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Evaluation of Mechanical and Tribiological Characteristics of LM-13 Hybrid Al-Metal Matrix Composites

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Abstract: LM-13 used for piston and applications where thermal stresses are more. This alloy can withstand higher temperatures and loads. It has good wear resistance properties and machinability. In this experimental study, Al alloy LM13-SiC & MoS_2 & Graphite hybrid composites were produced by stir casting method using Sic powder as reinforce particles with 150-micron average diameter and Al alloy as the matrix metal. The melt composites were stirred, then casted into a metallic mold. Different samples of 0, 2.5, 5 and 7.5 weight percent of Sic with constant weight percentage of MoS_2 and graphite were prepared. The casted composite specimens were machined as per test standards. Effects of weight percent of Sic particles on hardness, tensile strength and compressive strength of prepared composites have been investigated. The highest tensile and compressive strengths were achieved in the specimen containing 5%, 7.5 weight percent of SiC, which shows an increase in comparison with the unreinforced Al alloy. It has been observed that addition of Sic particles significantly improves hardness, tensile strength, and compressive strength properties as compared with that of unreinforced matrix. Wear and corrosion rate were minimum obtained with the ratio of 5% & 7.5 weight percent of Sic.
Keywords: LM-13 Sic particles, Al alloy Composite, Tensile Strength, Stir Casting

I. INTRODUCTION

A metallic matrix (often an alloy of Al, Cu, Fe, Mg, Ti, or Pb) with three-dimensional inclusions (often oxide, carbide, or nitride) is called a metal matrix composite (MMC). The reinforcing phases in these MMCs boost the modulus and strength of the composites while preserving the high ductility of the metallic alloy used as the matrix material. MMCs can be designed to provide superior mechanical, electrical, and even chemical qualities by selecting the right reinforcements and matrix material mix. This is especially important when homogeneous metals and alloys are unable to meet the ever-stricter specifications that engineers and designers are requesting for modern engineering applications. Because the applied load is distributed and transferred from the ductile matrix to the reinforcing phase, metal-matrix composites (MMCs) show resilience to high compressive and tensile stresses. By incorporating a reinforcing phase into the matrix by a variety of methods, including liquid, powder, and squeeze casting, these MMCs are created.

A. Composite

A composite material is one that has bulk properties that are significantly different from those of any of its elements and is made up of two or more separate phases, such as a matrix phase and a reinforcing phase. Although a small amount of spread phases can be found in the structures of many common materials, such as metals, alloys, coated ceramics, and polymer compounds mixed with additives, these materials are not regarded as composites because their physical properties are similar to those of their elements (for example, the physical properties of steel are similar to those of pure iron). High strength and stiffness, low density, high temperature stability, high electrical and thermal conductivity, tunable coefficient of thermal expansion, resistance to corrosion, enhanced wear resistance, and other favorable qualities are characteristics of composite materials.

Matrix Phase

1) The initial stage, which is continuous in nature.
2) Usually a phase that is less rigid and more ductile.
3) Holds the reinforcing phase while sharing a load with it.

B. Reinforcing Phase

1) The second phase, or phases, are discontinuously embedded in the matrix;
2) Because they are typically stronger than the matrix, they are also frequently referred to as reinforcing phases. When we talk about composites as engineering materials, we usually mean materials that have the following properties:
3) These are manufactured artificially, with the exception of natural materials like wood.
4) They have a clearly defined interface and are made up of at least two distinct species.
5) The volume % of components affects their qualities.
6) These have at least one attribute that none of the component parts have.

C. Types of AMCS

AMCs fall into one of four categories according on the kind of reinforcement they use.

1) AMCs reinforced with particles (PAMCs)
2) AMCs reinforced with whisker or short fibers (SFAMCs)
3) AMCs with continuous fiber reinforcement (CFAMCs)
4) AMCs reinforced with mono filaments (MFAMCs)

A list of some of the most important traits of these four AMC types may be found below.Aluminum's Use in the Auto Industry: Between 1978 and 1980, automakers reduced the average car's weight by almost 25%, to around 3,000 pounds, which improved performance and doubled fuel efficiency. According to some industry analysts, the typical car will need to shed an additional 500 to 700 pounds (16 to 22 percent) in order to comply with future emissions and fuel efficiency regulations. Because aluminum is strong, lightweight, corrosion-resistant, and easy to fabricate, automakers have been using it more and more frequently. Manufacturers lowered the average weight of cars and utilized significantly less iron and standard steel.

II. OBJECTIVES

In modern times, composite materials are more in demand because of their many qualities, which include low density, excellent wear resistance, high tensile strength, and smooth surface finish. Among the least costly and low-density reinforcing materials are graphite, silicon carbide (SiC), and molybdenum disulfide (MoS2). Additionally, consideration will be given to wear and tensile strength. An experimental setup with all required inputs has been prepared in order to accomplish all of that. In this work, a composite is created by varying the weight ratio at which MoS2, SiC, and Gr are added to aluminum metal. The composite needs to be made using the stir casting method, and its mechanical properties need to be examined.

III. MATERIALS AND METHODS

A. Aluminum LM-13

This alloy complies with LM13 of BS 1490:1988. The three conditions of castings that are standardized are fully heat treated (TF), solution treated, artificially aged and stabilized (TF7), and precipitation treated (TE).

B. Applications OF LM-13

Pulleys (sheaves), pistons for all kinds of gasoline and diesel engines, and other engine components that operate at high temperatures are all made of LM-13 alloy. Its low coefficient of thermal expansion, superior bearing qualities, and strong resistance to wear are its advantages.

C. Molybdenum Disulfide

Molybdenum disulfide (MoS2) has a hexagonal plane of S atoms on both sides of a hexagonal plane of Mo atoms as its crystal structure. With strong covalent connections between the Mo and S atoms and weak van der Waals forces holding layers together, these triple planes stack on top of one another. This enables them to be mechanically divided into MoS2 sheets that are two dimensions.

D. Silicon Carbide

The chemical formula for silicon and carbon is SiC, which is also referred to as carborundum or silicon carbide (SiC). In nature, it takes the form of the incredibly rare mineral moissanite. The process of silicon carbide grains together creates extremely strong ceramics that are frequently utilized in high endurance applications including vehicle brakes, car clutches, and ceramic plates used in bulletproof vests.

E. Graphite

Because of its high heat conductivity, low coefficient of friction, and resistance to corrosion, graphite will be utilized as soft reinforcement. Furthermore, in frictional applications, graphite will function as a solid lubricant.

Kinds and variations The three main forms of natural graphite are found in various mineral sources and are as follows:

1) Crystalline flake graphite, or flake graphite for short, is found as single, flat, plate-like particles with edges that can be angular or irregular when broken or hexagonal when whole.
2) Amorphous graphite: In the trade, extremely fine flake graphite is occasionally referred to as amorphous.
3) Bulp graphite, also known as vein graphite, is a large platy intergrowth of fibrous or acicular crystalline aggregates that occurs in fissure veins or fractures. It is most likely hydrothermally formed.

F. Applications

The main uses of natural graphite are in lubricants, brake linings, expanded graphite, steelmaking, refractoriness, and foundry facings. One of the strongest materials known is grapheme, which is found naturally in graphite and has special physical characteristics. However, further technological advancement will be needed to separate it from graphite.

IV. CASTING PROCESS

A. Stir Casting

Stirring mechanisms are used in stir casting to stir the molten metal matrix. Typically, the material used to make the stirrer can survive melting points greater than those of the matrix. In stir casting, a graphite stirrer is typically utilized. The impeller and cylindrical rod make up the stirrer's two primary parts. The motor shaft is linked to one end of the rod and the impeller to the other. Usually held vertically, the stirrer rotates at different rates due to a motor.

B. Factors Affecting Process

Information collected through various research papers show the following factors which affect the stir casting process the most. They are

1) Speed of stirring
2) Time duration of stirring
3) Stirring temperature

C. Calculation For All Ratios

Volume = $\pi/4\ d^2 * L$

$= \pi/4 * 2.5^2 * 40$---vol 196.25

Plate: L*B*H (cm)

=10* 1.5*1.5=22.5

196.25 +22.5 = 218.75

Al = 218.75*2.7=590g + 20% Extra-131.6 (Density-2.7 g/cm^3)

Total = LM-13-600 gram

Table 1: Matrix and Reinfrorcement Ratios

Ratio	LM-13 grams	SiC gms	MoS_2 gms	Graphite 1% gm
I	600	0	0	0
II	600	2.5%-15	5%-30	6
III	600	5%-30	10%-60	6
IV	600	7.5%-45	15%-90	6

Sample1: LM-13-100%
Sample2: SiC -2.5% + MoS_2-5% & Gr- 1% -LM-13
Sample3: SiC -5% + MoS_2-10% & Gr- 1% -LM-13
Sample4: SiC -7.5% + MoS_2-15% & Gr- 1% -LM-13

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V. MECHANICAL BEHAVIOUR ANALYSIS

The various mechanical behaviours were analysis to identify the LM-13 hybrid metal matrix composites.

A. Rockwell Hardness Value Evaluation Of AMMC'S

Using a Shivaganga hardness testing equipment, the different ratios of hybrid AMMC hardness strength were assessed using the Rockwell B scale. In the hardness analysis, ratio-3 produced the highest level of hardness. The hardness values and graphical representation are shown in Table:2 and Figure:1 below.

Table 2: Hardness Value of AMMCs

S. No	Composition	HRB
R_1	LM-13-100%	35
R_2	SiC -2.5% + MoS_2-5 % & Gr- 1% +LM-13	34
R_3	SiC -5% + MoS_2-10 % & Gr- 1% +LM-13	45
R_4	SiC -7.5% + MoS_2-15 % & Gr- 1% +LM-13	41

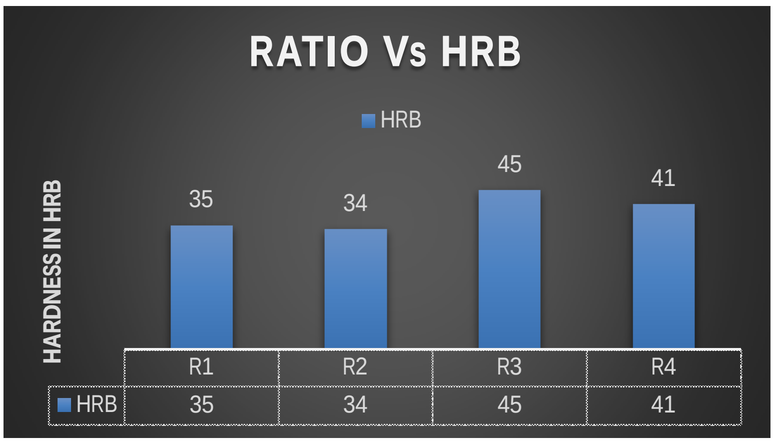

Figure:1 Graphical representation of Hardness Value

B. Impact Load Evaluation Of AMMC'S

The IZOD technique was utilized to evaluate the different ratios of the hybrid AMMC impact load on the Shivaganga impact testing machine. The analysis of the impact load test revealed that the minimum impact joules were found on ratios 3 and 4. The impact load values and graphical representation are shown in Table 3 and Figure 2.

Table 3: Impact Value of AMMCs

S. No	Composition	Impact Strength (Joules)
R_1	LM-13-100%	4
R_2	SiC -2.5% + MoS_2-5 % & Gr- 1% +LM-13	3.5
R_3	SiC -5% + MoS_2-10 % & Gr- 1% +LM-13	2
R_4	SiC -7.5% + MoS_2-15 % & Gr- 1% +LM-13	2

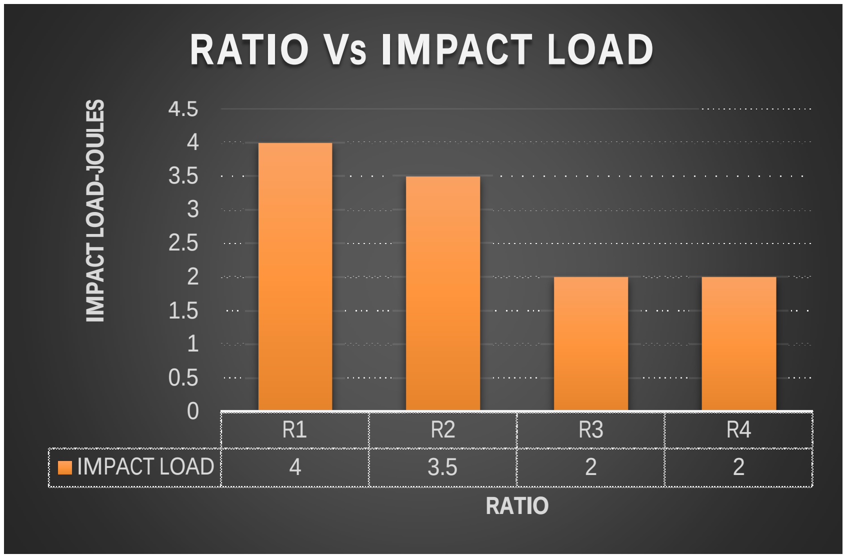

Figure:2 Graphical representation of Impact Value

C. *Tensile Strength Value Evaluation of AMMC'S*

The hybrid AMMC tensile strength values were analyzed in the range of FIE –UTE – 60KN. The greatest tensile strength was discovered on ratio 3-121.46 KN/mm2 during the tensile strength evaluation. Tensile strength numbers and a graphical depiction are shown in Table: 4 and Figure: 3 below.

Table 4: Tensile Strength Value of AMMCs

Sample	DIA (mm)	CSA (mm^2)	TL (KN)	TS $(N/mm)^2$	IGL (mm)	FGL (mm)	%E
R_1	16	201.06	20.84	103.65	73.2	73.2	0.0
R_2	16	201.06	22.86	113.69	73.2	74.0	1.09
R_3	16	201.06	24.42	121.46	73.2	74.0	1.09
R_4	16	201.06	20.95	104.21	73.2	73.5	0.41

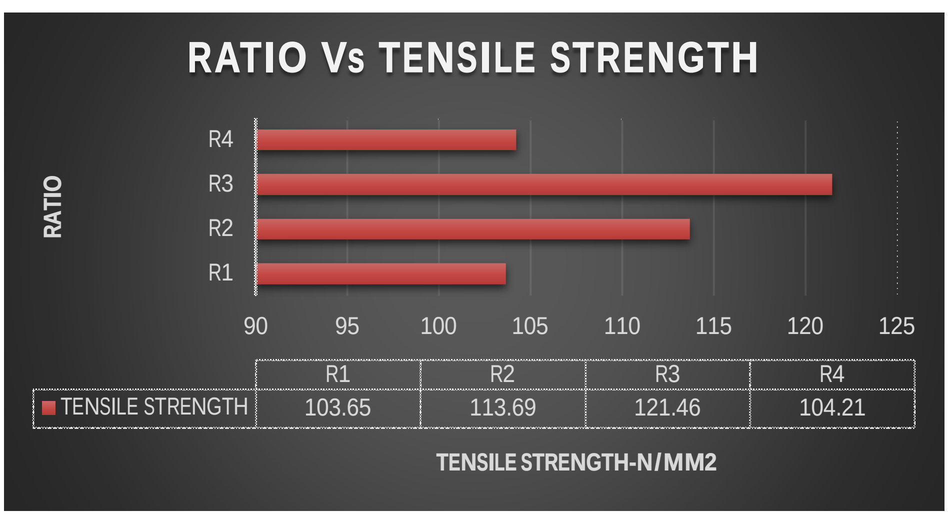

Figure: 3 Graphical representation of Tensile Value

D. Compression Test Value Evaluation of AMMC'S

The HEICO-2000KN was used to analyze the different ratios of hybrid AMMC compression strength values. The maximum compression strength was found on ratio 4-365.3 N/mm2 during the compression strength evaluation. The compressive strength values and graphical representation are shown in Table:5 & Figure:4 below.

Table 5: Compression Strength Value of AMMCs

S. No	Composition	Compression Strength N/mm^2
R_1	LM-13-100%	308.4
R_2	SiC -2.5% + MoS_2-5 % & Gr- 1% +LM-13	345.2
R_3	SiC -5% + MoS_2-10 % & Gr- 1% +LM-13	358.6
R_4	SiC -7.5% + MoS_2-15 % & Gr- 1% +LM-13	365.3

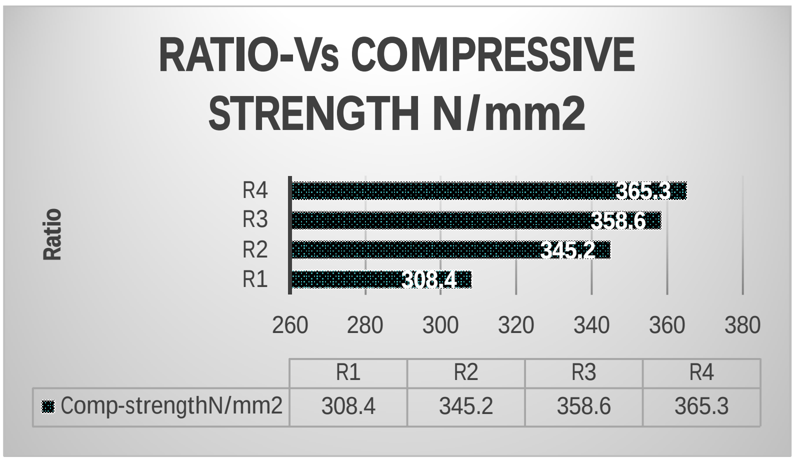

Figure: 4 Graphical representation of Compression Value

E. Wear Test

A tribometer is a device that measures tribological parameters between two surfaces in contact, such as wear volume, friction force, and coefficient of friction. A machine or equipment used to conduct experiments and simulations of the wear, friction, and lubrication processes that are the focus of tribology research is commonly referred to as a tribotester. According to the wear test analysis, a ratio of three indicates the lowest wear rate when compared to other AMMCs.

Technical Specification of Wear Machine –Pin on Disc

Test Speed: 511RPM, Normal Load: 20N, Pin Dia: 10mm, Track Radius: 30mm

WEAR RATE-sample-1, 2, 3 & 4

Table:6 Weight of testing specimen before and after

Ratio	Before Weight	After Weight	Difference
LM-13-100%	3.457	3.434	0.023
SiC -2.5% + MoS_2-5 % & Gr- 1% +LM-13	3.145	3.128	0.017
SiC -5% + MoS_2-10 % & Gr- 1% +LM-13	3.015	3.008	0.007
SiC -7.5% + MoS_2-15 % & Gr- 1% +LM-13	3.234	3.226	0.008

F. Corrosion (Salt Spray Testing Method)

Figure:5 Corrosion (Salt Spray Testing Tub)

At Assured Testing Services in Ridgway, Pennsylvania, salt spray testing was carried out in compliance with ASTM B117. This method offers a regulated corrosive atmosphere that has been applied to generate relative corrosion resistance data for metal specimens exposed in a test chamber. Seldom have salt spray results, when utilized as stand-alone data, been associated with performance prediction in natural contexts. In comparison to other AMMCs, the minimum corrosion rate obtained on ratio-2 was noted from the salt spray corrosion analysis.

Table: 7 Corrosion rate of the different various composite

Ratio	Initial Weight g	Final Weight g	Weight Loss g
LM-13-100%	7.873	7.768	0.105
SiC -2.5% + MoS_2-5 % & Gr- 1% +LM-13	7.181	7.175	0.006
SiC -5% + MoS_2-10 % & Gr- 1% +LM-13	6.268	6.252	0.016
SiC -7.5% + MoS_2-15 % & Gr- 1% +LM-13	6.972	6.894	0.078

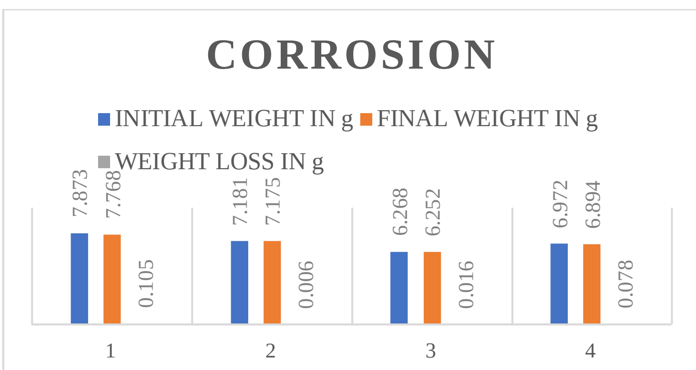

Figure:6 Graphical representation of Corrosion

VI. RESULT & CONCLUSION

Composite materials, in particular LM-13 and Molybdenum disulfide, silicon carbide, and graphite composites, exhibit good mechanical qualities when compared without the reinforcements of LM-13 aluminum alloy. The work improved the hybrid LM-13 metal matrix's mechanical and tribological properties. The maximum hardness was achieved on ratio-3 compare to other AMMCs. Because of the accumulation of reinforcement, impact strength is quite poor on Ratio-3 and 4. Exceptionally high tensile strength was attained. 121.46 N/mm2. Maximum compressive strength was attained with Ratio-4 SiC -7.5% + MoS_2-15% & Gr-1% +LM-13. The minimum wear rate obtained on Ratio- 3-SiC -5% + MoS_2-10% & Gr-1% +LM-13. The lowest corrosion rates observed on ratio 2 of the LM-13 hybrid metal matrix ratio.

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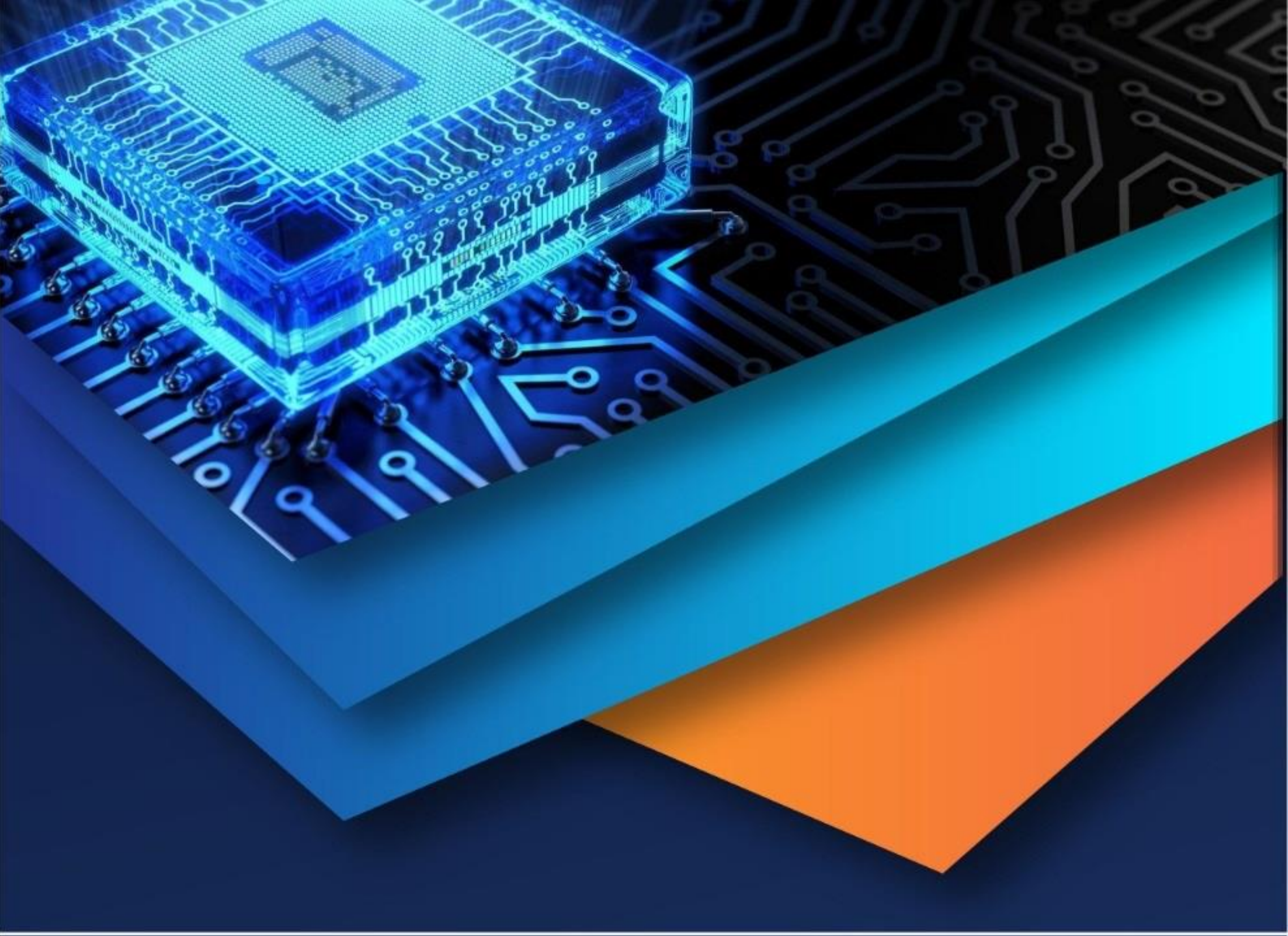

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