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Experimental Studies on Surface Roughness of Nickel Alloy-286 by Extrusion Honing Process

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Abstract: Extrusion Honing (EH) is also known as Abrasive flow machining (AFM) is a fine finishing process for difficult to reach internal surfaces through the action of extrusion pressure, combined with the abrading action of the polymer media laden with abrasive particles. The EH processes are advanced finishing techniques widely used as finishing solutions in high-end industries like aerospace, automobile, medical, tool and die, and prosthetic. EH processes are mainly used for polishing, deburring, removal of cast layers, radiusing and finishing intricate shapes by flowing abrasive laden viscoelastic carrier over the surfaces to be finished. Although EH have a wide range of applications and could be used in every shop floor as a finishing solution, their usage is limited owing to high initial and running costs associated with them. Finally, the future research challenges including the development of low-cost alternative media, development of tooling and fixture, and environmental issues in the area of extrusion are highlighted. In this work the experimental process is conducted using one way extrusion honing machine and the process is carried out on Nickel Alloy A-286, one of the super alloy having high hardness and high strength properties which is machined to get good surface finishing. In this paper a thorough research is done on how the process parameters have its impact on surface roughness of Nickel Alloy A-286. The results are obtained by measuring and analyzing the extruded surface with the help of surface roughness measuring instrument and significant progress in surface finish

Key Words: Surface finish, Extrusion honing, Nickel Alloy-286, Abrasive Flow machining, Silicon Polymer.

I. INTRODUCTION

Extrusion Honing (EH) is a process which was introduced during the late 1960s have emerged as an important non-traditional metal finishing process and is increasingly being utilized in recent years. AFF or Extrusion Honing is also known as AFM. The EH process has its application in a wide range of industries such as aerospace, defense, surgical and tool & die manufacturing. EH is used to deburr, radius and polish difficult to reach surfaces by extruding an abrasive laden polymer medium with very special rheological properties. It is widely used finishing process to finish complicated shapes and profiles. The polymer abrasive medium which is used in this process possesses easy flow ability, better self deformability and fine abrading capability. Layer thickness of the material removed is of the order of about 1 to 10 µm. Best surface finish that has been achieved is 50 nm and tolerances are +/- 0.5 µm. In this process tooling plays very important role in finishing of material, however hardly any literature is available on this of the process. In EH, deburring, radiusing and polishing are performed simultaneously in a single operation in various areas including normally inaccessible areas. It can produce true round radii even on complex edges. EH reduces surface roughness by 75 to 90 percent on cast and machined surfaces. It can process dozens of holes or multiple passage parts simultaneously with uniform results. Also air cooling holes on a turbine disk and hundreds of holes in a combustion liner can be deburred and radiused in a single operation. EH maintains flexibility and jobs which require hours of highly skilled hand polishing can be processed in a few minutes. EH produces uniform, repeatable and predictable results on an impressive range of finishing operations. Important feature which differentiates AFM from other finishing processes is that it is possible to control and select the intensity and location of abrasion through fixture design, medium selection and process parameters.

II. LITERATURE SURVEY

Rhoades L J [1] experimentally investigated the basic principle of AFM process and identified its control parameters. He observed that when the medium is suddenly forced through restrictive passage then its viscosity temporarily rises. Significant material removal is observed only when medium is thickened. The amount of abrasion during AFM depends on design of tooling, extrusion pressure, medium viscosity and medium flow volume. All these parameters ultimately change the number of particles interacting with the workpiece and the force acting on individual abrasive grain. A higher volume of medium flow increases number of interacting abrasive grains with the workpiece, hence more abrasion takes place. Number of cycles depend on the velocity of medium, during a given time period. Flow pattern of medium depends on its slug (medium exiting the workpiece) flow speed, medium rheology and passage size (cross-sectional area). AFM can be used in industrial applications such as precision deburring,

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edge contouring, surface finish, removal of thermal recast layers, etc. Williams and Rajurkar [2] used the full factorial experimental design to study the effect of medium viscosity and extrusion pressure on metal removal and surface roughness. Medium's viscosity effect is more significant on material removal as compared to extrusion pressure. It is also reported that major change in the surface finish is observed after finishing for a few cycle only.

Lingaraju K N and Raju H P [3] issued a journal on "Surface Finishing using Extrusion Honing Process on Monel- 400", in which they concluded that Surface finish at the exit side is exceptional than the entry side due to more desirable contact of the abrasive particles in the media at the exit side. Jain and Adsul [4] reported that initial surface roughness and hardness of the workpiece affects material removal during AFM process. Material removal and reduction in surface roughness value are reported higher for the case of softer workpiece material as compared to harder material. Material removal and reduction in surface roughness increase when percentage concentration of abrasive in the medium increases. They also concluded that among all the process parameters studied, the dominating one is the abrasive concentration followed by abrasive mesh size, and number of cycles. It was also reported that with higher abrasive mesh size, both MR and improvement in ΔRa value decrease.

Davies and Fletcher [5] reported a relationship between the number of cycles, temperature and pressure drop across the die for the given type of polymer and abrasive concentration. Increase in temperature results in decrease in medium viscosity and increase in volumetric flow rate. With increase in processing time, medium temperature increases that causes a change in medium viscosity. They 18 concluded that rise in temperature is due to a combination of internal shearing of the medium and finishing action of the abrasive grit. Williams and Rajurkar [6] showed that media viscosity and extrusion pressure significantly determine both surface roughness and the material removal rate. The authors indicated that the major improvement in surface finish takes place within the first few cycles. Their later work proposed methods to estimate the number of dynamic active grains involved in cutting and the amount of abrasive grain wear per stroke.

Loveless [7] reported that the type of machining operation used to prepare the specimen prior to AFM is important and affects the improvement achieved during finishing. As compared to the turned and milled surfaces, WEDM surfaces are found to be more suitable for AFM. The amounts of material removal from the WEDM and milled surfaces are significantly different from that of turning and grinding, because these machining processes produce different micro surface contours.

III. METHODOLOGY

A. Experimental Setup

This experimental set up is one way type of the Extrusion Honing process, i.e. the media flows in only one direction i.e., media is flow in only one direction. It consists of an abrasives media cylinder coupled to a hydraulic cylinder and to controls the actuation suitable directional control valve has been utilized. Abrasive media cylinders is a pistons cylinder arrangements with a end cap which acts as a tooling is to confine and directs the media flow through the specimen. The end cap is removed from the cylinder arrangement to fill the abrasives media into the cylinder and later the end cap is replaced. This end cap also has the fixture arrangement to hold the specimen during the experimentation. Abrasives media is enter the specimen from the one side to extrude out at another side. The extruded abrasives media is collected in the collector.

Fig 1: one way type of extrusion honing Machine

B. Experimental Procedure

1) Preparation of test specimens.
2) Preparation of the abrasive media.
3) Performing the extrusion honing trails.
4) Measuring surface parameters at different locations of the specimen using surface roughness measuring instrument (Surfcom 130A). ex Ra, Rz, Rt and Rpk.
5) Tabulation of results.

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C. Chemical Composition

The chemical composition of Nickel alloy 286 or INCOLOY alloy 286 is given in the following table.

TABLE 1
Chemical Composition

Element	**Content (%)**
Nickel, Ni	24.0-27.0
Iron, Fe	54 (Balance)
Chromium, Cr	14.8 (13.5-16.0)
Titanium, Ti	2.13 (1.90-2.35)
Molybdenum, Mo	1.30 (1.0-1.5)
Manganese, Mn	1.0 (2.0max)
Silicon, Si	0.50 (1.0max)
Vanadium, V	0.30 (.10-.050)
Aluminum, Al	0.18 (0.35max)
Carbon, C	0.040 (0.08max)
Phosphorous, P	0.020
Sulfur, S	0.015(0.030max)
Boron, B	0.0060(0.001-.01)

D. Physical and Mechanical Properties

TABLE 2
Physical properties

Properties	Metric	Imperial
Density	7.94 gm/cm^3	0.287 lb/in^3
Melting point Range	1370-1430^{o}C	2500-2600^{o}F
Specific Gravity	7.94	7.94
Specific Heat	419j/kg^{0}C	0.100Btu/Ib*^{0}f
Young’s Modulus	201Gpa	29.1×10^{3}ksi

TABLE 3
Mechanical properties

Properties	Metric	Imperial
Tensile strength	1035 MPa	150100 psi
Yield strength (@strain 0.200%)	759 MPa	110000 psi
Hardness, Brinell (estimated from Rockwell C value for Brinell test with 3000 kg load/10 mm dia ball)	304	304
Hardness, Knoop (estimated from Rockwell C value)	330	330
Hardness, Rockwell C value	36	36
Hardness, Vickers (estimated from Rockwell C value)	318	318

E. Preparation Of Test Specimens

Nickel Alloy A-286 specimens is selected as the test sample and have a diameter 25 mm of and length 12 mm with hole diameter of 6, 8 and 10 mm. The specimens were initially drilled using carbide drill bits and thoroughly washed with the acetone to remove the clogged and dust particles. The fig 2 shows the test specimens.

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Fig 2: Test Specimens

F. *Preparation of Abrasive Media*

Abrasive media is prepared by thoroughly mixing Silicone carbide abrasives with silicone polymer using abrasive mixture. The volume fraction of Silicone carbide abrasives with silicone polymer used is 35% and 36 size of abrasive. The fig 3 (a), (b), (c) shows the silicone media mixer, silicon Rubber and silicon polymer with abrasive as shown.

Fig 3(a): Silicon media mixer Figure 3 (b) Silicon Rubber Figure 3 (c): Silicon polymer with abrasive

G. *Experimental Trails*

When the machine is initially started, due to the hydraulic pressure the ram will push the silicon polymer with abrasive at constant pressure of 60bar through or across the specimen which is fixed at the end cap of the machine. The honed surface of the sample or specimen is then measured in the Surfcom 130A and surface parameters are noted down at the two position i.e. entry side and exit side. This trail is repeated for the 10 passes and the below fig 4 as shows the silicone polymer media is extrude process and Surfcom as shown in Fig 5.

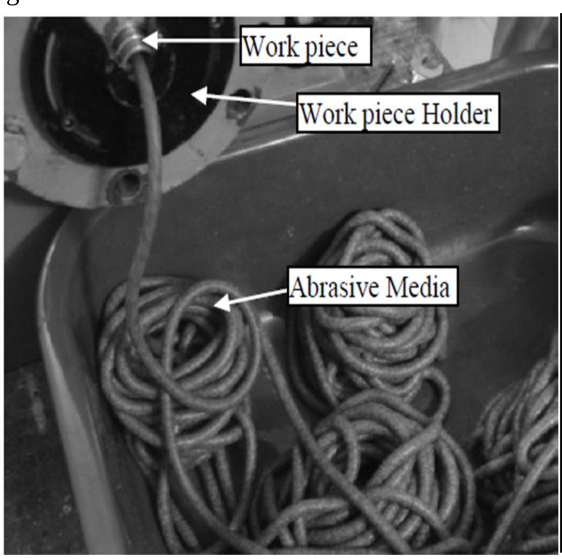

Fig 4: Silicone Polymer media is extrude over the workpiece Fig 5: Surfcom 130A

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IV. RESULTS AND DISCUSSION

A. Surface Roughness

Typical observed parametric influence of surface characteristics of extrusion honed nickel alloy-286 drilled specimen is illustrated in Fig 6 to 11. Extrusion honing is mainly used as surface finishing operation. The main aim of this work is to investigate the influence of extrusion honing process parameters on surface finish. Following plots show the variation of surface roughness parameters and material removed for nickel alloy. Here Ra, Rz, Rt, Rpk have been used as the surface roughness parameters and are measured at 2 locations (entry side and exit side) of the specimen. In this process mainly 35% of abrasive concentration of media and abrasive of 36 mesh size is used.

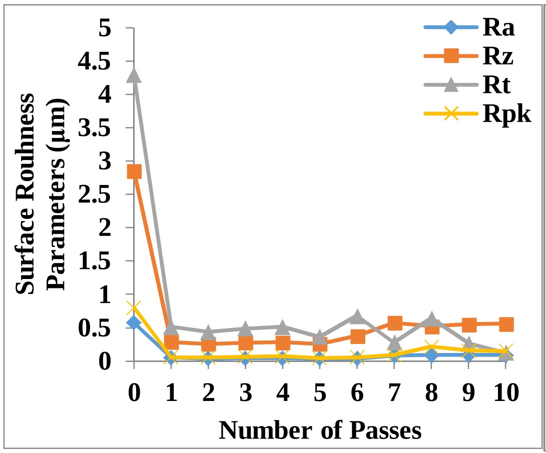

Fig 6: Entry point at 6mm Diameter

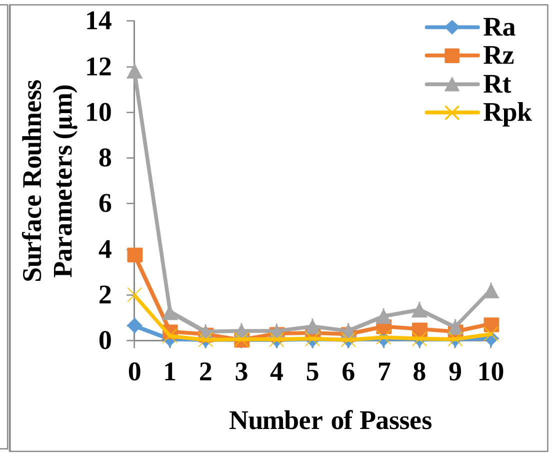

Fig 7: Exit point at 6mm Diameter

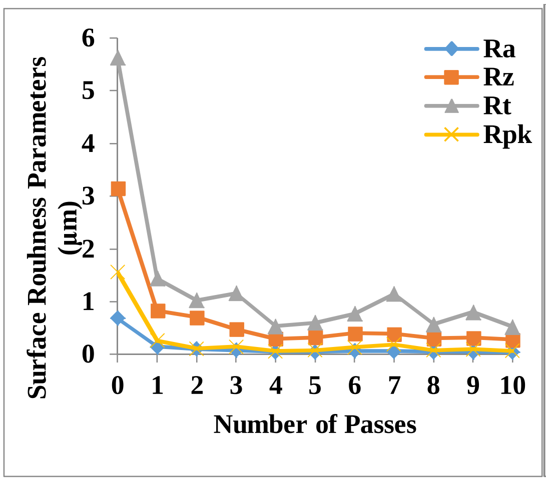

Fig 8: Entry Point 8mm Diameter

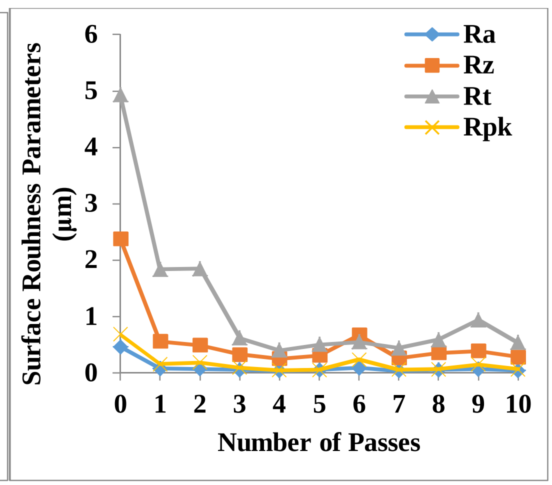

Fig 9: Exit Point 8mm Diameter

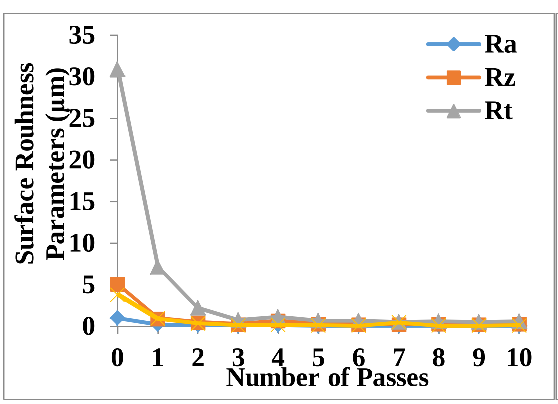

Fig 10: Entry Point 10mm Diameter

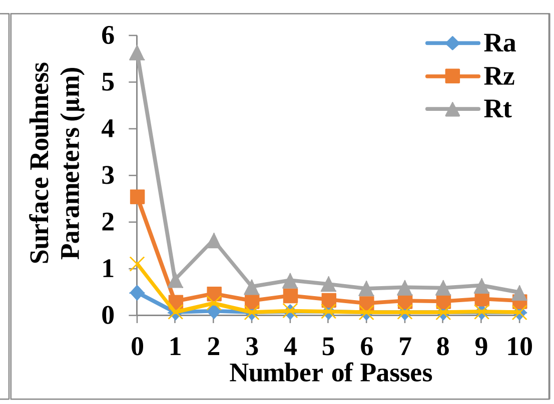

Fig 11: Exit Point 10mm Diameter

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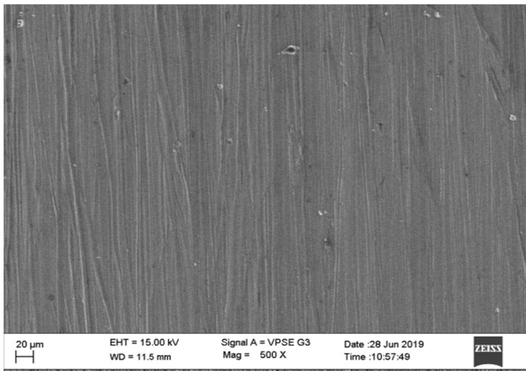
Effect of Number of Passes on Surface Roughness Parameter for 6, 8, 10 mm hole on first Point at Entry Side and Exit side

In all above graphs indicates that Zero pass shows the initial surface roughness before extrusion honing. It can be seen from the figure that there is a drastic change in surface roughness parameters in the first pass. As the number of passes increase there is a gradual improvement in the surface roughness. later there is rise in surface roughness parameters in 3rd or some passes. Further as the number of passes increases their surface roughness parameter improves. Later surface roughness improves till 10th pass. Further 10th passes surface roughness starts deteriorating.

B. Scanning Electron Microscope

SEM images are taken to observe the images of drilled hole and extruded hole of nickel alloy 286 specimen. The images 500 magnification are shown in below.



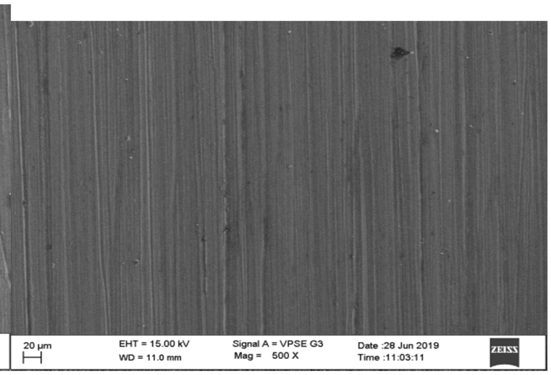
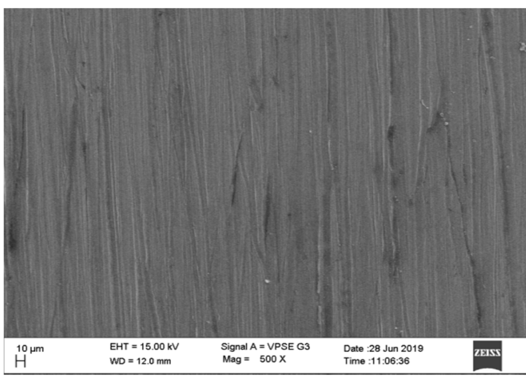


Fig 12: SEM image for 6mm dia hole at Entry Side Fig 13: SEM image for 6mm dia hole at Exit Side



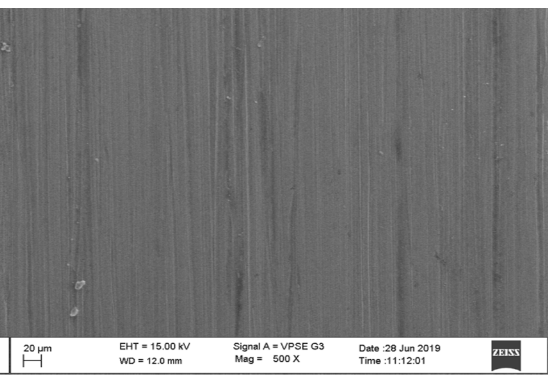
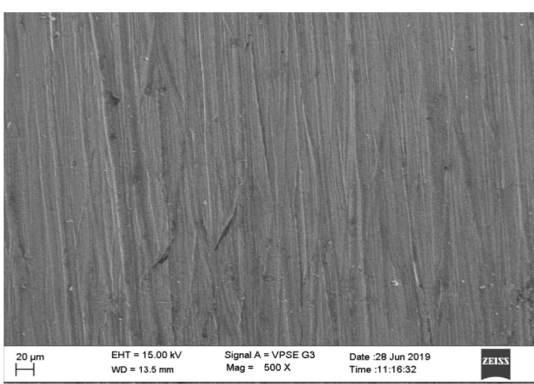


Fig 14: SEM image for 8mm dia hole at Entry Side Fig 15: SEM image for 8mm dia hole at Exit Side



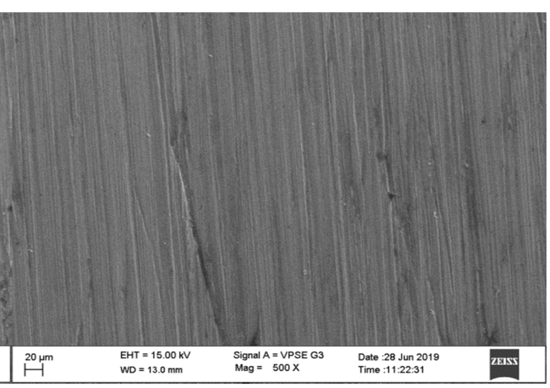


Fig 16: SEM image for 10mm dia hole at Entry Side Fig 17: SEM image for 10mm dia hole at Exit Side

The SEM image is taken for hole diameter 6mm, 8mm and 10mm for 10 passes of the entry and Exit side of test specimen lay pattern as shown in Fig 12 to 17 as shown.

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V. CONCLUSIONS

A. The select grade (40) polymeric medium can be used as abrasive carrier medium for extrude honing.
B. The extrude honing process in the lower pressure range yields reasonably good results in finishing nickel alloy 286.
C. Surface finish at the exit side is better than the entry side which shows better contact of the abrasive particles in the media at the exit.
D. At the entry and exit side of the specimen drastic reduction in surface roughness occurs by at early stage by 2nd pass indicating macro-irregularity correction. After that there will be steady improvement in surface finish up to 10^{th} pass, signifying micro-irregularity correction indicating honing process beyond which the surface deteriorating.
E. Surface in the middle zone is better than the entry/exit zone due to better contact with the abrasive medium.

VI. ACKNOWLEDGEMENT

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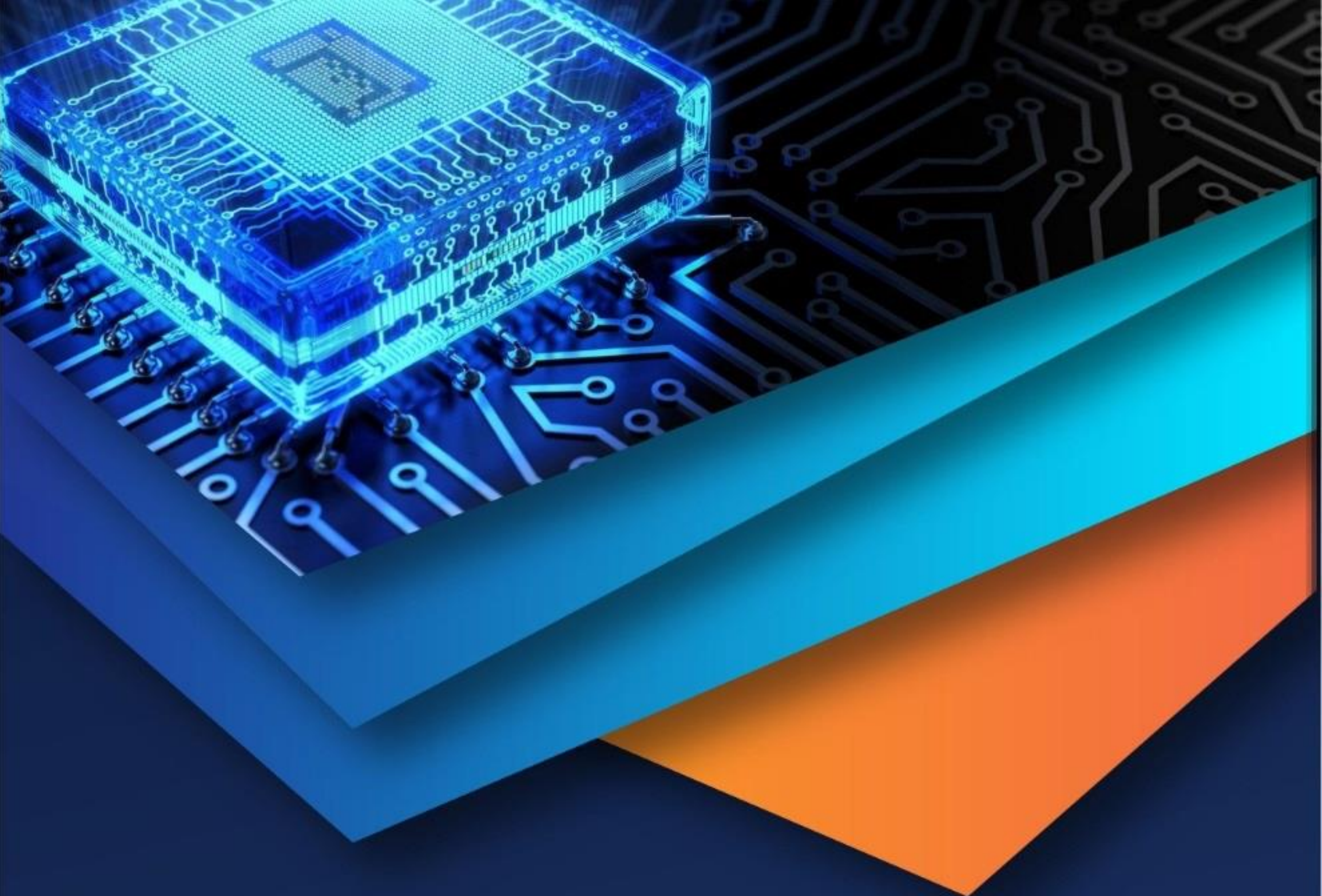

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