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Optimization of Machining Parameters for High-Speed Steel in End Milling Process via Taguchi Approach

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Abstract: This paper presents on optimizing the end milling process parameters based on the Taguchi method to minimize surface roughness and increase material removal rate for the work piece of Al-6063 alloy with high speed steel. The input parameters are speed (rpm), feed rate (mm/min) and depth of cut (mm). S/N ratio is calculated by using Taguchi method under the L_{18} orthogonal array (OA). This S/N ratio is analysed by using analysis of variance (ANOVA), and also find out the effects of control factor with help of analysis of variance. Finally, confirmation tests were carried out, And Results shown that, Taguchi design is the significant method to optimizing the end milling parameter's and improve 27% of surface roughness and increase 30% of material removal rate.
Keywords: ANOVA, End Milling, Material removal rate, Surface roughness, Taguchi Method.

I. INTRODUCTION

Milling is one of the basic machining processes which is widely used in the manufacturing industries like Architectural, Window frames, Shop fittings, cycle industries, etc. because it is capable of producing, variety of products with complex geometries. It has generally good mechanical properties and is heat treatable and weld able in al-6063 aluminium alloy. Surface roughness is an important measure of the technological quality of a product and a factor that greatly influences manufacturing cost. [9] To finding out the optimal value of surface roughness and material removal rate by using Taguchi method. [7] Used Taguchi and Response Surface Methodologies for minimizing the surface roughness in Turning. Taguchi's parameter design approach has been used to accomplish this objective. Furthermore, a statistical analysis (ANOVA) is performed to see which process parameters are statistically significant.[5] the impact of surface roughness was observed by Feed, Speed and Depth of Cut, there was strong interactions among different end milling parameters.[6] to solve the stated within minimum number of trials as compared with a full factorial design suitable for tag chi. [4.10]After that find out the Signal to Noise ratios (S/N) and then analyse the effect of the control parameters in the milling operation. In order to minimize the number of trial experimental, which is used for the Taguchi experimental design approach, a powerful tool for designing high quality system, was developed by Taguchi. The mean response for each run in the inner array, with help of tag chi method. Totally based on statistical design of experiments through the solving and product/process design optimization [1]. It's very easily analysis ANOVA method which is used for Pareto principles. It is a quick and easy method to analyse results of parameter design. [3] It does not require an ANOVA table and therefore does not use *F*-tests. Analysis of variance (ANOVA) is used to identify, which is most significant in this process parameters of end milling machine.

II. METHODOLOGY

A. Experimental set up

The experiments were conducted on a HASS CNC vertical Milling machining Centre as shown in Figure 2.1(a). The work piece is placed at the centre of the Machine and held using machine vice.1 GB program memory, 15" colour LCD monitor, USB port, memory lock key switch, rigid tapping and 95-gallon (360 litter) flood coolant system. The cutting tool high speed steel having four flute 12 mm diameter 75 mm shank length of the End mill cutter has been used for experiments. The dimensions of the work piece specimen were taken as 50 mm × 50 mm and 16 mm. As per experimental design were conducted L_{18} OA, Fig 1 Show that Experimental setup for end milling machining process. Initially dry machining parameters considered as Speed, Feed, and Depth of Cut. The investigations were carried out on the CNC vertical milling machine, with driving power of 14 kW and maximum speed is 4000 rpm obtain. All the investigations were without the application of coolant and lubricating agents. The trial were taken for the range of 1000 rpm to 2000 rpm, Feed rate 75 to 165 mm/min, Depth of cut 0.2 to 1.0 mm. gave minimum surface roughness with some variation. The initial machining parameter was used to operators for machining Aluminium AI-6063 alloy were as follows: speed 1250 rpm, feed 75 mm/min, and depth of cut 0.2 mm.

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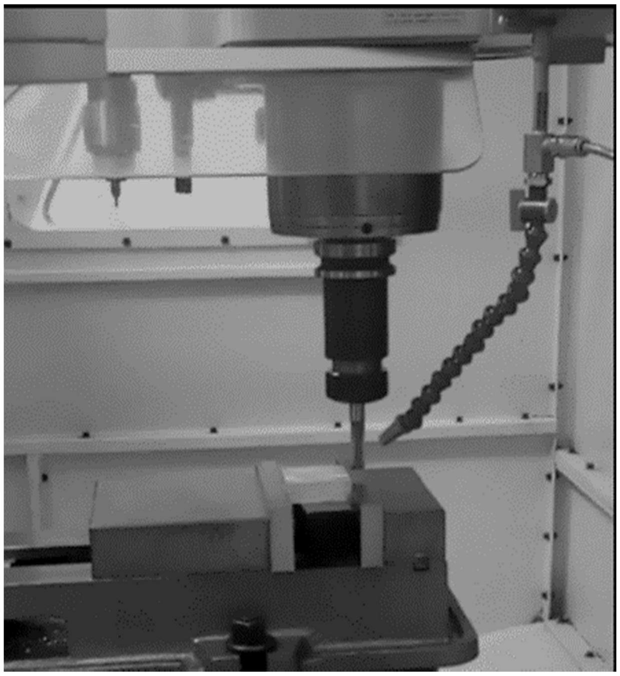

Fig 1 Experimental set up for end milling process

Fig 2 Surface Roughness Tester mitutoyo

Table1 End Milling Machining Parameters and levels

Symbol	Parameters	Level-1	Level-2	Level-3
A	Speed (rpm)	1250	1705	2160
B	Feed (mm/min)	75	115	165
C	Depth of cut(mm)	0.2	0.6	1.0

B. *Selection Of Material*

In recent trend, most of the application using the aluminium 6063 alloy because of less weight ration and also good mechanical properties. This material is heated in Lower temperature it will melted and easily to manufacturing and time consumption is very less obtain. The work piece of Al-6063 alloy dimension is 50 mm × 50 mm and 16 mm. chemical composition are show in table 2.

Table 2 Chemical composition

Mn %	Cu %	Mg %	Zi %	Cr %	Si %	Fe %	Others	Al %
0.10	0.10	0.45	0.10	0.10	0.2	0.35	0.15	Balance

Material removal rate (MRR) was calculated by using given equation

$$MRR = \frac{w(i) - w(f)}{\rho * t} mm^3 / sec \qquad 1$$

Where,

W (i) = Initial weight of work piece in gm,
W (f) = Final weight of work piece in gm,
t = Machining time in seconds
ρ = density of AL (2.7×10-3 gm/mm^3)

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Table 3 Measured Ra and MRR

S no	Speed (rpm)	Feed (mm/min)	Depth of cut (mm)	Ra (µm)	MRR (mm3/min)
1	1200	75	0.2	0.418	160.36
2	1200	115	0.6	0.383	320.8
3	1200	165	1	0.395	383.13
4	1600	75	0.2	0.22	290.4
5	1600	115	0.6	0.442	412.56
6	1600	165	1	0.513	428.4
7	2000	75	0.6	0.612	366.32
8	2000	115	1	0.214	541.233
9	2000	165	0.2	0.527	782.494
10	1200	75	1	0.873	414.106
11	1200	115	0.2	0.731	644.57
12	1200	165	0.6	0.556	882.484
13	1600	75	0.6	0.62	709.587
14	1600	115	1	0.43	580.263
15	1600	165	0.2	0.71	894.419
16	2000	75	1	0.65	977.58
17	2000	115	0.2	0.413	610.8
18	2000	165	0.6	0.867	939.402

III. RESULTS AND ANALYSIS

A. Taguchi Method

This method uses a special design of orthogonal arrays to study the entire parameter space with a minimum number of experiments. Minitab 18 software was used for optimization and graphical analysis of experimental data. In the framework of Taguchi method L18 (OA) has been used in order to explore the process interrelationships within the experimental frame the OA has 3 columns and 18 rows. The OA follows a random run order. The run order is a completely random ordering of the experiments which is followed when running the experiments so that experimental error is reduced as far as possible. Taguchi recommends analysing the mean response for each run in the inner array and also suggest to analyse variation using an appropriately selected signal to noise ratio (S/N). There are three signals to noise ratios

Smaller the better $S/N_{SB} = -10 * \log (\Sigma(Y^2)/n))$ ……………1

Larger the better $S/N_{LB} = -10 * \log (\Sigma(1/Y^2)/n)$ ……….......2

Nominal-the-better $S/N_{NB} = -10 * \log (Y^2)$ …………………3

S/N= signal to noise ratio. y_i= observed value of the experiment test. n = number of observation in a trials.

The Taguchi technique is approach a experimental style technique, which is helpful in reducing the quantity of experiments by various victimisation orthogonal arrays and additionally tries to reduce effects of the factors out of management. The basic philosophy of the Taguchi technique is to confirm quality in the style part. The best approach of the Taguchi technique area unit to decrease the experimental time, to reduce the price and to search out vital factors in a very shorter period. [12] The most reliable of Taguchi's techniques is that the use of parameter style, that is AN engineering technique for product or method style that focuses on determinative the parameter (factor) settings manufacturing the simplest levels of a high quality characteristic (performance measure) with minimum variation. The general aim of quality engineering is to form periodical set, that relation to all noise factors. The foremost necessary stage within the style of orthogonal array experiment lies within the choice of control factors [14]. As many factors as potential ought to be enclosed so as to that would be potential to spot non-significant variables at the earliest opportunity [4, 8]. Taguchi creates a typical orthogonal array to accommodate this demand. Taguchi used the quantitative relation (S/N) ratio because the quality characteristic of choice. S/N quantitative relation is employed as a measurable worth instead of standard deviation as a result of because the mean decreases, the standard deviation compared decreases and contrariwise. Taguchi has through empirical observation found that the 2 stage optimisation procedure involving S/N ratios so provides the parameter level combination, wherever the quality deviation is minimum whereas keeping the mean not off course [13]. Taguchi method under the Design of Experimental. To evaluate the maximum and minimum value of the S/N ratio.

Table 4 Measured S/N Ratio For Ra And Mrr

S no	Surface Roughness Ra (µm)	Material removal rate (mm3/min)	SNRA1 Ra (µm)	SNRA2 MRR (mm3/min)
1	0.418	160.36	7.5765	44.1019
2	0.383	320.8	8.3360	50.1247
3	0.395	383.13	8.0681	51.6669
4	0.22	290.4	13.1515	49.2599
5	0.442	412.56	7.0916	52.3097
6	0.513	428.4	5.7977	52.6370
7	0.612	366.32	4.2650	51.2772
8	0.214	541.233	13.3917	54.6677
9	0.527	782.494	5.5638	57.8696
10	0.873	414.106	1.1797	52.3422
11	0.731	644.57	2.7217	56.1854
12	0.556	882.484	5.0985	58.9141
13	0.62	709.587	4.1522	57.0201
14	0.43	580.263	7.3306	55.2725
15	0.71	894.419	2.9748	59.0308
16	0.65	977.58	3.7417	59.8030
17	0.413	610.8	7.6810	55.7180
18	0.867	939.402	1.2396	59.4570

B. Conceptual S/N ratio approach

Taguchi recommends analysing the effect of the S/N ratio magnitude relation using abstract approach that involves graphing the consequences and visually characteristic the factors that seem to be important, without victimization ANOVA, therefore creating the analysis simple approach. In this S/N ratio, Smaller - the better characterises is used to identify the surface roughness (Ra) at that same Larger-the better is used to identify the material removal rate. In signal to noise ratio is one of the main cretic factor during machining time because of noise will comes from various factors and effect the quality of surface roughness and decrease the material removal rate.

C. Analysis of variation ANOVA

The procedures after the experimental runs are analysing data and identifying the optimal levels for all the control factors table 5. The results of the surface roughness measurements and also material removal rate measured the value, along with the additional parameters of the expanded orthogonal array.

Table 5 Analysis of Variance for S/N ratio of Ra

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Speed (rpm)	2	4.791	2.396	0.17	0.850
Feed (mm/min)	2	27.858	13.929	0.96	0.413
Depth of cut (mm)	2	9.834	4.917	0.34	0.720
Error	11	159.567	14.506		
Total	17	202.050			

Response Table 6 for Signal S/N ratio of MRR

Level	Speed (rpm)	Feed (mm/min)	Depth of cut (mm)
1	52.22	52.30	53.69
2	54.26	54.05	54.85
3	56.47	56.60	54.40
Delta	4.24	4.30	1.16
Rank	2	1	3

Response Table 7 for Signal S/N ratio of Ra

Level	Speed (rpm)	Feed (mm/min)	Depth of cut (mm)
1	5.497	5.678	6.612
2	6.750	7.759	5.030
3	5.980	4.790	6.585
Delta	1.253	2.968	1.581
Rank	3	1	2

Table 8 Analysis of Variance for S/N ratio of MRR

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Speed (rpm)	2	54.038	27.019	1.59	0.247
Feed (mm/min)	2	55.992	27.996	1.65	0.236
Depth of cut (mm)	2	4.074	2.037	0.12	0.888
Error	11	186.696	16.972		
Total	17	300.800			

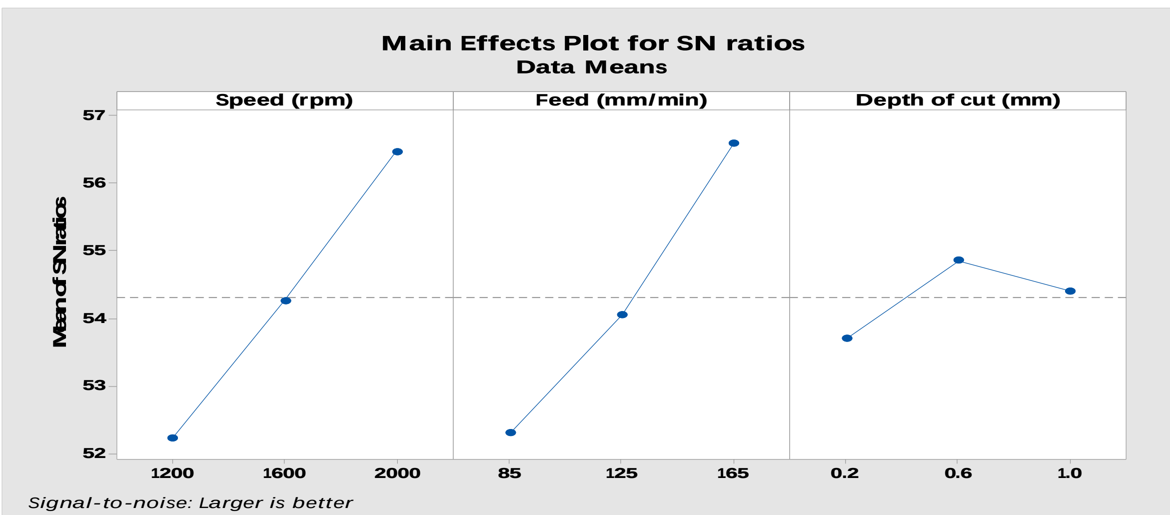

Fig 3 S/N ratio to shoe that higher value is optimal level parameters

Response Table 9 for Mean value of Ra

Level	Speed (rpm)	Feed (mm/min)	Depth of cut (mm)
1	0.5593	0.5655	0.5032
2	0.4892	0.4355	0.5800
3	0.5472	0.5947	0.5125
Delta	0.0702	0.1592	0.0768
Rank	3	1	2

Response Table 10 for Mean value of MRR

Level	Speed (rpm)	Feed (mm/min)	Depth of cut (mm)
1	467.6	486.4	563.8
2	552.6	518.4	605.2
3	703.0	718.4	554.1
Delta	235.4	232.0	51.1
Rank	1	2	3

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Fig 4 Residual plots for S/N ration of Ra value

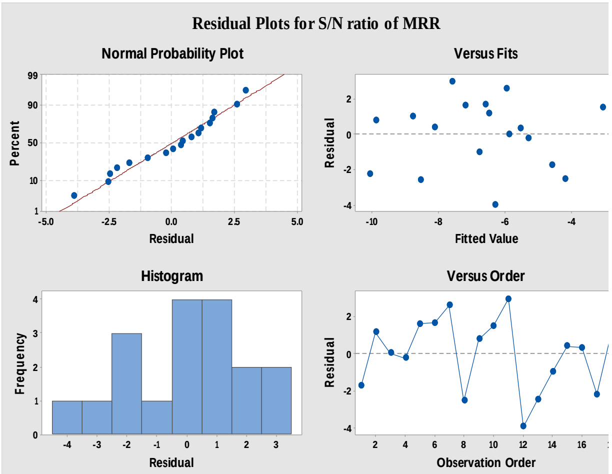
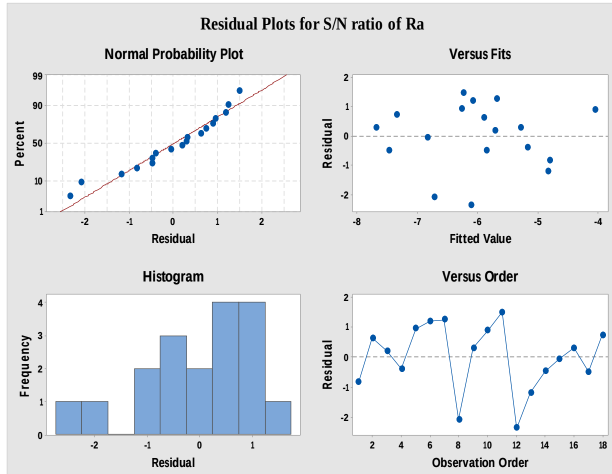


Fig 4 Residual plots for S/N ration of MRR value



A residual plot may be a graph that's wont to examine the goodness-of-fit in regression and analysis of variance. Examining residual plots helps you establish whether or not the standard statistical procedure assumptions area unit being met. If these assumptions area unit glad, then standard statistical procedure regression can manufacture unbiased constant estimates with the minimum variance.

IV. CONFIRMATION TEST RESULTS

After obtaining the best level of machining parameters and approach through the above process, in order to verify the improvement of output quality characteristics, a confirmation test is performed. Taguchi method is used to optimize the input parameters and same time with help of ANOVA is used for analysis the variation of control factor. the S/N ratio value are obtain in above table 6 & 7 in this table, which one is optimal value, that can be calculated by using the formulae given in Eq. 2

$$\gamma = \gamma m + \sum_{i=1}^{q} (\gamma j + \gamma m) \qquad (2)$$

Where,

γ = predicted machining parameters,
γm =Total mean of Taguchi grade,
$\bar{Y}j$ = Mean of Taguchi relational grade at the optimal level.
q = number of machining parameter

Table 11Mean Response optimal value

machining Initial parameter		Optimal machining parameter	
		Predict value	Experimental value
Parameter level	S1F1D1	S3F3D2	S3F3D2
Surface roughness (µm)	0.566	0.745	0.696
MRR (mm3/min)	369.54	910.54	878.04

Table 12 Signal S/N ratio optimal value

machining Initial parameter		Optimal machining parameter	
		Predict value	Experimental value
Parameter level	S1F1D1	S3F3D2	S3F3D2
S/N ratio of Surface roughness (µm)	5.637	6.27	3.650
S/N ratio of MRR (mm3/min)	49.59	64.93	59.30

V. CONCLUSION

The conclusions derived from optimizing machining parameters and approach in end milling Al-6063 material are as follows. Experiments are performed based on L_{18} OA chosen from Taguchi's Method and analysis is done using analysis of variation for optimizing multiple performance characteristics. Surface roughness and *MRR*. The optimum level of input control parameters obtained are speed of 2000 (rpm) feed rate as 175 mm/min, depth of cut as 0.6 mm. Improvement in Material removal rate from 0369.54 to 878.04 and same time surface finish is improve from 0.566 to 0.696. Confirms the improvement in the milling process with change in milling parameters and approach. Taguchi method was applied to identify the S/N ratios and increase the MRR from 49.59 to 59.30 and surface roughness 5.63 to 3.650 with respectively. Interactions between Material removal rate and relating to Ra. According to the ANOVA analysis, the feed rate has an effect on Ra and MRR at a reliability level of 95%. In dry machining process, improve the machinability performance characterises.

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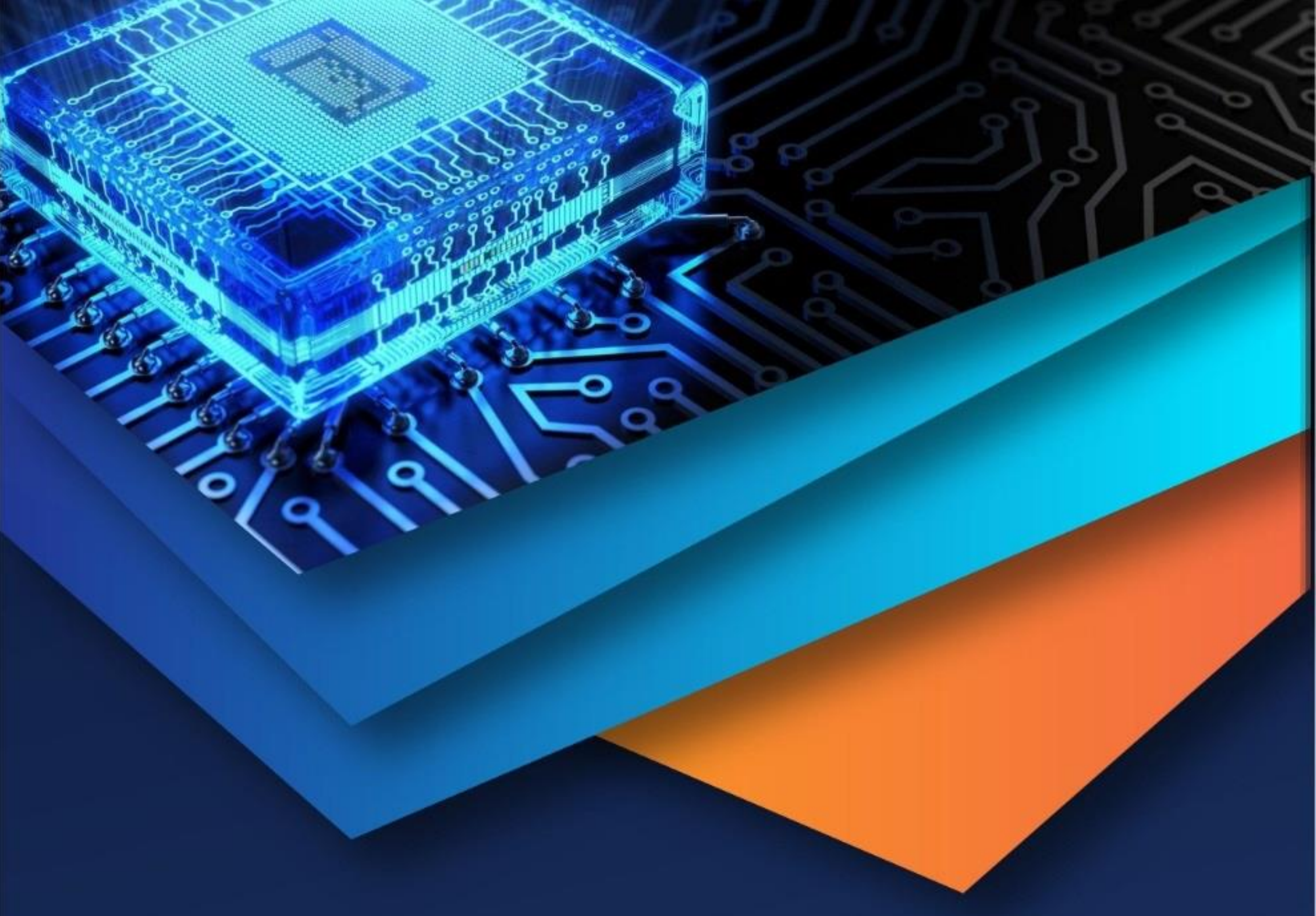

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