iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** I **Month of publication:** January 2021

DOI: https://doi.org/10.22214/ijraset.2021.32706

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue I Jan 2021- Available at www.ijraset.com

Charecterisation and Mechanical Properties Evaluation of Aluminium Alloy T6-6061(Reinforced with ZrO_2) subjected to Forging

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***Abstract:** This Paper involves the development of Aluminium T6 6061 alloy using forging process. The Standard Al T6 6061 alloy ingots was melted and super-heated in the electrical resistance furnace for about 8 hours at 750^{0}C. The superheated melt was reinforced with zirconium dioxide in 3% and 6% weight proportions. The molten metal was poured into a cylindrical rod die of dimensions 300mm x 200mm and allowed to solidify at ambient temperature. The cast specimens were later forged for comparison study purposes. The microstructure and mechanical characterization of forged and unforged cast specimens. The microstructural characterization of forged cast sample exhibits fine grain structure with spherical morphology of secondary magnesium and silicon magnesium and silicon phase in the Al matrix whereas the unforged cast sample indicates coarse with dendrite type morphology. The strength results in terms of tensile of forged cast specimen reveals significant improvement in the tensile strength over the unforged cast specimens due to unforged cast specimen due to refined grain structure. The hardness results in terms of brinell hardness of reinforced specimens showed decrement compared to their base alloy.*
***Keywords:** Aluminium T6 6061 alloy, ZrO_2, Stir casting, Optical Microscopy, Keller's reagent.*

I. INTRODUCTION

Metal matrix composites (MMCs) are increasingly becoming a new class of material in aerospace applications because, their properties can be tailored through the addition of selected reinforcements [1-2]. In particular, particulate reinforced MMCs have recently found special interest because of their specific strength and specific stiffness at room and elevated temperatures [3]. Applications of Aluminum-based MMCs have increased in recent years as engineering materials. The introduction of a ceramic material into a metal matrix produces a composite material that results in an attractive combination of physical and mechanical properties which cannot be obtained with monolithic alloys. Discontinuously reinforced aluminum matrix composites have emerged from the need for light weight, high stiffness materials which are desirable in many applications, mainly on automobile products such as engine piston, cylinder liner, brake disc/drum etc. The strengthening of aluminum alloys with a reinforcement of fine ceramic particulates has greatly increased their potential in wear resistant and structural applications [1–13]. There is an increasing interest in the development of metal matrix composites (MMCs) having low density and low cost reinforcements. Although these MMCs have better properties including high strength, high stiffness and better wear resistance their usage is limited due to their high manufacturing cost. Among the various discontinuous reinforcements used, glass particulate is one of the most inexpensive and low-density reinforcement. Incorporation of glass particles reduces the cost and density of aluminum and itsalloys.

II. LITERATURE REVIEW

A.M.S.Hamouda, S.Sulaiman, T.R.Vijayaram, M.Sayuti, M.H.M.Ahmad**.**[1] discusses the processing and characterization of quartz particulate reinforced aluminum- silicon alloy matrix composite which were fabricated by stir casting technique with percentages of SiO_2 particle varying from 5 to 30 wt% with particle size of 65µm in steps of 5 wt%. Hardness values were measured for the quartz particulate reinforced LM6 alloy composites and it has been found that it gradually increases with increased addition of the reinforcement phase. The tensile strength of the composites decreases with the increase in addition of quartz particulate.

Sudarshan, M.K. Surappa**.**[2] in their paper deals with the mechanical properties such as hardness, tensile strength, compressive and damping characteristics of A356 Al and A356 Al-fly ash prepared using stir-cast technique and hot extrusion, in which 6-12 wt% of fly ash was dispersed in the base matrix. Bulk hardness, matrix micro hardness, 0.2% proof stress of A356 Al–fly ash composites are higher compared to that of the unreinforced alloy. Additions of fly ash lead to increase in hardness, elastic modulus and 0.2% proof stress. Composites reinforced with narrow size range fly ash particle exhibit superior mechanical properties compared to composites with wide size range particles.

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A356 Al–fly ash MMCs were found to exhibit improved damping capacity when compared to unreinforced alloy at ambient temperature. Damping capacity of fly ash reinforced Al-based composite increases with the increase in volume fraction of flyash.
Joel Hemanth.[5] have studied the mechanical and abrasive, slurry erosive wear with chilling effect of fused silica (SiO_2) as reinforcement and aluminum alloy (A356) as a base material. The chills used were metallic and non- metallic chills. The fused silica particles of size 50–100μm were used as reinforcement varying from 3-12 wt% in steps of 3 wt% Strength, hardness and wear resistance increase up to 9 wt. % additions of dispersoid and copper chill was found to be the best because of its high volumetric heat capacity.
E.Mohammad Sharifi, F. Karimzadeh, M.H. Enayati. [3] Investigated the mechanical and tribological properties of boron carbide reinforced aluminum matrix nanocomposites were fabricated by mechanical alloying with percentages of boron carbide varying from 5 to 15 wt% in steps of 5 wt%. The sample with 15 wt% B4C had the optimum properties. This sample had a value of 164 HV which is significantly higher than 33 HV for pure Al. Also, ultimate compressive strength of the sample was measured to be 485 MPa which is much higher than that for pure Al (130 MPa). The wear resistance of the nanocomposites increased significantly by increasing the B4C content. Dominant wear mechanisms for Al–B4 Cnanocomposites.
Sujit Kumar Jha, Devibala Balakumar and Rajaligam Paluchamy, et.al [6] investigated on Experimental Analysis of Mechanical Properties on AA6060 and 6061 Aluminium alloys. Due to the substantial increased in demands of aluminum in industries like automotive industry and building industry, it is required for improvement of its mechanical properties by addition of alloying elements of aluminum. The objective of this research is to study the effect of various alloys addition to aluminum and their effects on tensile strength, hardness and microstructure. The mechanical properties of AA6060 and AA6061 aluminum alloy have been characterized in terms of tensile strength and hardness. The results has been used to determine the tensile strength and % elongation of the specimen. From results, it has been observed that mechanical properties of Al-alloys increasing up to 0.65% of Mg addition due to grain refinement, whereas increase in Mg contents beyond 0.71% mechanical properties starts decreasing. The microstructure of the fracture surface after tensile strength has been examined using inverted microscope.
In the present investigation, aluminum based metal matrix composite containing 3 to 6 wt% of ceramic particulates of mesh size 90microns were successfully synthesized. Evaluating the mechanical properties of produced composites.

III. MATERIALS

A. Matrix Materials

The matrix material used in the experimental investigation was an aluminum alloy (6061) whose chemical composition is listed in Table 1. It therefore has a low melting point 660°c. Aluminium alloy in its unmodified state is extensively used in sand casting and die-casting. The molten metal has high fluidity and solidifies at constanttemperature.

Table 1: Chemical composition of Aluminum Alloy 6061 by wt%

Cu	Mg	Si	Fe	Mn	Cr	Zn	Aluminum
0.4	1.2	0.80	0.70	0.15	0.35	0.25	Balance

B. Reinforcement Materials

The reinforcement material used in the investigation was ceramic particulates zirconium dioxide of the particle size of 70 to 90 weighing 60gm (3wt %) is heated up to 750^{o}C for 8 hours. After reaching the superheated temperature, the reinforcement particulates are stirred by hand using a stirrer for about 5 minutes.

IV. EXPERIMENTAL PROCEDURE

Cleaned Aluminum ingots weighing 2 kg are taken in a clay graphite crucible. The crucible is charged into electrical resistance heating furnace set at 750^{0}C. The furnace is switched on for melting of aluminum and temperature (750^{0}C) maintained for about 8 hours. The reinforcement material used in the investigation was ceramic particulates zirconium dioxide of the particle size of 70μ to 90μ weighing 60gm (3wt %) is heated up to 750^{o}C for 8 hours. After reaching the superheated temperature, the reinforcement particulates are stirred by hand using a stirrer for about 5 minutes. The slag was removed from the melt and the reinforcement treated mixture was then poured into the die of dimension 300mm and diameter 20mm and allowed to solidify at ambient temperature. After about 5 minutes, the developed composite was removed from the mould and subjected to hand forging by reducing diameter up to 18 to 16mm. The same procedure was followed to develop the composite with 6wt% ZrO_2. The superheated molten Al alloy was poured into the cylindrical rod die. The obtained specimen was forged using hammer for further comparison.

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A. Tensile Strength

The tensile tests were conducted in the standard computer interfaced UTM at room temperature. The samples were prepared according to ASTM E8M. The tensile properties of the alloys were determined by performing the tension test on standard cylindrical tensile specimens. A typical tensile specimen as per ASTM standard is shown in Fig. 1.

The test involved crosshead speed set at 2mm/min till rupture of the specimen. During the tests, the loading elongation data was recorded by the computer interfaced with the UTM. The specimens after the tensile test are as shown in Fig. 2. The result obtained during the specimen testing is tabulated in below table 2.

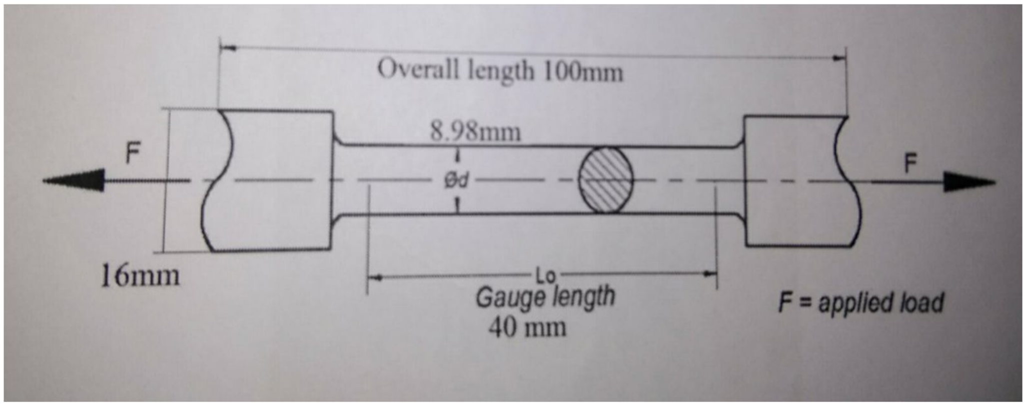

Fig.1. Tensile Specimen as per ASTM standard

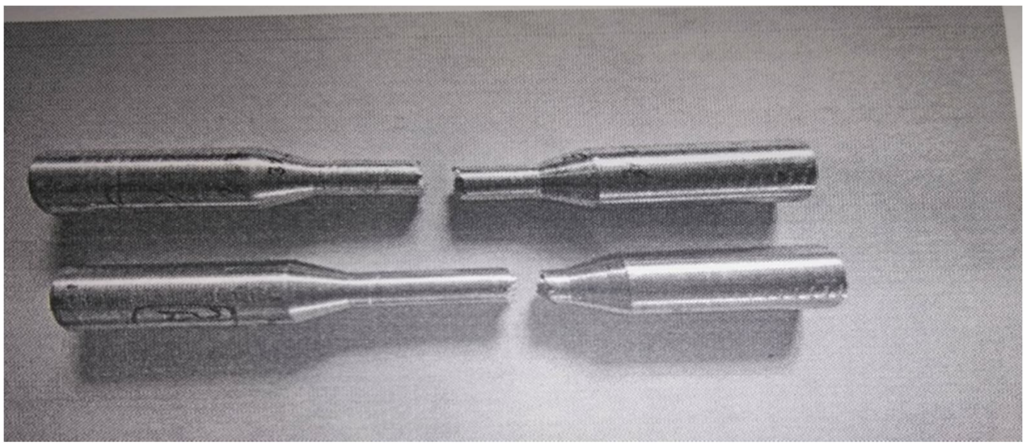

Fig. 2. Tensile test specimen after test

Table 2: Tensile property of the specimen

Sample	C/S area (mm^2)	Peak load (N)	% Elongation	Break Load (N)	UTS (N/mm^2)	Young's Modulus (MPa)
Al T6 – 6061	63.36	4257	2.70	2800	67.58	2502.15
Al+3wt.% $Zr0_2$ Forged	63.36	5523	2.44	2878	87.16	3574.79
Al+3wt.% $Zr0_2$ Unforged	63.36	4282	2.7	2800	67.58	2502.15
Al+6wt.% $Zr0_2$ Forged	63.36	7830	3.39	1403	123.58	3640.75
Al+6wt.% $Zr0_2$ Unforged	63.36	8586	7.77	1408	135.51	1744.51

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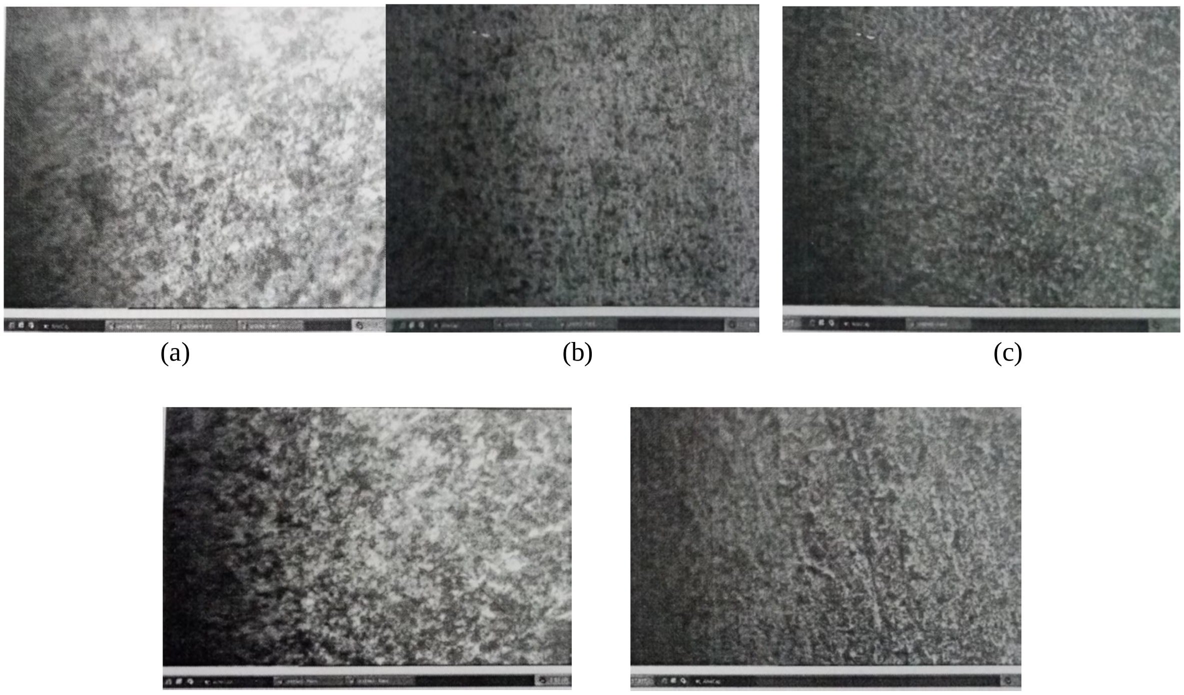
V. RESULTS AND DISCUSSION

A. *Evaluation of Microstructure*



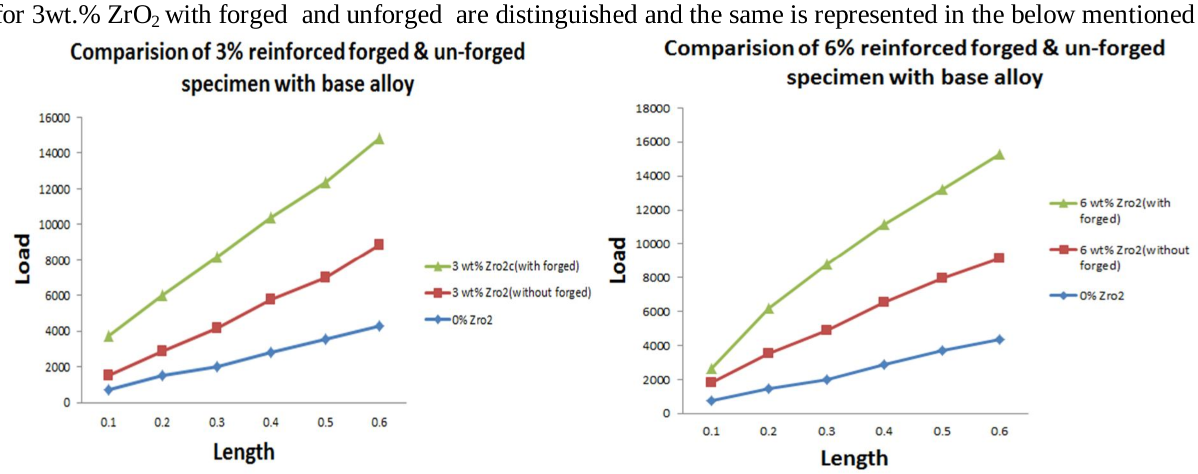
(a) (b) (c)

(d) (e)

Fig 3: Optical Microstructure of Aluminium Alloy at 20X Magnification

In Microstructural Analysis the developed composite both of forged and unforged specimens are discussed in terms of distributions of reinforcements, grain refinement and grain morphology. They are further compared with microstructure of the base alloy. The microstructures of the Base alloy and developed composites (3wt% & 6wt% ZrO_2 reinforcement additions) with 20X are shown in Fig. 3 (a to e). The size of the secondary phase approximately measured from the micron scale reveal 3 to 4 microns in the case of developed and forged specimens. The refinement in the grain size is primarily attributed to presence of micro sized reinforcement particulates which acts as multiple nuclei sites during solidification process and also effect of recrystallization process taking place during hot forging process in contrast with the unforged matrix alloy. No porosity is absorbed in the forged samples.

The percentage elongation as a function of load for 3wt.% ZrO_2 and 6wt.% ZrO_2 as shown in the Fig. 4 (a) and (b) the characteristic features for 3wt.% ZrO_2 with forged and unforged are distinguished and the same is represented in the below mentioned figures.



(a) (b)

Fig. 4(a & b): Percentage Elongation as a function of load (Composite with 3wt. % and 6wt. % ZrO_2)

VI. CONCLUSION

Synthesis of Aluminum T6-6061 alloy based composites (MMC's) was successfully accomplished. This technical reveals the following: Micro structural analysis showed fine refinement, fairly uniform distribution of reinforcement with no porosity. Mechanical characterization revealed significant improvement in strength and hardness. The developed forged specimens reveals significant improvement in the strength properties along enhanced ductility, which can be primarily attributed to refined grain structure achieved through forging process and presence of reinforcement and its increasing weight percentage in the matrix alloy.

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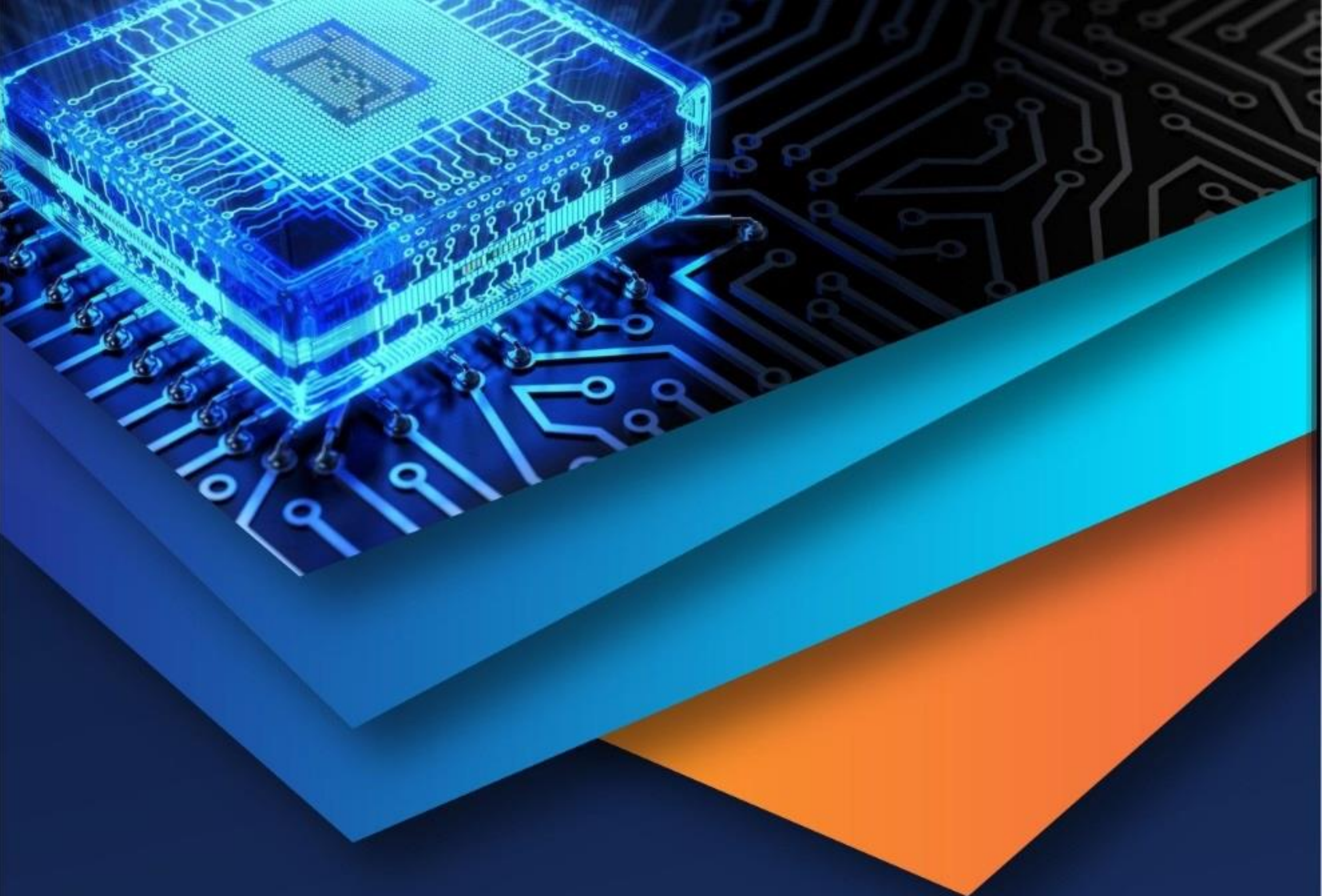

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