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# Study on Hardness of Graphene and S-Glass Reinforced Al-6061 Metal Matrix Composites

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***Abstract: This research work investigated the influence of the graphene and S-glass fiber on the hardness of the Al6061 / S-Glass & Graphene particulate MMCs. Metal Matrix Composites (MMC's) consist of either pure metal or an alloy as the matrix material, while the reinforcement generally a ceramic material. Aluminium composites are considered as one of the advanced engineering materials which have attracted more and more benefits. Now a days these materials are widely used in space shuttle, commercial airlines, electronic substrates, bicycles, automobiles, etc., Among the MMC's aluminium composites are predominant in use due to their low weight and high strength. The key features of MMC's are specific strength and stiffness, excellent wear resistance, high electrical and thermal conductivity. Hence, it is proposed to form a new class of composite. The Al 6061(Aluminium alloy 6061) reinforced with graphene and S-glass fiber to form MMCs were investigated. The stir casting technique of liquid metallurgy was used for the fabrication of the composite material. The composite was produced for different percentages of graphene and S-Glass fiber(varying Graphene with constant S-Glass fiber and varying S-Glass fiber with constant Graphene percentage). The specimens were prepared as per ASTM standard size by turning and facing operations to conduct hardness tests and they were tested using Brinell hardness testing machine. Through the results, it is concluded that hardness of the prepared hybrid composites is higher than the base Al 6061 alloy.***
***Keywords: Al 6061, Graphene, S-Glass fiber, Hardness, BHN.***

## I. INTRODUCTION

In this research paper we study the variation of hardness of different compositions of the hybrid composites, material preparation for the test, test the specimen, results and conclusion. A metal matrix composite (MMC) is composite material with at least two constituent parts, one being a metal. The other material may be a different metal or another material, such as ceramic or organic compound. Aluminium is the most popular matrix for the metal matrix composites (MMCs). The Al alloys are quite attractive due to their low density, their capability to be strengthened by precipitation, their good corrosion resistance, high thermal and electrical conductivity, and their high damping capacity. They offer a large variety of mechanical properties depending on the chemical composition of the Al – matrix. They are usually reinforced by Al2O3, SiC, C but SiO2, B, BN, B4C, AlN may also be considered.

In the 1980s, transportation industries began to develop discontinuously reinforced AMCs. They are very attractive for their isotropic mechanical properties and their low costs. MMCs are nearly always more expensive than the more conventional materials they are replacing. As a result, they are found where improved properties and performance can justify the added cost. Today these applications are found most often in aircraft components, space systems and high – end or "boutique" sports equipment. The scope of applications will certainly increase as manufacturing costs are reduced.

The main objective of this project is to develop Al (6061)/ S-Glass & Graphene particulate MMCs where the S-glass & Graphene are used as reinforcement material &Al (6061) is used as matrix material. The different weight % of reinforcement will be added to matrix and liquid casting technique for the preparation of Al (6061)/ S-Glass & Graphene MMCs thus the developed composites will be tested for hardness.

A. K. Dhingra (1986) [1], had derived that the composite structures have shown universally a savings of at least 20% over metal counterparts and a lower operational and maintenance cost. R.L. Trumper (1987) [2], stated that the researchers all over the world are focusing mainly on Aluminium because of its unique combination of good corrosion resistance, low density and excellent mechanical properties. The unique thermal properties of Aluminium composites such as metallic conductivity with coefficient of expansion that can be tailored down to zero, add to their prospects in aerospace and avionics. MechmetAcilar, FerhatGul (2004) [3], have shown in their work that the choice of Silicon Carbide as the reinforcement in Aluminium composite is primarily meant to use the composite in missile guidance system replacing certain beryllium components because structural performance is better without special handling in fabrication demanded by latter"s toxicity. A.Alahelisten (1996) [4], J.Q.Jiang (1996) [5] P.N.Bindhumadhan (2001) [6], stated that though their low density (35% lower than that of Al) makes them competitive in terms of strength/density values. Magnesium alloys do not compare favorably with Aluminium alloys in terms of absolute strength. The reason for

Aluminium being a success over magnesium is said to be mainly due to the design flexibility, good wettability and strong bonding at the interface.

In this present investgation, the effect of S-Glass & Graphene particle with Aluminium & its percentage will be studied. Thus this will aid in reaching an optimum weight of percentage reinforcement the specific objective & scope of the present investigation.

The organization of this document is as follows. In Section 2 (Methods and Specimen Preparation), gives detailed information of preparation of MMCs of different composition. In Section 3 (Result and Discussion), represents the variation of hardness due to the variation in the composition of the composites and also includes the SEM images of the tested specimens. The Section 4(Conclusion) compiles the conclusions drawn from experiment followed by references.

## II. METHODS AND SPECIMEN PREPARATION

*A. Casting*

1) *Fabrication of Test Specimens:* Stir casting technique of liquid metallurgy is used to prepare Al 6061 Hybrid composites.It consist of resistance Muffle-furnace and a stirrer assembly was used to synthesize the composite.
2) *Preheating of Reinforcement:* Muffle furnace was used to preheat the particulate to a temperature of 700° C. It was maintained at the temperature till it was introduced in to the Al 6061 alloy melt.


Fig. 1 Furnace Setup

3) *Melting of Matrix Alloy:* The melting range of Al 6061 alloy is of 700-800°C. A known quantity of Al 6061 ingot wear pickled in 10% NaOH solution at room temperature for 10 min. The smut formed was removed by immersing the ingots for 1 min mixture of one part nitric acid and one part water followed washing in methanol. The cleaned ingot after drying in air were loaded into the graphite crucible of the furnace for melting. The melt was super-heated to a temperature of 800°C and maintained at that temperature. The molten metal was then degassed using Hexa-Chloro ethane tablets for about 8 min.

Fig. 2 Meltig Ingots

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4) *Mixing and Stirring:* Alumina coated stainless steel impeller was used to stir the molten metal to create a vertex. The impeller was of centrifugal type with three blades welded at 45° inclination and 120° apart. The stirrer was rotated at a speed 300-400 rpm and a vertex was created in the melt. The depth of immersion of impeller was approximately one third of the height of the molten metal from the bottom of the crucible. The pre-heated particulates of Graphene and short S-Glass fiber were introduced into the vertex at the rate of 120 gm/min. Stirring was continued until interface interactions between the particles and the matrix promoted wetting. The melt was degassed using Hexo chloro ethane tablets and after reheating to superheated temperature (800°C) it was poured into the preheated die.

Fig. 3 Mechanical Stirrer in Action

5) *Pouring of Molten Metal into Dies:* Then after few minutes of stirring, the liquid metals with reinforcements are poured into the dies. The dies were are preheated and coated additives to ease the process of removing the casting.

Fig. 4 Pouring of Molten metal into die

Fig. 5 Casted specimen in the die

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*B. Specimen Preparation*

The casted specimens are withdrawn from the mould and machined to required dimension according to ASTM for conducting hardness test and lathe is used for this purpose.

Fig. 6 Hardness Test Specimens(Before testing)

The percentage of reinforcements used in different specimens is as shown in table 1

Table 1: Percentage Of Reinforcements

| Specifications | % Graphene | % S-Glass Fiber | % of Al-6061 |
|---|---|---|---|
| A0.5G1S | 0.5 | 1 | 98.5 |
| A05G3S | 0.5 | 3 | 96.5 |
| A0.5G5S | 0.5 | 5 | 94.5 |
| A1G1S | 1 | 1 | 98 |
| A1G3S | 1 | 3 | 96 |
| A1G5S | 1 | 5 | 94 |
| A1.5G1S | 0.5 | 1 | 97.5 |
| A1.5G3S | 1.5 | 3 | 95.5 |
| A1.5G5S | 1.5 | 5 | 93.5 |
| A2G1S | 2 | 1 | 97 |
| A2G3S | 2 | 3 | 95 |
| A2G5S | 2 | 5 | 93 |

*C. Experimentation*

1) *Hardness Test:* The specimen is placed on the top of the table and raised it with the elevating screw, till the test sample just touched the ball.

Load is applied on the specimen for a certain period, during which indenter presses onto the specimen. The steel ball during this period moved to the position of the sample and made indentation.

The diameter of the indentation made in the specimen is recorded by the use of the micrometer microscope. The diameter of indentations is taken and the BHN is calculated. Figure 7 shows the Hardness specimen after the test and Table 2 represents the test results.

Fig. 7 Specimens after testing

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Table 1: Hardness Test Results

| Designation | Indentation Diameter(mm) | BHN |
|---|---|---|
| A0.5G1S | 1.1 | 40.26 |
| A0.5G3S | 1.2 | 2.55 |
| A0.5G5S | 1.2 | 43.22 |
| A1G1S | 1.3 | 41.30 |
| A1G3S | 1.1 | 45.23 |
| A1G5S | 1.3 | 41.30 |
| A1.5G1S | 1.25 | 45.61 |
| A1.5G3S | 1.3 | 46.22 |
| A1.5G5S | 1.3 | 49.22 |
| A2G1S | 1.35 | 44.22 |
| A2G3S | 1.1 | 47.05 |
| A2G5S | 1.3 | 48.30 |
| 100Al | 1.4 | 35 |

## III.RESULT AND DISCUSSION

Hardness are found for the developed composites of different weight % of Graphene, S-Glass Fiber and Al-6061. The present work attempts to understand the influence of reinforcements on hardness of the Al alloy-based Hybrid composites.

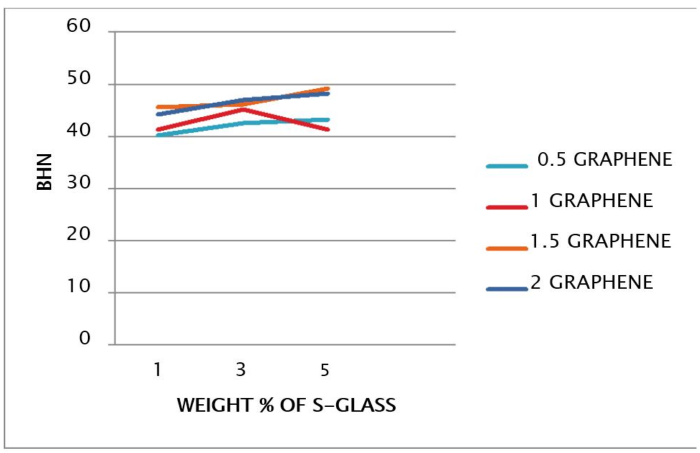


Fig. 8 The effect of Graphene and S-glass fiber on the Brinell Hardness of the composite.

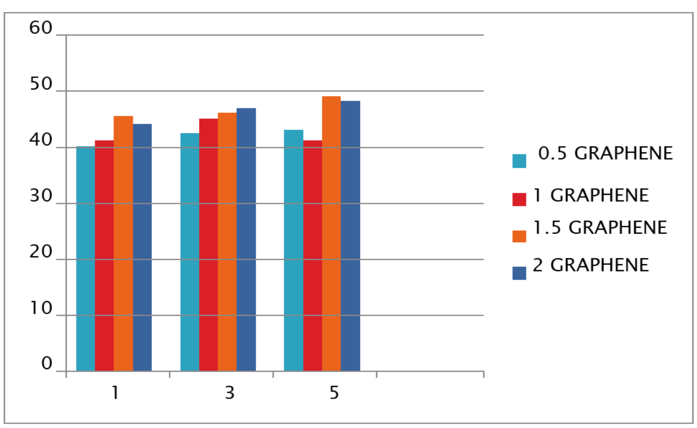


Fig. 9 Bar representation of the Hardness Test Result

*A. Scanning Electron Microscope Studies*

The cleaned, dried and etched specimens are prepared and subsequently mounted on specially designed aluminium suturing (holder). The specimens thus mounted were viewed under JeolJSM6510 LV scanning electron microscope at an accelerating voltage of 20KV below figures (10-17) shows the SEM micrograph of the different combinations of the hybrid MMC at different magnifications.

Pure Al6061

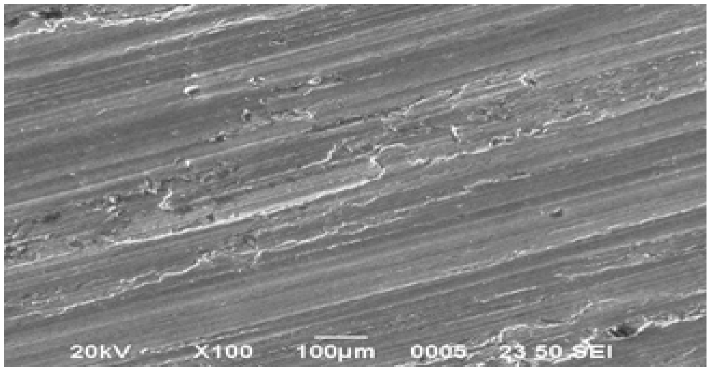


Fig. 10 Al6061 seen under SEM at 100X

0.5%Graphene +1%S-Glass 98.5% Al6061 MMC

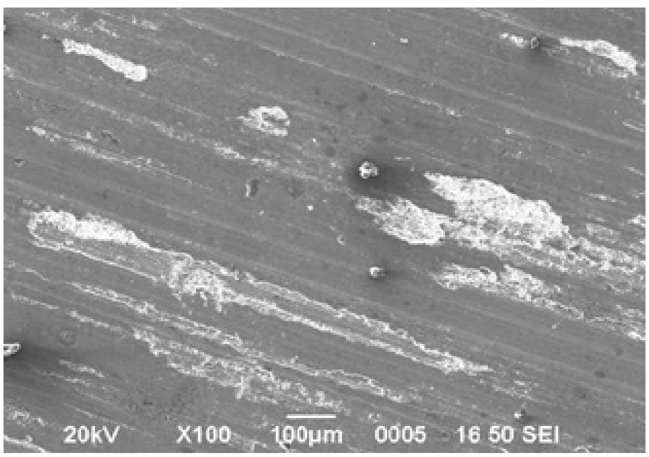


Fig. 11: 0.5%Graphene +1%S-Glass+98.5% Al6061 MMC seen under SEM at 100X

1%Graphene+1%S-Glass+98%Al6061 MMC

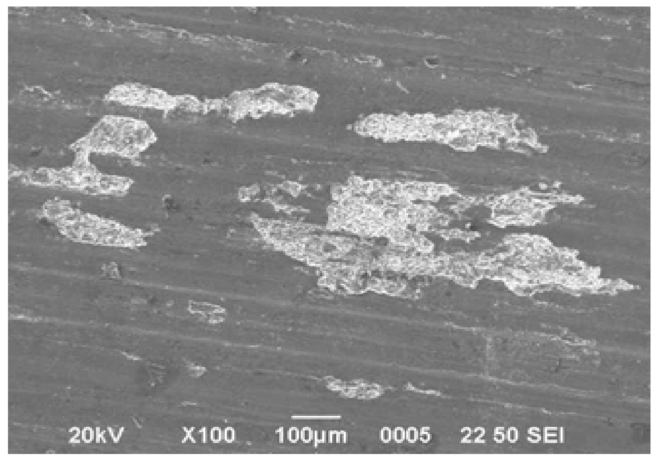


Fig. 12: 1%Graphene +1%S-Glass+98% Al6061 MMC seen under SEM at 1000X

1%Graphene +3%S-Glass +96% Al6061 MMC

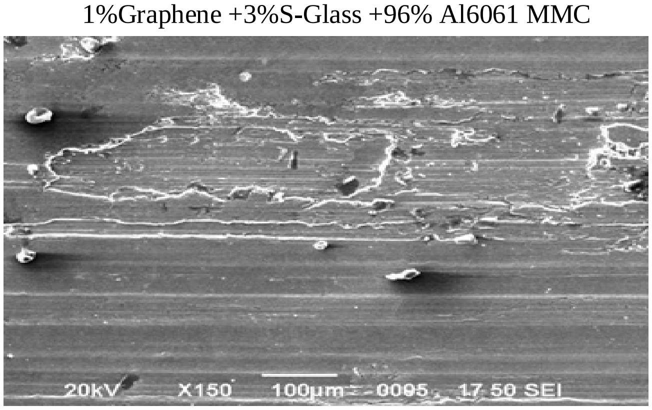


Fig.13: 1%Graphene+3%S-Glass+96% Al6061 MMC seen under SEM at 150X

1.5%Graphene+1% S-Glass +97.5% Al6061 MMC

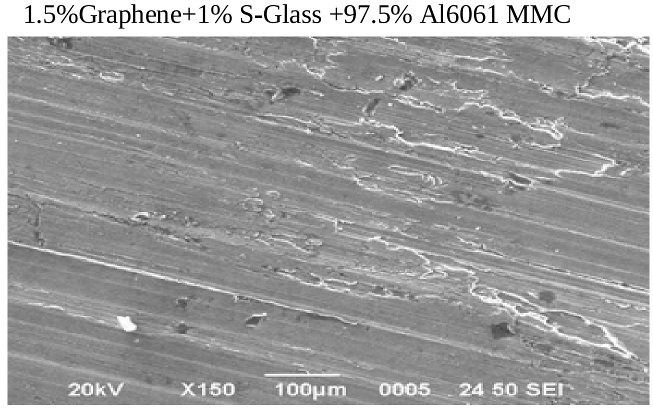


Fig. 14: 1.5%Graphene +1%S-Glass +97.5% Al6061 MMC seen under SEM at 150X

1.5%Graphene+5%S-Glass+93.5% Al6061 MMC

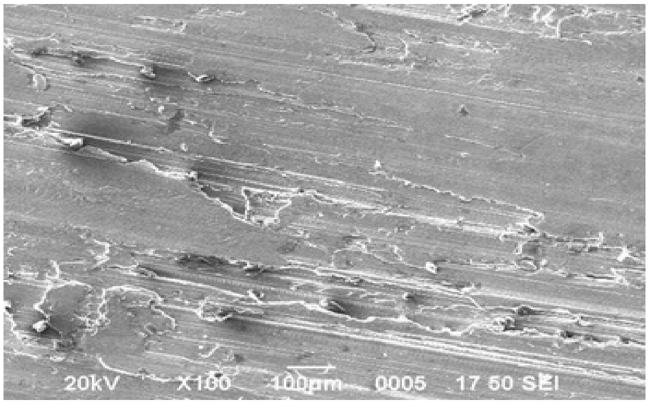


Fig. 15: 1.5%Graphene+5%S-Glass+93.5% Al6061 MMC seen under SEM at 150X

2%Graphene+1%S-Glass+97% Al6061 MMC

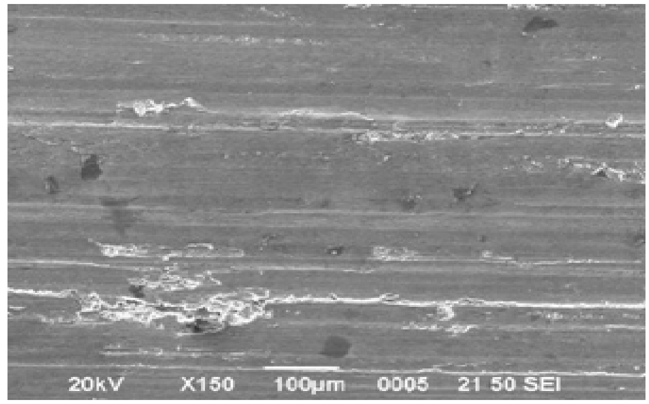


Fig. 16: 2%Graphene+1%S-Glass+97% Al6061 MMC seen under SEM at 150X

2%Graphene +5%S-Glass +93% Al6061 MMC

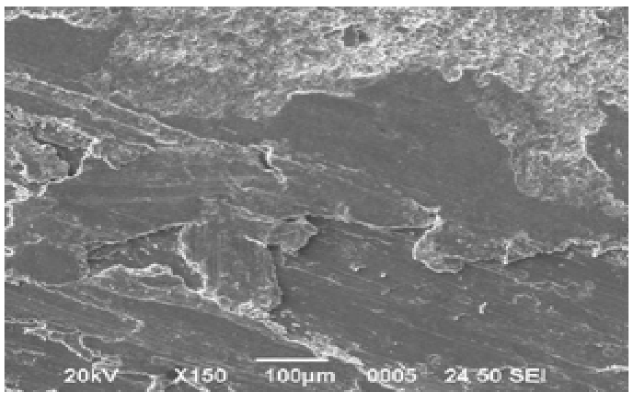


Fig. 17: 2%Graphene+5%S-Glass+93% Al6061 MMC seen under SEM at 150X

SEM microstructure of Aluminums S-glass & Graphene composites containing in different compositions are shown in figures. The photographs show that the graphene and S-glass are uniformly dispersed in the aluminum matrix. Graphene particles were also clearly visible dendrite microstructure observed in the sample containing 0.5 wt % Graphene sintered at 650°C indicates to the formation of composites phase due to reaction between Aluminum and Graphene particles. The microstructure of the composites materials was determined by scanning electron microscope, the micrograph reveled a relative uniform distribution of reinforced particles and good interfacial integrity between matrixes.

## IV. CONCLUSIONS

For the hardness Al 6061 hybrid composite material containing S-Glass & Graphene particulates were fabricated successfully by varying wt% of Graphene from 0.5 to 2% using stir casting method. Keeping S-Glass 6% as constant, by increasing the Graphene particulates, we can conclude that Hardness of the prepared hybrid composites is higher than the base AL 6061 alloy. Addition of 5wt% S-Glass increases hardness considerably. Whereas the addition of Graphene 2wt% particulates decreases the hardness but is higher than the Al6061 alloy.

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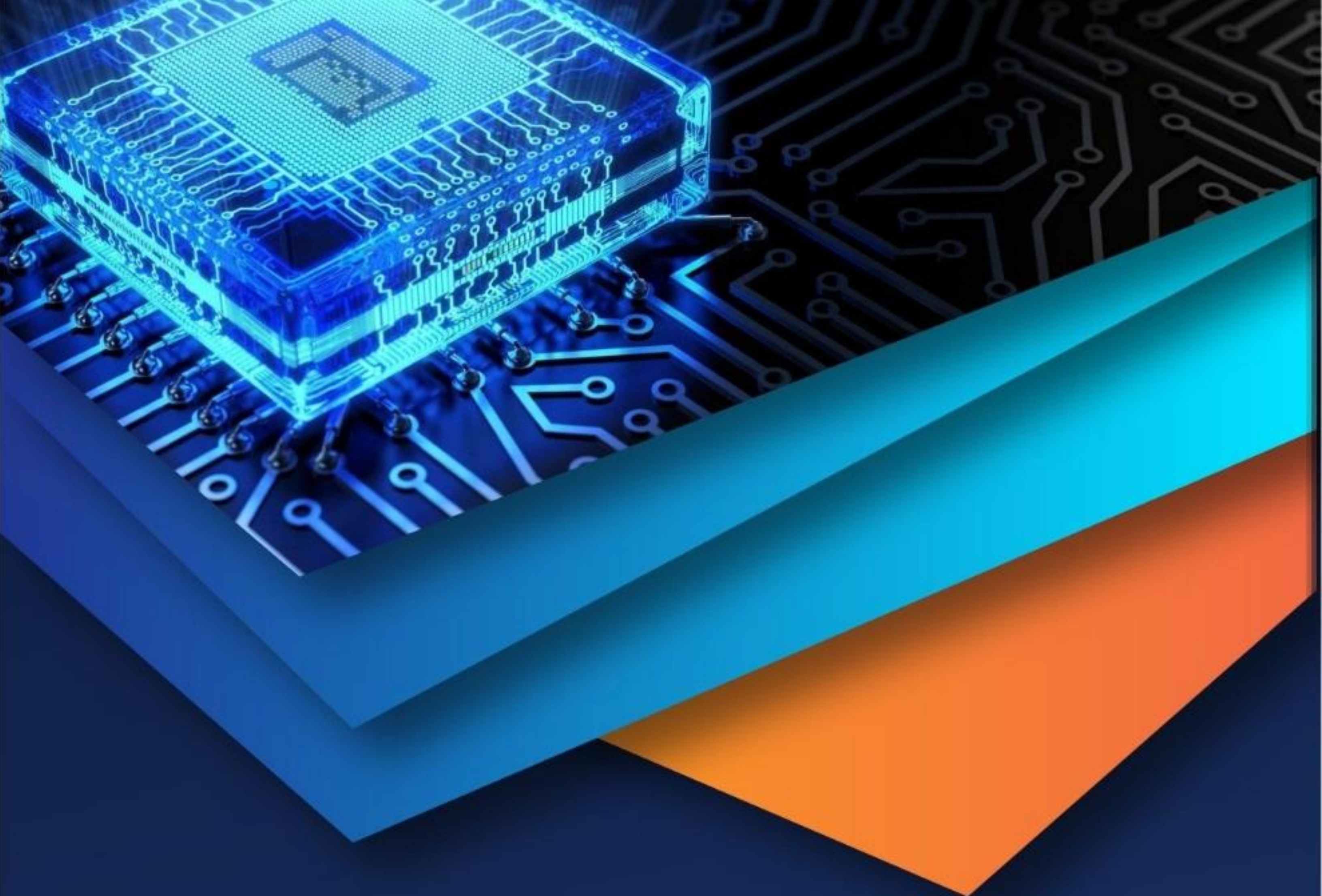


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