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Review on Non Traditional Machining of Metal Matrix Composites

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Abstract*: Material Science is an everlasting field in engineering world. There is a scope for researchers and scientists to carryout investigation until a last metal is available in the earth. Due to globalisation and technological development there is a necessity to find new combination of materials for specified applications in various fields ranging from Nano scale level to large aerospace industries. A single crystal material cannot be used for all range of applications because of its rigid property and behaviour. This equips the researchers to introduce composite materials instead of isotropic materials. Metal Matrix Composites having special attention among other composites due to flexibility of altering properties which is better substitution for monolithic materials like steel. Since MMCs having hard abrasive particles it is not easy to machine by conventional machining process. The only way to machine MMCs with less or without tool wear, less power consumption is non-traditional machining process. The present review paper focus on the machining of MMCs through non- conventional machining process like EDM, EDD and ECM. Also this paper covers the effect of input process parameters on output responses like Metal Removal Rate (MRR), Tool Wear rate (TWR) and Surface Character. Many authors were used different statistical tools to optimize the process parameters.
Keywords*: Metal Matrix Composites, Non-traditional Machining, EDM, EDD, ECM

I. INTRODUCTION

Day by day the researchers are proposing a lot of new metals for different applications with unique properties. It is not an ease of work to alter the properties and behaviour of monolithic metals. But it is possible in case of Metal Matrix Composites. Hence MMCs attracts the researches and industries to concentrate on it. So it is strongly believed that composites are better alter for monolithic metals [1]. In order to get better surface finish and dimensional accuracy it has to be machined. Due to the presence of hard reinforcements in the composites and extensive tool wear, it is very difficult to machine through conventional process [2]. To overcome this drawback the industries are preferring for non-traditional machining process. Tool wear and power consumption for machining is predominantly depends on reinforcement particle size and volume fraction [3]. Many researchers are showing their interest on Electrical Discharge Machining (EDM), ECM among the other non- traditional processes. EDM works based on the erosion principle. Repeated spark is produced on workpiece to melt locally [4]. To increase the Metal Removal Rate (MRR) and better surface finish, electrically conductive particles are mixed with dielectric fluid [5].

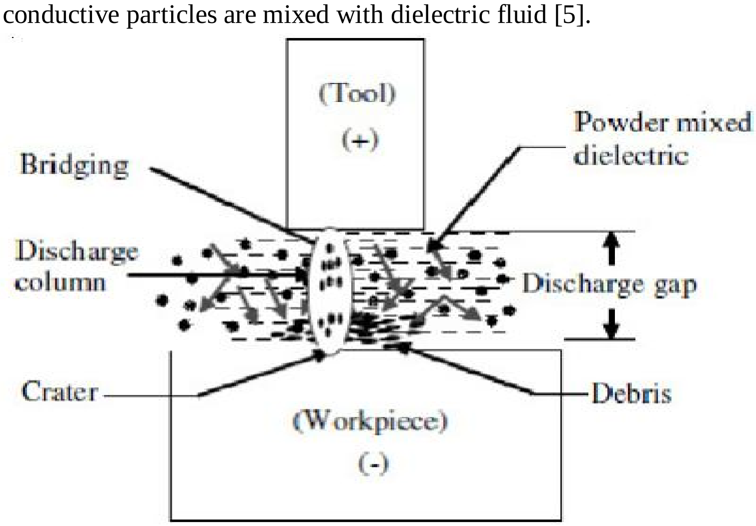

Fig.1.Electrical Discharge Machining (EDM)

Electrochemical machining (ECM) process works based on electrolysis principle. It is a reverse of electroplating process. In ECM process, tool is connected with negative terminal and specimen is connected to the positive electrode for machining.

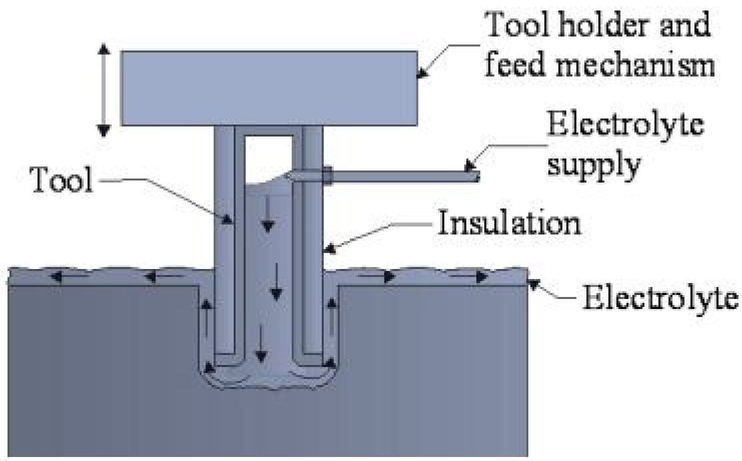

Fig.2.Electricochemical Machining (EMC)

In this process, metal ions moves from the workpiece (anode) to tool (cathode). Electrolyte fluid brings away the machined material.

II. LITERATURE REVIEW

Chethan Roy et.al [6] investigated the machinability of AMCs using Al powder mixed Electrical Discharge Machining. Al 6061 has taken as matrix material and reinforced with SiC, titanium diboride. 34 mm diameter specimen was made through stir casting process and machined in to 10 mm thickness circular plates using wire cut EDM. 10 mm diameter and 120 mm length Electrolytic copper electrode is used as tool. One end of the tool is drilled through its center, having 6 mm diameter and 110 mm length. Other end of the tool is having three drilled holes of 2 mm diameter and 10 mm length at 120° apart.

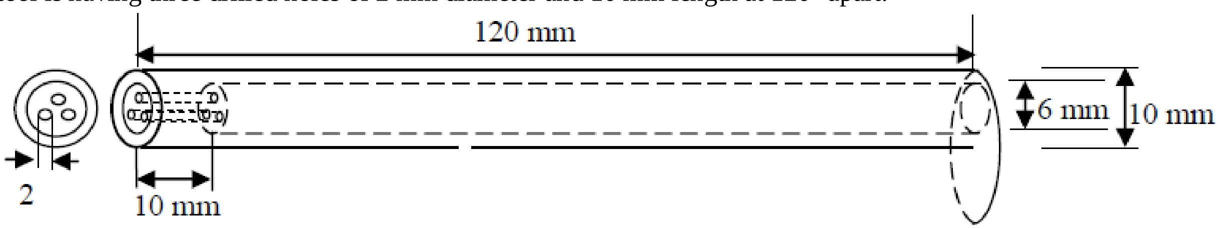

Fig.3. Electrolytic copper tool [1]

Kerosene is used as a dielectric medium, it is mixed and recirculated with Al powder throughout the machining process. The workpiece and tool is fully submerged in the dielectric fluid during machining. After the experiment, the effect of input parameters viz. Al powder concentration in kerosene, peak current and pulse on current on MRR, surface roughness and TWR were studied. Optimum process parameters are identified for maximum MRR, minimum TWR and surface roughness using MINITAB.

Gangadharudu Talla et.al [7] have optimized the powder mixed electric discharge machining of Aluminium metal matrix composites. In this work, aluminium and alumina powder has taken and were milled in energy ball mill. During milling process Liquid toluene was used to control the process. The specimen samples are fabricated through conventional compacting process at a pressure of 250 MPa. Acetone is added to serve lubrication in order to prevent clustering of particles. The compacted specimens are sintered in an argon atmosphere at 500 ° C and then cooled to room temperature for one day. The sintered specimen is heated to 400 °C and quenched in chill water. Again the quenched specimen is heated to 200°C and cooled in muffle furnace for 8 hours. In EDM process, 12 mm copper electrode is used to machine the specimen. Al powder is used as a dielectric and it is suspended in kerosene. Experiments were carried out based on Taguchi L18 orthogonal array. The effect of duty cycle, powder concentration, peak current, and pulse on time were studied on the response of MRR and surface roughness. Multi objective optimization technique is used to find optimal process parameters.

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Nilesh G. Patila, P.K. Brahmankar [8] have tried semi empirical for surface character in wire EDM for machining AMCs reinforced with ceramic. Aim of this study is to develop semi empirical model for surface finish based on the effects of constituents. Buckingham's π theorem was used to gather all the variables involving in the problems as a dimensionless parameter.
Based on Buckingham's π theorem, surface roughness was expressed in terms of dimensionless parameter

$$Ra = f(Ip, Ps, Tm, Lf, \sigma, K, Cp, \rho, \varepsilon, Vf) \quad (1)$$

(2)

Eq (2) represents the final form of semi empirical model. \
Experiments were conducted using Robofil 290 WEDM machine. Five specimens are taken to machine at same input parameter settings. In each set, three trials were performed by varying peak current. Apart from this, separate experiments were conducted on five specimens to build semi empirical models based on RSM. Table.1 shows the levels and input parameter ranges for RSM experiments.

Table.1. Levels and input parameters range for RSM

Parameters	Levels				
	-2	-1	0	+1	+2
Peak Current, A	80	160	240	320	400
Off-Time, µs	10	12	14	16	18

$$R_a = B \times \sqrt{\frac{\alpha^2 \varepsilon}{C_p}} \times \left(\sqrt{\frac{I_p^2 C_p}{\alpha^2 \alpha K}} \right)^{b1} \left(V_f \sqrt{\frac{P_s^2 C_p}{\alpha^2 \varepsilon}} \right)^{b2} (T_m \varepsilon)^{b3} \left(\frac{L_f \varepsilon}{C_p} \right)^{b4}$$

Mitutoyo surface roughness tester was used to measure surface roughness. From the experiment results, the power indices of semi empirical model was determined. Finally the author proposed that the surface finish is depends on coefficient of thermal expansion, thermal diffusivity, melting temperature, heat of fusion and size of reinforcements. Surface roughness decreases with increasing the volume fraction of SiC and increases with increasing volume fraction of alumina.
Rajkumar et.al [9] have identified the effect of EDM parameters on microwave heat treated AMCs. Al 6061 is reinforced with Boron Carbide (15 vol %) and graphite (5 vol %). Specimens are fabricated in stir casting process. Specimens are undergone conventional and microwave furnace heat treatment. In conventional, the heat treatment was done in muffle furnace at 520°C for 9 hours. In microwave heat treatment process, the specimens was heated in 850W microwave furnace at 520°C for 3 hours. Both heat treated specimens are machined in EDM and its machinability was compared. The machining input parameters like current density, pulse off time and pulse on time are optimized using Taguchi method against the response parameters such as TWR and MRR.

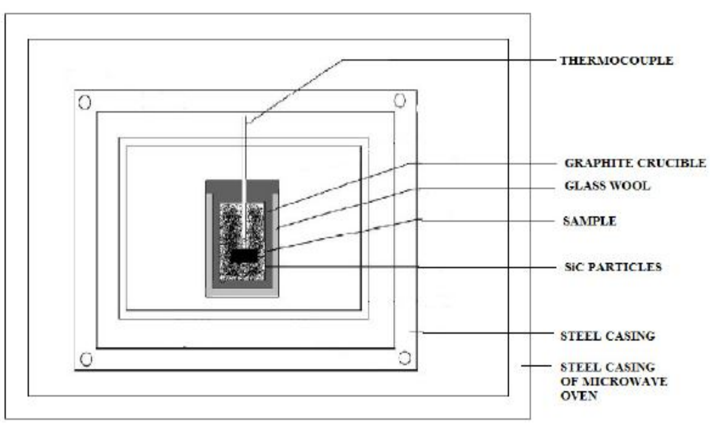

Fig.4.Microwave furnace

Hardness testing was carried out in Rockwell hardness tester and impact test was conducted in Izod impact tester. In EDM, the specimens are act as cathode and 14.7 mm diameter copper electrode act as anode. MRR was achieved by spark produced between anode and cathode. From the experimental results MRR increases with increase in current and pulse on time. At the same time MRR decreases with increase in pulse off time. It is concluded that microwave heat treatment is an effective way compared with conventional. Current and pulse on time mainly prominent parameters which affects the machining process. Nilesh Patil et.al [10] have studied the influence of reinforcement volume fraction and wire electrode material for machining of Al/SiC MMCs in WEDM. CuZn50 coated copper and brass were chosen as an electrodes. Experiments are conducted based on full factorial DoE shown in table 2.

Table.2. Process Parameters and Levels

Process Parameters	Level (-1)	Level (+1)
Pulse on-time	0.4 µs	1 µs
Pulse off-time	12 µs	16 µs
Servo Voltage	40	50
Wire type	Brass	Coated Copper
Reinforcement volume fraction	10%	30%

From the experiments MRR, surface finish and kerf width are observed as responses and the result revealed that the electrode type, volume fraction of reinforcement and pulse on- time greatly affects the response parameters. The cutting rate was improved by 58% while using coated copper electrode due to Zinc coat than plain brass electrode. It is also revealed that the Cutting Rate was decreased with increasing SiC volume fraction. But surface characters are improved with increasing SiC content. Kerf with was reduced in the case of coated electrode. Abhishek Singh et.al [11] have done their work on machining of MMCs in Electro-Discharge Drilling and EDM. MMCs consists of Al 6063 and 10% SiC and fabricated in stir and squeeze casting method. Finally the process parameters are optimized. EDD machining was performed on Z-axis NC EDD setup. 6 mm thick composite specimen has taken to machine.

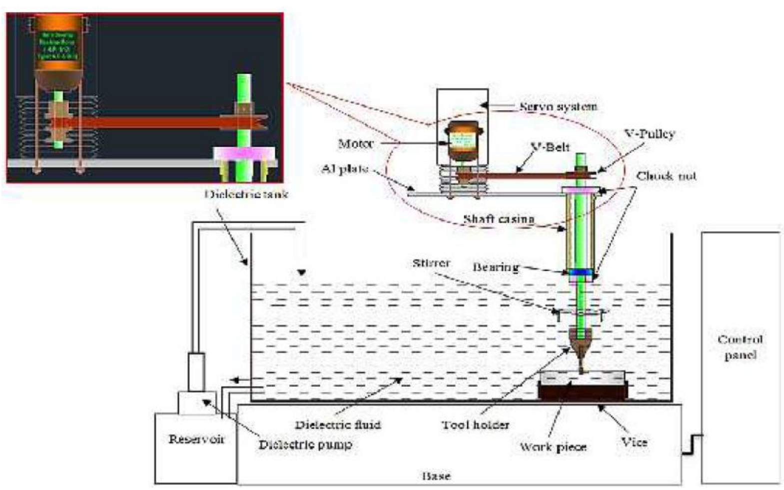

Fig.5. Experimental setup of EDD

Copper tool has chosen as an electrode. During machining, gap voltage, arc off time, polarity and flushing are kept at constant parameters. Discharge current, tool speed and arc on time are taken as controllable parameters. Spark gap of 0.05 mm has maintained throughout the entire process. MRR and TWR are the output variables. Initial trial has been conducted and the range of controllable variables are identified. Design expert v7 software was used to form design matrix. Box- Behnken design method is applied to make regression equations. ANOVA test has been conducted on all the machining parameters.

$$MRR= 69.46198+3.52531*A+0.49244*B+0.19676*C+0.013313*A*B+2.08371e\text{-}3*A*C+1.22123e\text{-}4*B*C-0.20081*A2-3.01702e\text{-}3*B2-2.14329e\text{-}4*C^2 \quad (3)$$

$$TWR= -3.21353+0.24611*A+0.020244*B+8.21244e\text{-}3*C-5.225e\text{-}4*A*B-1.09104e\text{-}4*B*C-3.90000e\text{-}6*A*C-7.06181e\text{-}4*A^2-9.48882e\text{-}5*B^2-7.34056e\text{-}6*C2 \quad (4)$$

Eq. 3 and 4 represents the final mathematical model for MRR and TWR. Variables A,B and C denotes discharge current, arc on time and tool speed respectively. The effect of input parameters on the responses of MRR and TWR was observed. Lastly it is concluded that, MRR is high in EDD compared to EDM but TWR is more in EDD. Discharge current plays a vital role on both MRR and TWR. Increasing Arc on time results decreasing output responses.

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Damian przestacki et.al [12] carried research work on machining of composites using laser technique. Work focuses on improving the machinability of composite compared with conventional turning process. An investigation was done on cutting force, tool wear and surface roughness. In conventional turning, Cubic Boron Nitride and sintered carbide inserts were used as cutting tool. AlSi9Mg and aluminium matrix composite has been selected for study.

Fig.6. Laser Assisted Machining Setup

CO_2 laser was used to produce heat on workpiece. Both the cases of machining process has been carried out using different inserts. Laser beam increases the workpiece temperature locally and it leads to reduce tool wear. It results improved machinability and tool life as well as lowers the cutting time.

Matthias Hackert-Oschätzchena et.al [13] analysed the influence of Pulsed Electro Chemical Machining on surface characteristics of AMCs machining process. EN AW 2017 reinforced with 10% SiC particles is taken as workpiece. In ECM process the electrolyte is flushed in the gap between electrodes. Owing to exchange of electric charge the work piece id dissolved in the electrolyte in the form of ions.

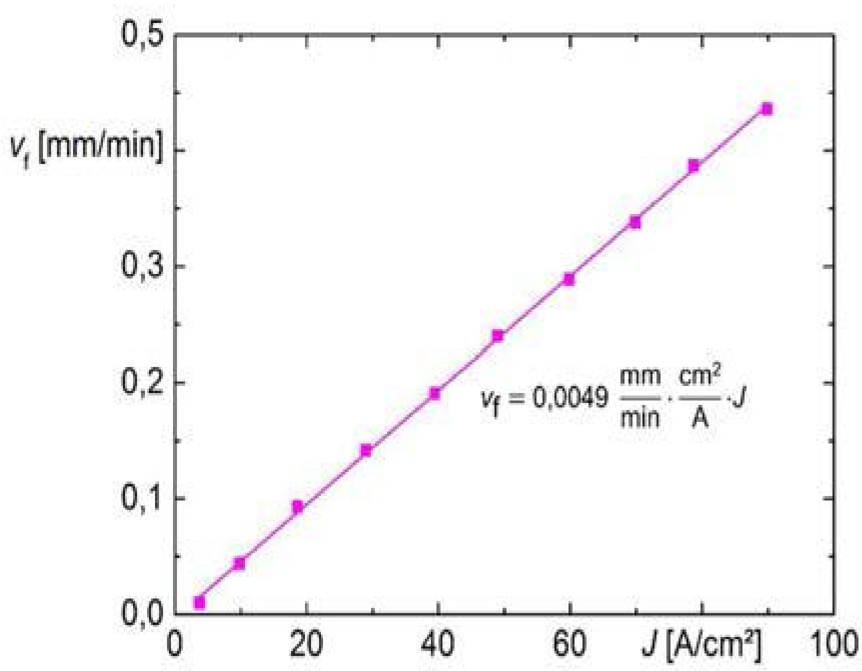

Fig.7. Feed Velocity (V_f) Vs Current Density (J)

Fig.5. shows the relationship between feed velocity and current density. Both parameters varies linearly. The surface characteristics of machined specimens are analysed by using SEM.

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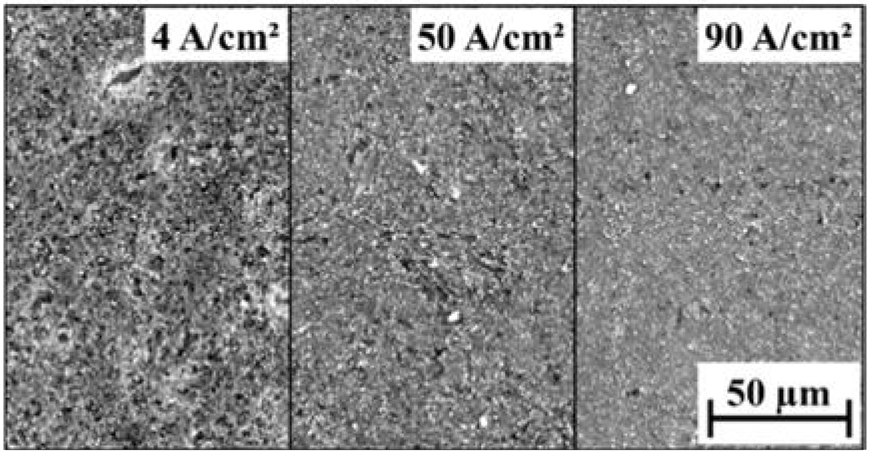

Fig.8. SEM images of AMCs different current densities

Fig.6. shows the SEM images of machined specimens to explore its surface texture and it can be visualised that the surface becomes smoother with increasing current density. Within the experimental range, the current efficiency is 110%.

III.CONCLUSIONS

From the literature review it is clear that non- traditional machining process is best opt to machine composite materials instead of conventional machining. Many authors concluded that, volume fraction of reinforcement, peak current and pulse on current are greatly affects the MRR, surface roughness and TWR. MRR increases with increase in current and pulse on time and decreasing with increasing pulse off time.

IV. FUTURE SCOPE

Most of the researchers were tried their work in only EDM and ECM. There is lot of scope to machine composite materials in other non-traditional machining process.

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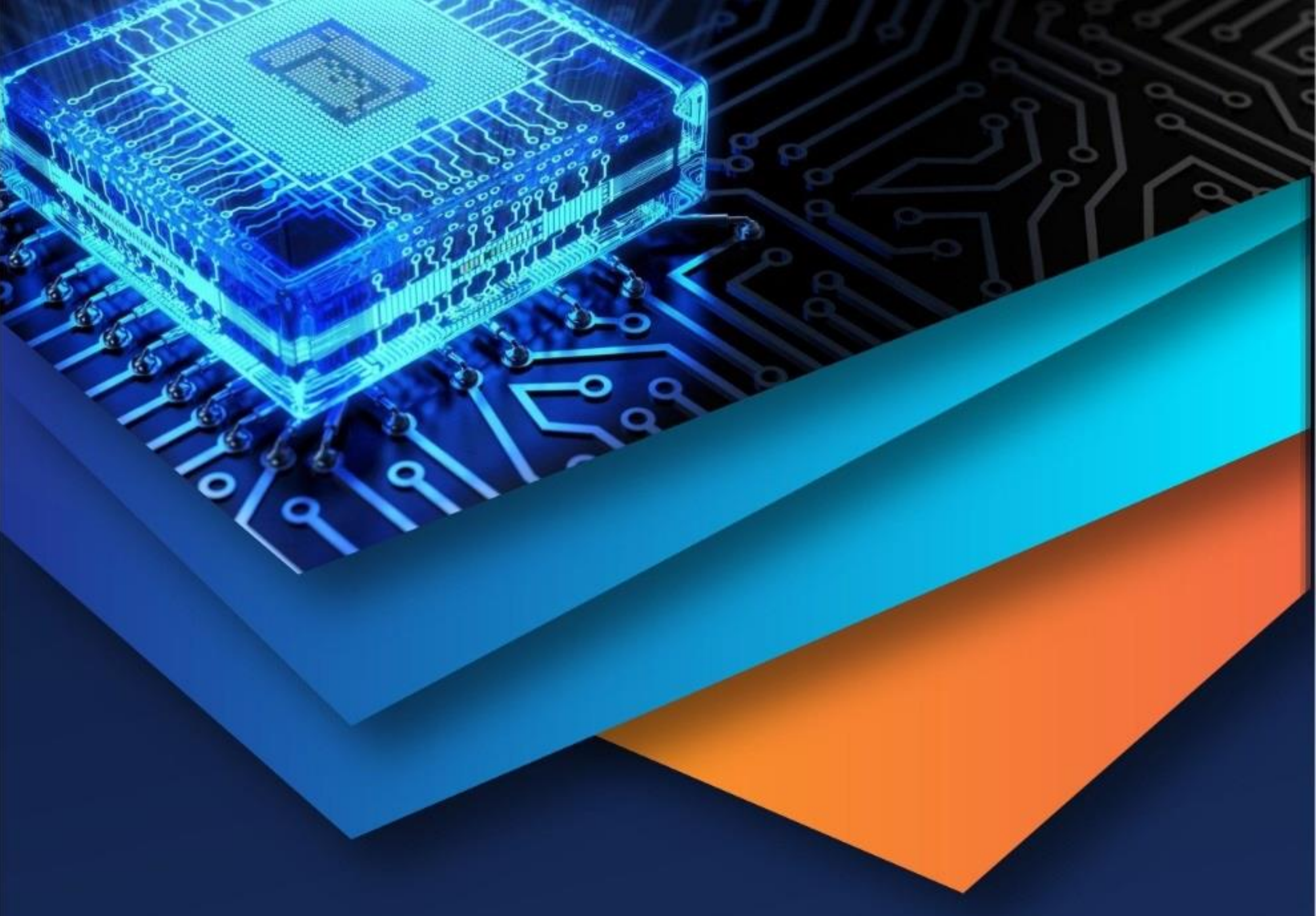

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