iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 Issue: IX Month of publication: September 2020

DOI: https://doi.org/10.22214/ijraset.2020.31342

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue IX Sep 2020- Available at www.ijraset.com

Investigation of MRR, TWR and Radial Overcut at Varying Depth of Machining during Die Sinking EDM

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***Abstract:** The present experimental investigation is conducted on EDM is performed on AISI 4140 or EN-19 as workpiece with copper as electrode (tool) to establish the relationship between process parameters of EDM on material removal rate, tool wear rate and radial overcut. Depth of machining is also considered as a process parameter in this investigation. The investigation concluded that material removal rate, tool wear rate and radial overcut were majorly influenced by the peak current and depth of machining. Pulse on time was found to be the least dominating parameter for all the performance measures.*
***Keywords**: EDM, SEM, Radial Overcut, MRR, TWR*

I. INTRODUCTION

Electrical Discharge Machining is a controlled material removing method utilized to machine metal through spark erosion. The process uses an electric spark through the electrode as the cutting tool for machining the workpiece in order to produce the finished product of required size and shape. The material removal method is done in dielectric medium in order to enhance the efficiency of the technique and applies a pulsating electrical charge of high-frequency current through the electrode over the workpiece. This eliminates a very tiny layer of metal from the work in controlled manner. EDM spark erosion is similar to have an electrical short which burns a hole in a piece of material it is in contacts. In the EDM process, both the work material and the electrode material must be electrically conductive.

A study conducted was by Subramanian Gopalakannan and Thiagarajan Senthilvelan [1] to find the effect of pulsed current on material removal rate, electrode wear, surface roughness and diameteral overcut in corrosion resistant stainless steels viz., 316 L and 17-4 PH. The materials used for the work were machined with different electrode materials such as copper, copper-tungsten and graphite. It is observed that the output parameters such as material removal rate, electrode wear and surface roughness of EDM increase with increase in pulsed current. The results reveal that high material removal rate have been achieved with copper electrode whereas copper-tungsten yielded lower electrode wear, smooth surface finish and good dimensional accuracy.

The study of Pravin R. Kubade and V. S. Jadhav [2] investigated the influence of EDM parameters on EWR, MRR and ROC while machining of AISI D3 material with a copper electrode. The parameters considered were pulse-on time (Ton), peak current (Ip), duty factor (t) and gap voltage (Vg). It is found that the MRR is mainly influenced by peak current where as other factors have very less effect on material removal rate. Electrode wear rate is mainly influenced by peak current and pulse on time, duty cycle and gap voltage has very less effect on electrode wear rate. Peak current has the most influence on radial overcut then followed by duty cycle and pulse on time with almost very less influence by gap voltage.

To study the influence of process parameters and electrode shape configuration on the machining characteristics such as surface quality, material removal rate and electrode wear Shishir Mohan Shrivastava and A.K. Sarathe [3] conducted experiments and found better machining performance was obtained generally with the electrode as the cathode and the work-piece as an anode and it was observe that for high MRR main process parameters are peak current, pulse on time ,pulse off time, whereas for electrode wear were mainly influenced by peak current and pulse on time. Surface quality was mainly influenced by peak current. As far as tool shape configuration concerned best tool shape for higher MRR and lower TWR is circular, followed by square, triangular, rectangular, and diamond cross sections. In a research, Abhishek Gaikwad, Amit Tiwari, Amit Kumar and Dhananjay Singh [4] studied the effect of control factors (i.e., current, pulse on time, pulse off time, fluid pressure) for maximum material removal rate (MRR) and minimum electrode wear rate (EWR) for EDM of hard material Stainless steel 316 with copper as cutting tool electrode. In this paper both the electrical factors and non electrical factors has been focused which governs MRR and EWR. Paper is based on Design of experiment and optimization of EDM process parameters.

The technique used is Taguchi technique which is a statistical decision making tool helps in minimizing the number of experiments and the error associated with it. The research showed that the Pulse off time, Current has significant effect on material removal rate and electrode wear rate respectively.

In an investigation conducted by Y. H. Guu [5] of surface characteristics of Fe-Mn-Al alloy analyzed by means of the atomic force microscopy (AFM) technique and concluded that the higher discharge energy caused more frequent melting expulsions, leads to deep and large crater formation on surface of work, resulting in a poor surface finish. Another investigation conducted by George et al [6] optimized the machining parameters in the EDM machining of C-C composite using Taguchi method. The process variables affects electrode wear rate and MRR, according to their relative significance, are gap voltage, peak current and pulse on time respectively.

C.H. Cheron [7] machined XW42 tool steel and concluded that material removal rate with Cu electrode is greater than graphite electrode. He also concluded that Cu is suitable for roughing surface while graphite is suitable for finishing surface. A similar study was conducted by Ahmet Hascalık and Ulas¸Caydas [8] using parameters such as pulse current and pulse duration and concluded that electrode material has an obvious effect on the white layer thickness, the material removal rate, surface roughness and electrode wear are increasing with process parameters.

II. EXPERIMENT AND METHODOLOGY

ELECTRONICA ZNC EDM machine was used for machining the samples. The machine was available at Dilawar Engineering Works, Lucknow The machine setup is shown in figure 1. The material used for this work is AISI 4140 or EN-19. The samples for experiment were 8 mm thick and 16 mm in diameter which were prepared by a centre lathe. The tool or electrode material used for this work is 100% Copper. The tool specimen was prepared of dimensions as 1 inches length and 5 mm diameter.

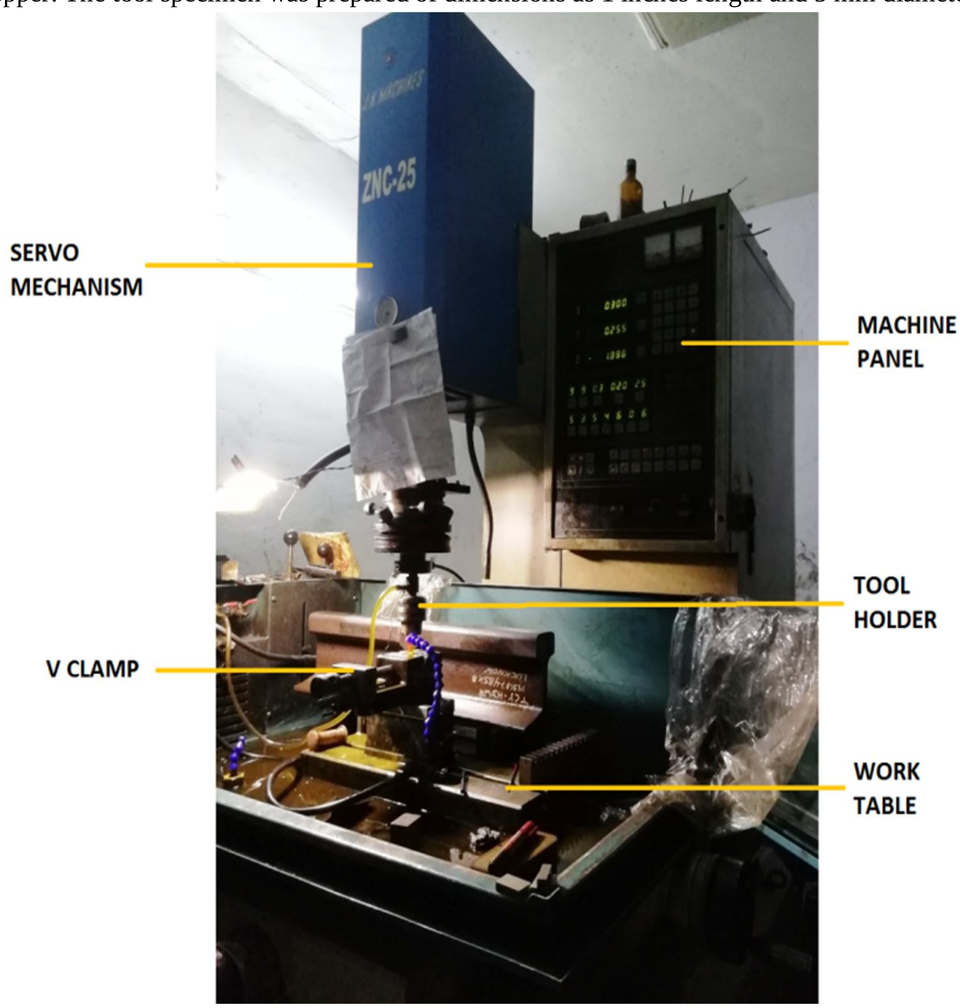

Fig. 1 Setup of EDM for experiments

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue IX Sep 2020- Available at www.ijraset.com

The parameters selected for present research are peak current, pulse on time and depth of machining while the responses selected are MRR, TWR and radial overcut. The experiments were designed on the basis of Taguchi L9 orthogonal array and the experiments were performed accordingly. SEM was conducted in order to assess the radial overcut after machining. The following table 1 shows the set of parameters with corresponding values of MRR, TWR and Radial Overcut.

Table I: Parameter Set For Experiment With Corresponding Values Of Mrr, Twr And Radial Overcut

Exp. No	Ip	Ton	Depth of Machining	MRR (mm^3/min)	TWR (mm^3/min)	Radial Overcut (μm)
1	3	20	0.5	0.559	0.245	0.01
2	3	30	0.8	0.499	0.087	0.02
3	3	40	1.1	0.900	0.296	0.04
4	6	20	0.8	1.429	0.626	0.03
5	6	30	1.1	1.253	0.549	0.05
6	6	40	0.5	0.571	0.500	0.04
7	9	20	1.1	1.039	0.364	0.06
8	9	30	0.5	1.737	0.507	0.02
9	9	40	0.8	2.548	0.372	0.04

III.RESULTS AND DISCUSSION

A. Material Removal Rate

For calculation of MRR, the specimen is weighed before machining and after each run using electronic balance. The weight difference gives the amount of material lost during machining which is noted down as weight loss. During machining of specimen, the machining time is also noted down for each run to calculate MRR.

The following table II shows the ANOVA for MRR. It is elucidated from the table that the major influencing parameter for MRR is peak current with a contribution of 53.88%. It is followed by depth of machining while the least influencing is pulse on time with a contribution of 4.61%.

TABLE II: ANOVA for MRR

Source	DOF	SS	Adj MS	F Value	Contribution
Ip	2	1.9218	0.9609	1.93	53.88%
Ton	2	0.1643	0.0821	0.16	4.61%
Depth of Machining	2	0.4826	0.2413	0.48	13.53%
Error	2	0.9981	0.4991		27.98%
Total	8	3.5668			100%

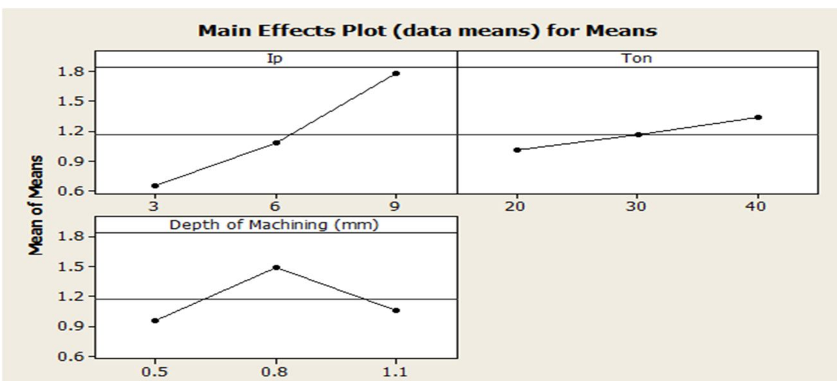

Fig. 2 Main effect plot for MRR

The figure 2 above presents the mean effect plot for MRR. It shows that the MRR increases with both peak current and pulse on time. In addition, peak current has major influence on MRR. It probably occurred because the intensity of spark is more at higher level of parameter and hence MRR increases. A similar influence is seen when pulse on time is increased.

MRR is observed to follow an initial increasing and then decreasing trend with depth of machining and it is the second most influencing parameter for MRR and has only 13.53% contribution.

B. Tool Wear Rate

The following table III shows the ANOVA for TWR. It is elucidated from the table that the major influencing parameter for TWR is peak current with a contribution of 80.49%. The pulse on time and depth of machining are least influencing have negligible dominance on TWR.

Table III: ANOVA for TWR

Source	DOF	SS	Adj MS	F Value	Contribution
Ip	2	0.18456	0.09228	4.83	80.49%
Ton	2	0.00151	0.00075	0.04	0.66%
Depth of Machining	2	0.00501	0.00251	0.13	2.18%
Error	2	0.03821	0.01910		16.67%
Total	8	0.22929			100%

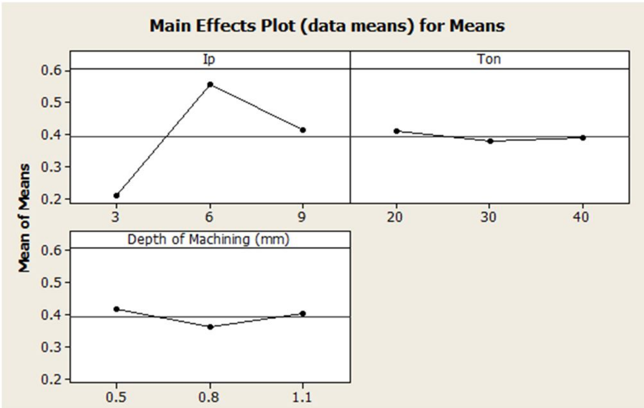

Fig. 3 Main effect plot for TWR

The figure 3 above illustrates that the tool starts to degrade with increase in levels of peak current but when the value of peak current is increased above 6A, the TWR tends to decrease. This is due to the formation of debris in the spark gap causing the ineffectiveness of the spark intensity. Pulse on time and depth of machining has negligible influence on TWR and the graph obtained are almost flat.

C. Radial Overcut

The Radial Overcut in EDM is a defect of machining caused by sparks striking the circumference of the machined hole. These sparks will increase the diameter of the machined hole as compared to diameter of the tool. Radial Overcut was estimated by SEM. Figure 4 shows the SEM image of machined sample 7.

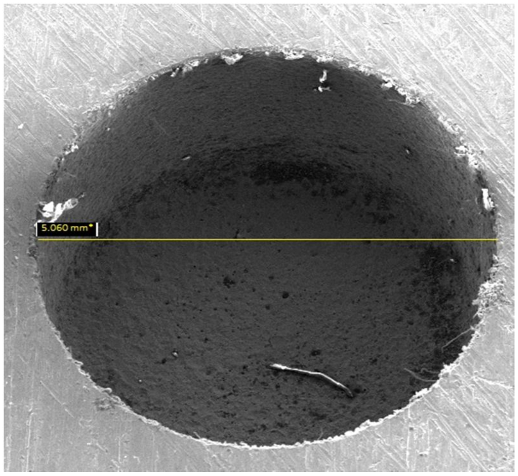

Fig. 4 SEM image of machined sample 7 for WLT

The following table IV shows the ANOVA for Radial Over cut. It is elucidated from the table that the major influencing parameter for ROC is depth of machining followed by peak current. The pulse on time is the least influencing parameter and has negligible influence on radial overcut. Its contribution is 7.69%.

Table IV: ANOVA for WLT

Source	DOF	SS	Adj MS	F Value	Contribution
Peak Current	2	0.0005556	0.0002778	3.57	27.48%
Pulse on Time	2	0.0001556	0.0000778	1.00	7.69%
Depth of Machining	2	0.0011556	0.0005778	7.43	57.14%
Error	2	0.0001556	0.0000778		7.69%
Total	8	0.0020222			100%

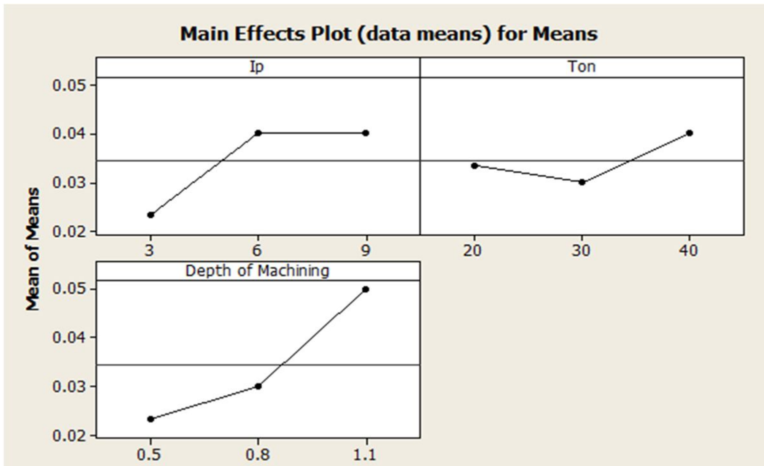

Fig. 5 Main effect plot for Radial Overcut

The above graph shows the effect of input parameters on radial overcut. By increasing the peak current and depth of machining, the radial overcut increases. Depth of machining is the most dominating factor for radial overcut with a contribution of 57.14% and has major influence on it. More number of sparks strike at higher depth of machining, hence influence of depth of machining is highest and radial overcut increases due to more sparks striking the walls of the hole. Peak current is found to be the second most dominating parameter for radial overcut with a contribution of 27.48%. With pulse on time, the radial overcut first decreases. On further increase in pulse on time value, the radial overcut tends to increase. Pulse on time has least influence on radial overcut and has a contribution of only 7.69%.

IV. CONCLUSIONS

The present experimental study describes the optimization of input machining parameters in Electrical Discharge Machining of EN-19 with copper electrode using L9 orthogonal array of Taguchi method. Factors like Current, Pulse on Time and Depth of Machining and their interactions were found. These results show the performance of parameters at different levels to optimize the MRR, TWR and Radial Overcut. Following conclusions are made:

A. Material Removal Rate increases with both peak current and pulse on time. In addition, peak current has major influence on MRR. It probably occurred because the intensity of spark is more at higher level of parameter and hence MRR increases. The result shows that the contribution of current is most and is 53.88%. A similar influence is seen when pulse on time is increased.

B. Material Removal Rate is observed to follow an initial increasing and then decreasing trend with depth of machining and it is the second most influencing parameter for MRR and has only 13.53% contribution.

C. The tool starts to degrade with increase in levels of peak current but when the value of peak current is increased above 6A, the TWR tends to decrease. This is due to the formation of debris in the spark gap causing the ineffectiveness of the spark intensity. Pulse on time and depth of machining has negligible influence on TWR and the graph obtained are almost flat.

D. The results also elucidates that peak current is the most crucial factor for TWR has contributes 80.49% towards TWR. It is also seen that pulse on time is the least influencing parameter and has negligible contribution towards TWR.

E. By increasing the peak current and depth of machining, the radial overcut increases. Depth of machining is the most dominating factor for radial overcut with a contribution of 57.14% and has major influence on it. More number of sparks strike at higher depth of machining, hence influence of depth of machining is highest and radial overcut increases due to more sparks striking the walls of the hole.

F. Peak current is found to be the second most dominating parameter for radial overcut with a contribution of 27.48%. With pulse on time, the radial overcut first decreases. On further increase in pulse on time value, the radial overcut tends to increase. Pulse on time has least influence on radial overcut and has a contribution of only 7.69%.

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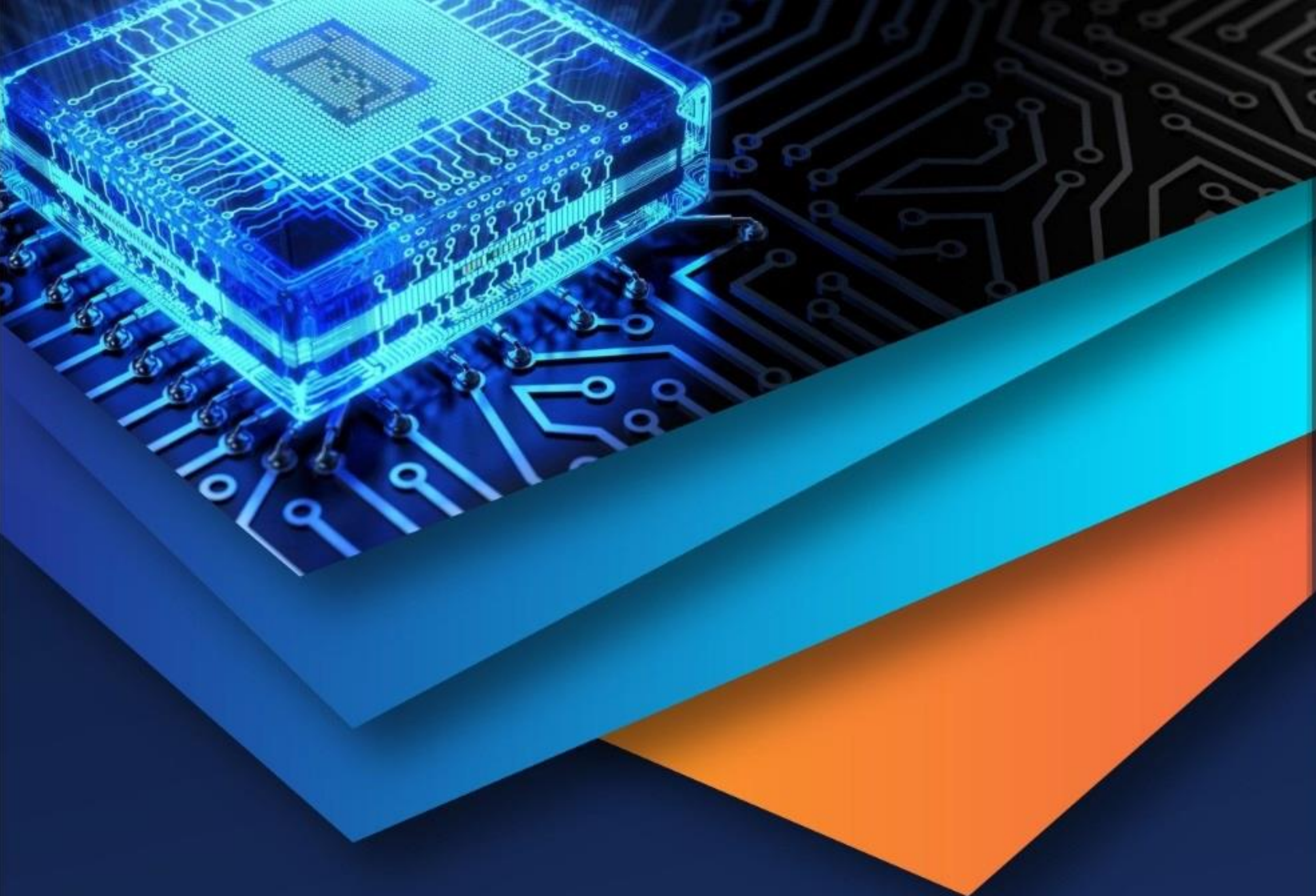

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