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Optimization of Material Removal Rate during Turning of Al2014t4 Material on CNC Lathe Using Taguchi Technique

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Abstract: - Machining of Aluminum alloy is observed by using carbide tool. There are number of parameters like cutting speed, feed and depth of cut etc. which must be given consideration during the machining of medium Aluminum alloy. This study investigates the effects and significance of process parameters on Material Removal Rate (MRR) in turning of AL2014T4. By using Taguchi method single response optimization problem is solved. The optimization of MRR is done using fifteen experimental runs based on Box Benhen design matrix method .A mathematical equation is developed based on process parameters within the experimental domain. The optimum levels of process parameters and their importance for MRR are identified based on raw data. The data is analyzed and raking is given, which parameter has significant role in MRR .Optimal results were verified through confirmation experiments
Keywords: Taguchi method, response surface method, minitab16, CNC Turning,, MRR, Box Benhen design matrix.

I. INTRODUCTION

In this paper, Optimization methods[1] in metal cutting processes are considered for improvement of MRR quality by in put parameters . This paper focuses on developing an empirical model for the prediction of MRR turning operation. The working parameters are feed, depth of cut, spindle speed, and output are MRR and cutting time. One of the most important linear regression analyses with logarithmic data transformation is applied in developing the empirical model. The values of MRR is predicted by this model are then verified with extra experiments. Metal cutting experiments and statistical tests demonstrate that the model developed in this work produces smaller errors than those from some of the existing models and have a satisfactory result in both model construction and verification. MINI TAB 16 is a software which is to establish the initial model and refined model. The coefficients of mathematical modeling is based on the response surface method regression model.

A. Response Surface Methodology (RSM) [2]

It is a collection of mathematical and statistical techniques useful for analyzing problems where several independent variables influence a dependent variable .It seeks to relate an average response to the value of quantitative variables that affect the output response.

B. Experimental Methodology

The study was carried out using a CNC XLTURN machine equipped with a maximum spindle speed of 3000rpm, feed rate of 1.2 m/min and multiple tool change capabilities (max no. of tools 8) and with 1HP spindle horse power. The machine is capable of a 2-axis movement along X, Z directions. CNC programs can be developed in a FANUC software. The work piece material used is AL 2014-T4 in the form of 80mm length and 22mm diameter cylindrical rods. The level of parameters selected for the experiments were given in table 2 Fifteen experiments are carried out according to the BOX BEHNKEN design. The metal removal rate measured by using a weight balancing machine with one gram as least count.

C. Procedure for Experimental Methodology

1) Carbide tool is selected for machining
2) Based on Box Behnken for three level three factorial to do 15 experiments are chosen

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3) Selection of factors for ANOVA are speed, feed and Depth of cut).
4) Selection of confidence level 95% based on ANOVA to get predicted values
5) Actual material removal rate is measured for machined work pieces using balancing on weight basis and readings are noted
6) Predicted values are compared with actual values to test the machining inputs speed, feed and Depth of cut

Table – 1 Composition of AL2014T4

Component	Wt. %	Component	Wt. %	Component	Wt. %
Al	90.4 - 95	Mg	0.2 - 0.8	Si	0.5 - 1.2
Cr	Max 0.1	Mn	0.4 - 1.2	Ti	Max 0.15
Cu	3.9 - 5	Other, each	Max 0.05	Zn	Max 0.25
Fe	Max 0.7	Other, total	Max 0.15		

D. Selection of Box Behnken

There are four common quadratic designs for codeing which includes Box behnken design, Central Composite Circumscribed (CCC), Central Composite Inscribed (CCI) and Central Composite Face centered (CCF). In all these designs Box Behnken provides optimum design matrix for 3 level - 3 factor case. And it requires fewer runs than other designs

It is one of the designs in the RSM technique that requires fewer treatment combinations than other designs in case of involving 3 or 4 factors. This property prevents a potential loss of data in those cases. In this paper Box-Benhken Design matrix for three factor-three level machining is done for indicating the coded matrix for fifteen number of runs

E. Development of Optimal Working Zones [3]

The optimum working zone depends on the desired work piece. Experiments were conducted separately for each combination to find the operating working region. Finding of this region was necessary to fix up the limits of the process parameters. The upper and lower limits are denoted as +1, and –1 respectively. Trial runs were conducted by changing one of the factors and keeping the remaining at constant value. The maximum and minimum limits of all the factors were thus fixed

Table – 2 Input parameters and their levels

Parameter	-1	0	+1
Speed (rpm)	600	1200	1800
Feed(mm/min)	30	60	90
Depth of cut (mm)	0.2	0.5	0.8

Table -3 Experimental results with coded and un coded values and S/N RATIOS

s.no	Coded values			Un Coded values			MRR	
	Speed rpm	Feed(mm/min)	Depth of cut mm	Speed rpm	Feed(mm/min)	Depth of cut mm	PRACTIAL VALUES	S/N RATIO VALUES
1	-1	-1	0	600	30	0.5	0.944	0.500
2	1	-1	0	1800	30	0.5	0.817	1.745
3	-1	1	0	600	90	0.5	2.40	-7.60
4	1	1	0	1800	90	0.5	2.91	-9.27
5	-1	0	-1	600	60	0.2	0.58	-4.73
6	1	0	-1	1800	60	0.2	0.62	-4.152
7	-1	0	1	600	60	0.8	0.94	-0.537
8	1	0	1	1800	60	0.8	1.3	2.278

9	0	-1	-1	1200	30	0.2	0.32	-9.89
10	0	1	-1	1200	90	0.2	2.38	7.53
11	0	-1	1	1200	30	0.8	2.38	7.53
12	0	1	1	1200	90	0.8	1.49	3.46
13	0	0	0	1200	60	0.5	1.66	4.402
14	0	0	0	1200	60	0.5	1.79	5.057
15	0	0	0	1200	60	0.5	1.79	5.057

F. Selection of Design and Mathematical Model [3]

Effect of the machining parameters on metal removal rate being the major part of investigation it was considered for design the experiments.

G. Selection of Factors [4]

Identification of important process control variables

Identification of correct factors is very important to get a good and accurate model. Among many parameters that effect the MRR , the following were important: Speed, feed and depth of cut.

Finding the limits of the process variables

Trial experiments were carried out to find out the working range for metal material removal range by varying one process variable and keeping other process variable constant.

The various values of factor examined in an experiment are known as limits.

For the convenience of recording and processing, the experimental data was observed.

The upper and lower limits were coded as +1, -1 respectively or simply (+) and (-) for the case of recording and processing of the observed data by using the following relationship.

Coded Value = (Natural value – Average value) / Variation in the value

Natural Value = Value under consideration

Average Value = (upper limit + lower limit) /2

Variation value = (upper limit – lower limit)

II. TAGUCHI METHOD[5]

Traditional experimental design methods are very complicated and difficult to use. Additionally, these methods require a large number of experiments when the number of process parameters increases. In order to minimize the number of tests required, Taguchi experimental design is a powerful tool for designing high-quality system. This method uses a special design of orthogonal arrays to study the entire parameter space with small number of experiments only. Taguchi recommends analyzing the mean response for each run in the inner array, and he also suggests analyzing the data by using an appropriate chosen signal-to-noise ratio (S/N values)

There are 3 Signal-to-Noise ratios of common interest for optimization of Static Problems.

A. Smaller-The-Better

S/N = -10 Log (1/n Σ i=0 1/y2)

B. Larger-The-Better

S/N = -10 Log10 [mean of sum squares of reciprocal of measured data]

C. Nominal-The-Best

S/N = 10 Log10 Square of mean/.variance.

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Analysis of raw data-Table 4

level	Speed (A)	Feed(A)	Depth of cut(c)
1	1.125	1.144	0.975
2	1.687	1.24	1.758
3	1.411	2.295	1.5275
Delta	0.4772	1.1151	0.7838
Rank	3	1	2

Analysis of S/N Ratio is calculated by using larger the better by using rawdata-Table5

level	Speed (A)	Feed(A)	Depth of cut(c)
1	-3.091	-0.028	-2.8105
2	1.9288	+1.0535	0.8416
3	-2.349	-1.47	3.182
Delta	-1.1622	1.0255	0.3715
Rank	3	1	2

By using ranking method importance of each parameter in MRR is identified and ranks are given. 1 rank means more effect to remove MRR than 2 and 3 ranks. The equations below are the verification of experimental data with taughi method. It is observed that ranks are same for raw data and S/N ratio values.

Predicted mean of raw data = A1+B1+C1- 2(Y)

1.125+1.144+0.975-2(1.488)

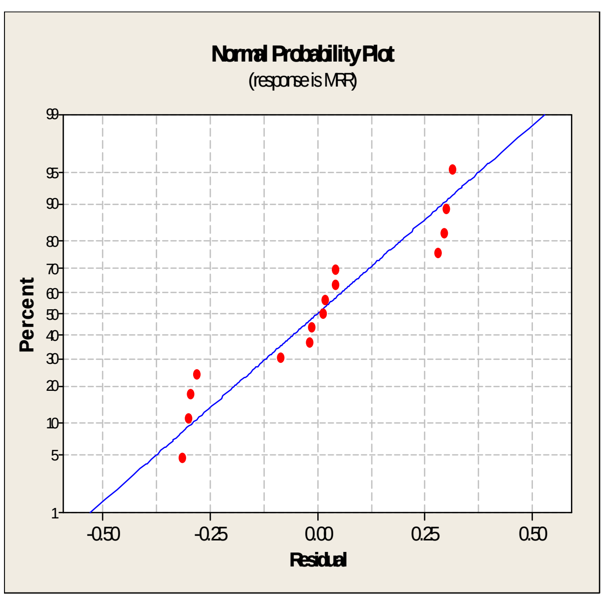
= 0.268mm/min

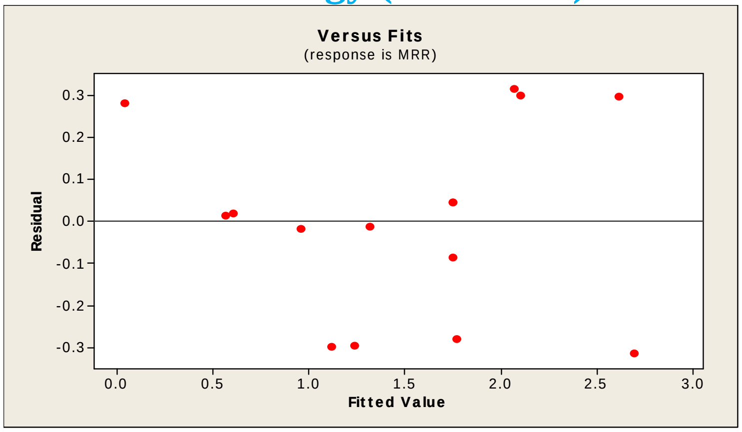
Predicted mean of S/N Ratio = A1+B1+C1- 2(Y)

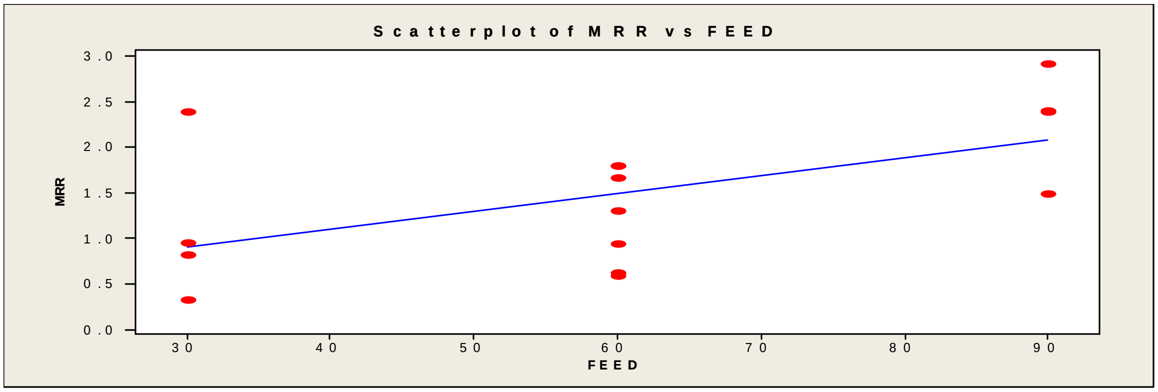
= -3.091-0.028-2.8105-2(0.920)

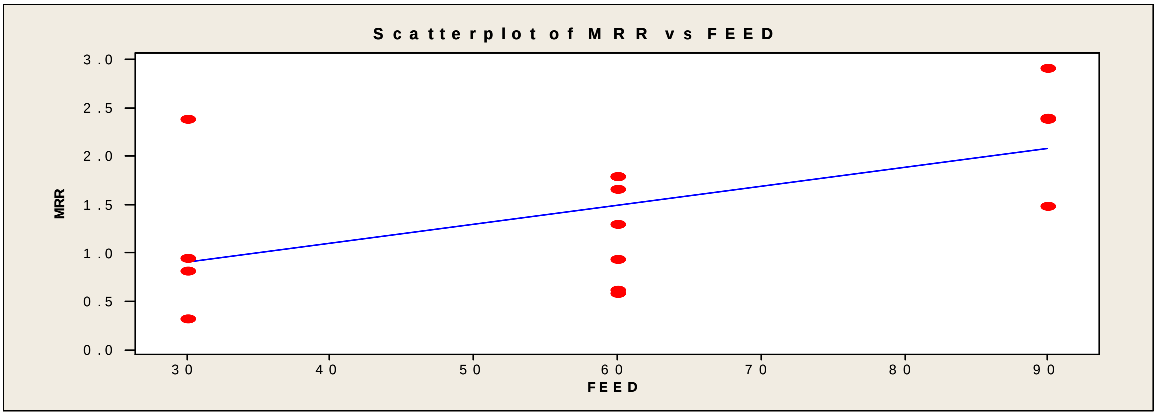
= -7.7695 db

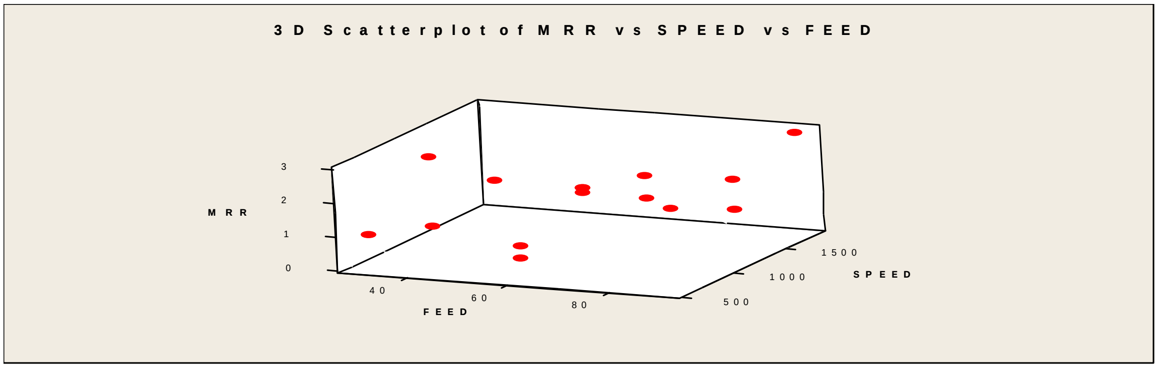
III. GRAPHS AND RESULTS

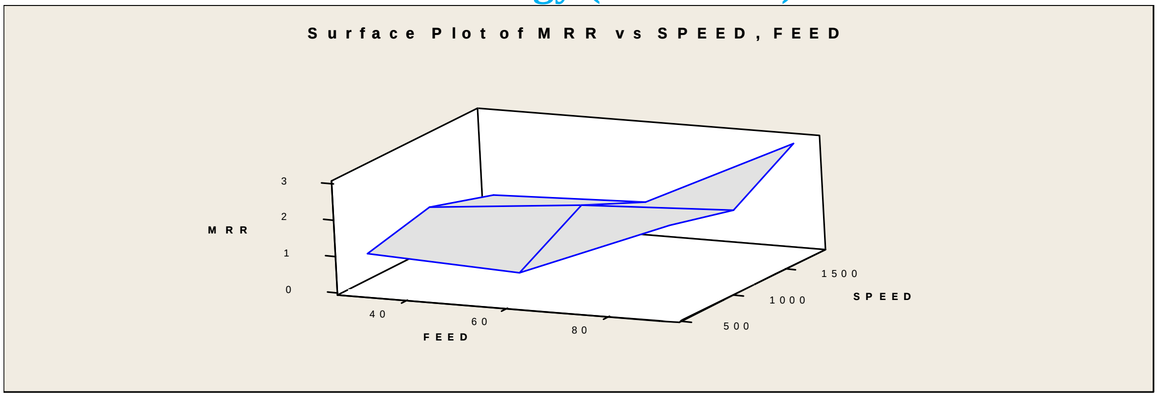


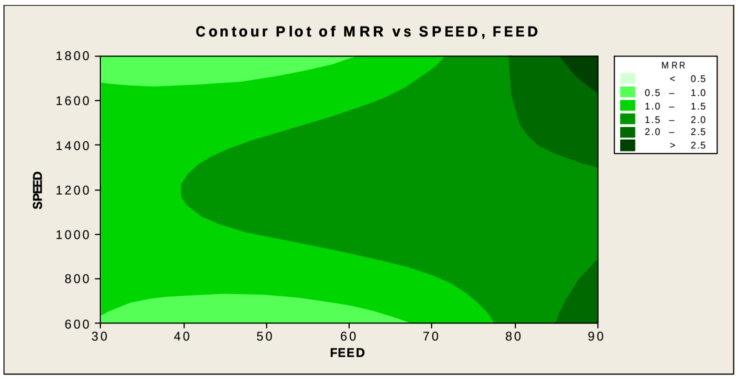

Versus Fits
(response is MRR)
Residual
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Fitted Value

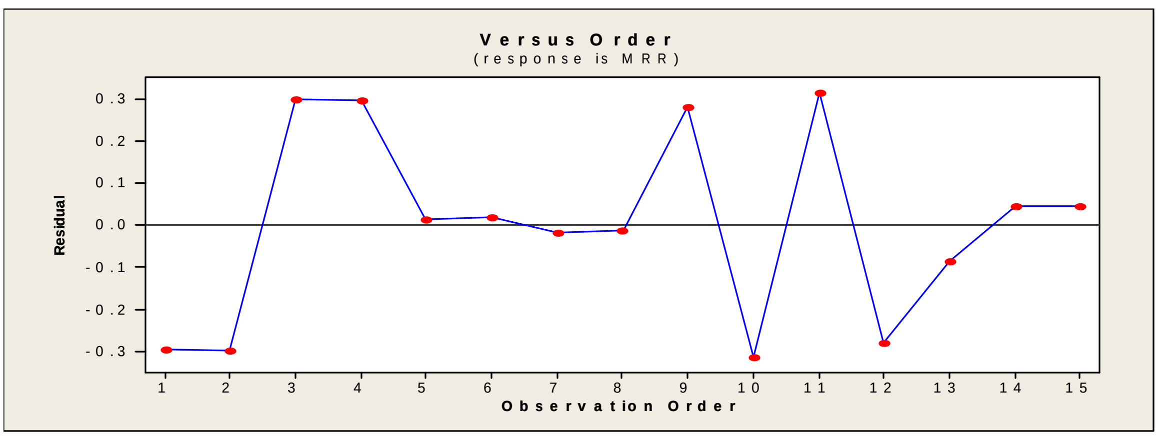

Scatterplot of MRR vs FEED
MRR
3.0
2.5
2.0
1.5
1.0
0.5
0.0
30
40
50
60
70
80
90
FEED

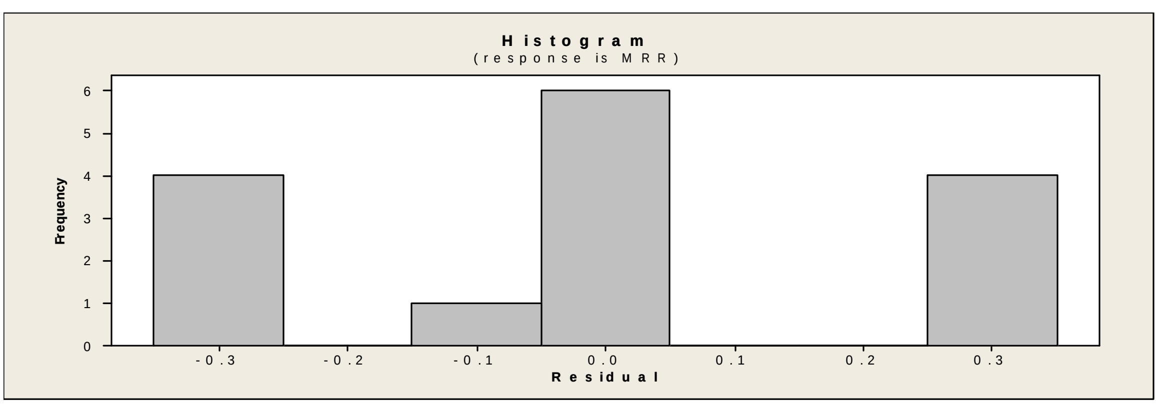

Scatterplot of MRR vs FEED
MRR
3.0
2.5
2.0
1.5
1.0
0.5
0.0
30
40
50
60
70
80
90
FEED


3D Scatterplot of MRR vs SPEED vs FEED
MRR
3
2
1
0
40
60
80
FEED
1500
1000
500
SPEED


Surface Plot of MRR vs SPEED, FEED
MRR
FEED
SPEED


Contour Plot of MRR vs SPEED, FEED
SPEED
FEED
MRR
< 0.5
0.5 – 1.0
1.0 – 1.5
1.5 – 2.0
2.0 – 2.5
> 2.5


Versus Order
(response is MRR)
Residual
Observation Order


Histogram
(response is MRR)
Frequency
Residual

A. Results of Conformation

1) Regression Analysis: MRR versus Speed, Feed, Depth Of Cut

The regression equation is

MRR = - 2.97 + 0.00195 SPEED - 0.0036 FEED + 10.9 DOC - 0.000001 SP*SP
+ 0.000446 FD*FD - 5.62 DC*DC + 0.000009 SP*FD + 0.00044 SP*DC
- 0.0819 FD*DC

Predictor	Coef	SE Coef	T	P
Constant	-2.965	1.698	-1.75	0.141
SPEED	0.001948	0.001570	1.24	0.270
FEED	-0.00355	0.03139	-0.11	0.914
DOC	10.926	2.868	3.81	0.013
SP*SP	-0.00000106	0.00000055	-1.93	0.112
FD*FD	0.0004464	0.0002196	2.03	0.098
DC*DC	-5.622	2.196	-2.56	0.051
SP*FD	0.00000885	0.00001055	0.84	0.440
SP*DC	0.000444	0.001055	0.42	0.691
FD*DC	-0.08194	0.02109	-3.88	0.012

S = 0.379703 R-Sq = 91.7% R-Sq(adj) = 76.7%

2) Analysis Of Variance:

Source	DF	SS	MS	F	P
Regression	9	7.9602	0.8845	6.13	0.030
Residual Error	5	0.7209	0.1442		
Total	14	8.6811			

The model F-value for MRR 6.13 implies the model is significant. There is only .030 chance that model F value this large could occur due to noise. The values less than 0.440 indicate model terms are significant. In this feed speed,doc, FD*FD, DC*DC,AND FD*DC are significant terms

IV. CONCLUSIONS

From the experiments performed the following conclusions are drawn.

Ranking is developed for material removal rate in order to predict the values of material removal rate within the range of the turning parameters selected.

From 1st experiment continuous chips with 300mm are generated.

From 2nd experiment discontinuous chips with 400mm are generated.

From 4th experiment chips are jammed with tool with average length 120mm are generated.

The adequacy of the developed model is checked using ANOVA at 95% confidence level is found to be adequate.

From 5th experiment chips with less curvature and less pitch are generated.

From 7th experiment chips with large radius of curvature and flat chips are generated.

From 8th experiment large thick chips with are generated.

From 11th experiment continuous chips surrounding the tool are generated.

From 12th experiment flat chips with less curling are developed.

From the main effect plots, it is clear that the given input parameter has a significant effect on metal removal rate in this experimental range.

Machining time is more when feed is less .

Machining time is less for4th experiment and MRR is high 2.91.

A. Scope Of The Future Work

MRR and surface finish can be combined to find the ranking to get optimum machine conditions.

Experiment can be carried out with different tools and materials.

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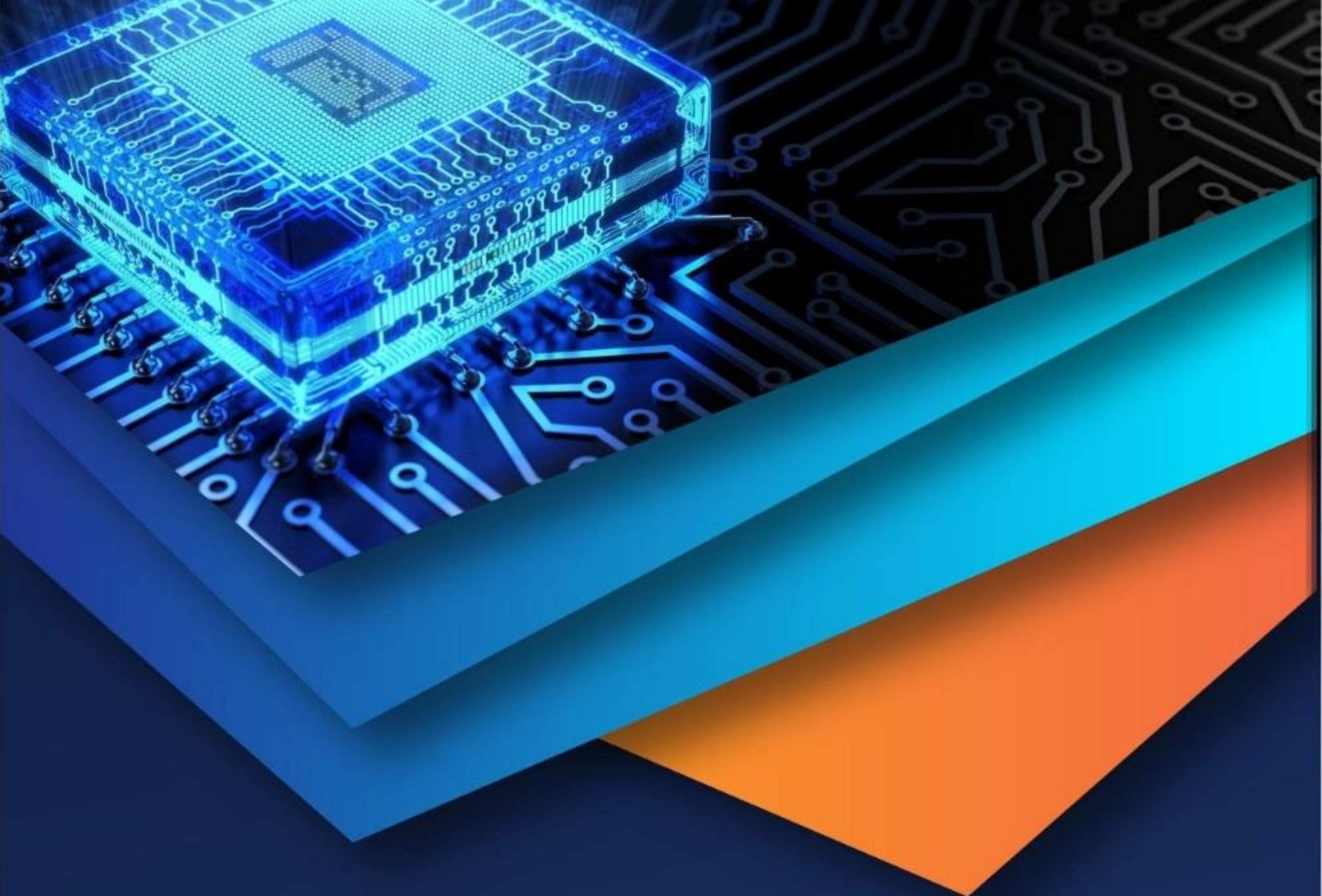

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