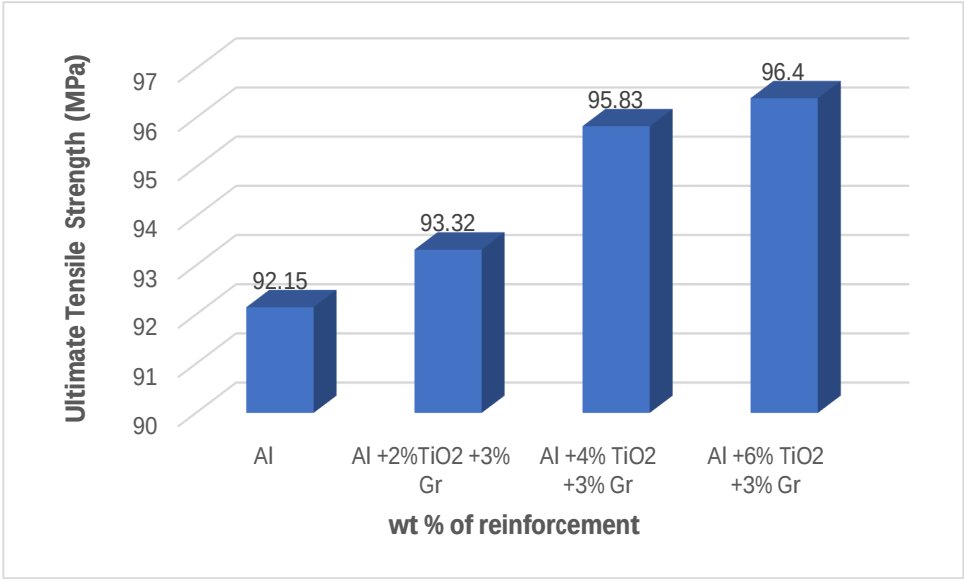

Figure 5.5: Ultimate tensile strength (MPa) V/S Weight % composition of TiO_2

B. Hardness Test Result

Table5.2. Hardness Test Results

Samples	Compositions	RHN
1	Al	88.14
2	Al +2%TiO_2 +3% Gr	89.23
3	Al +4% TiO_2 +3% Gr	91.30
4	Al +6% TiO_2 +3% Gr	92.58

From the Table 5.2 the test results show that the Rockwell hardness of the composite material increases with titanium di-oxide and graphite content in the composite material. The result shows that the hardness number increases for every 2% increase of titanium dioxide and 3% of Gr.

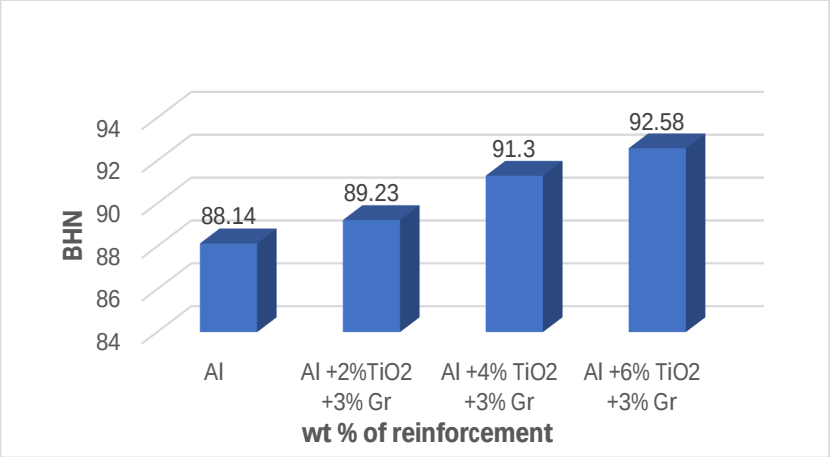

Figure 5.6: The Rockwell hardness number for different composition TiO_2

VI. CONCLUSION

The Aluminium-TiO_2 and graphite (Gr) metal matrix composite is prepared by stir casting method by varying the amount of TiO_2 and graphite (Gr) particles. The different experiments are carried out on the fabricated aluminium TiO_2 metal matrix composite as per ASTM standard. Composites reinforced with Al +6% TiO_2 +3% Gr exhibits good hardness behaviour as compared to other percentage with the increase in composition of Al +6% TiO_2 +3% Gr reinforced with aluminium were successfully fabricated. The TiO_2 Particles distribution with Aluminium is confirmed by SEM images. Consequently, the ultimate tensile strength of the composite is recommended for the Al +6% TiO_2 +3% Gr reinforced material. Finally, from all the experiment reveals that by increase of material properties of Aluminium alloy by adding the reinforcement up to certain level.

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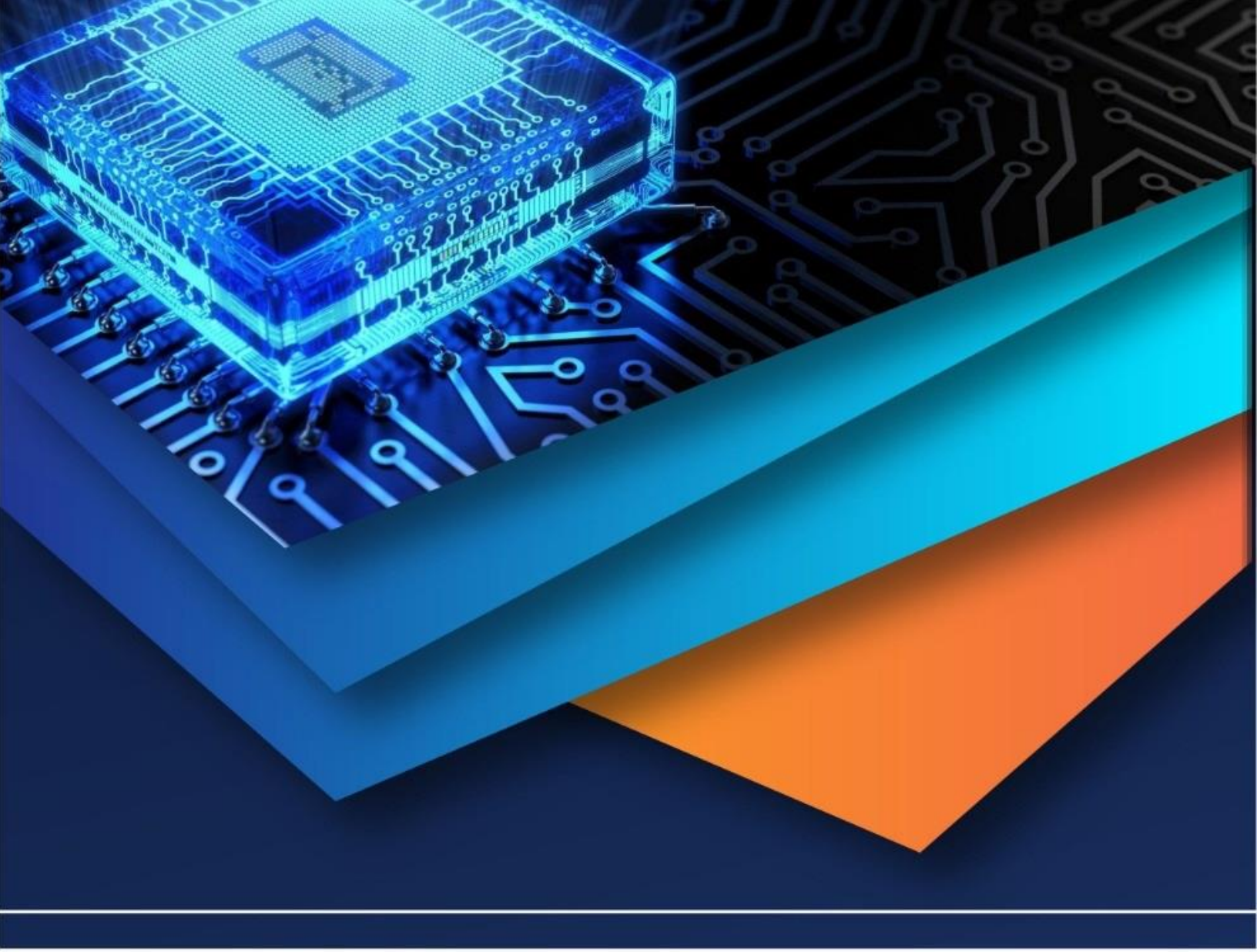

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