

Optimization of CNC Parameters using Taguchi and ANOVA

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Abstract

Now-a-day's Computer Numerical Controlled machines are being used in every kind of manufacturing processes. Reliability on CNC machines abnormally increasing. CNC machines easily realize the programs like tool-offset, compensation of tool, various degree of computation, and the ability to send the data and receive it from various sources, including remote sources also. CNC machines move the cutting equipment in light of orders that are pre-programmed and offer high accuracy. Nine experiments are performed and Material Removal Rate, Tool Wear Rate is calculated. Taguchi Method expresses the Uniqueness of Variation of Response Analysis by Using the Signal to Noise Ratio. Aluminum is used as the work piece material to get the optimal levels of MRR and TWR. ANOVA is used to determine the optimized values for MRR and TWR and Plots of S/N Ratio were drawn.

Keywords: - CNC machines, MRR and TWR, Taguchi Method expresses.

INTRODUCTION

Computer Numerical Control lathe machine

A Computer numerical control (CNC) machine is mostly preferred machine than the conventional one to meet the complex designs like curved geometries in 2-Dimensional and 3-Dimensional which are very expensive to be done by conventional

machines. These CNC machines can make sound machining components with high reliability and precision.

In the turning process, there are so many types of processes are there, in those we preferred for step turning. Step Turning is the removal of external material from the external diameter of a cylindrical work

piece by means of single point cutting tool which is attached to the tool post and moved parallel to the work piece axis with programmed Speed, Feed and Depth of Cut, by performing turning operation a neat and clean cylindrical work piece can be formed. In turning the diameter of the work piece machined up to prescribed length and the length of the work piece remains same. Turning operation is done on lathe that gives the mechanical power to rotate the work piece material at a specified speed and feeds the cutting tool at programmed rate and depth of cut. Several parameters like ductility nature of the work piece and its brittleness specifies the motion and speed of the cutting tool. These parameters are selected for each operation based upon the work piece material, tool size, etc. the parameters which defined by us are speed of the spindle, depth of cut, feed.

Work Piece Material

There are so many types of materials are there, which are used as work piece in CNC lathe. According to the requirement of job or operation and the properties of the material and their classifications, the work piece material would be selected. Every individual material has its own specified properties and applications, by depending up on the requirements, and

applications and properties such as toughness, corrosion resistance, hardness, machinability, weight, weld-ability, work-ability strength, heat treating etc, the material for the operation is selected. For this project we use aluminium as working material. There are so different compositions of aluminium alloys are there, depending up on the percentage of compositions used in them they are classified.

ANOVA (Analysis of the Variance)

Variance Analysis could be utilized as an experimental tool to observation determination. It is a group of statistical models of statistics and estimation of procedures which are associated by them, used to analyse the differences among the means of groups that exists in the samples. The ratio between the Regression Mean square and Mean Square error is determined by ANOVA, and it is known as F-ratio or ratio of the variance. Clearly, ANOVA test find outs the influence of the Independent variables on the dependent variables or response in the regression study. There are two types of ANOVA is there, unidirectional (one-way ANOVA) and multi directional (two-way ANOVA). This one way and two way are by depending up on the no of independent variables in our analysis of a variance test.

One-way ANOVA: This expresses the impact or influence of a sole factor on a sole response variable. It is used to find out if any statistically significant variation in middle of the means of 3 or more independent or unrelated groups.

Two-way ANOVA: This is an extended version of the 1-way ANOVA. In 1-Way ANOVA, we have 1 independent variable of independent which affects a response variable. But in 2-Way ANOVA, implies 2 independents that affect the dependent response variable.

Here, ANOVA is used to determine the importance of cutting parameters in rate of material removal and TOOL WEAR RATE.

LITERATURE SURVEY

Arjun Avinash et al. have examined the Effects of Machining Parameters in Turning Process for Grooving operation on Aluminium and Optimizing by the application of Taguchi Method". In this project they had find out the S/N ratios by depending up on the Taguchi Method and the software Minitab.

Rama Rao BSV had optimized the Process Parameters of WEDM using Taguchi Method. They perfectly examined

the effects of process parameters on the response by using Taguchi method. EN8 and EN24 are machined in this project by using WEDM. 18 experiments are conducted by L18 orthogonal array designed by Taguchi method, so that 18 no of experiments with different combinations of parameters for each experiment. And analysis has done to get the maximum MRR and they had achieved it.

Ashish Yadav et al. had done the Optimization of Turning Parameters for their Effect on En 8 material work piece hardness by using Taguchi parametric optimization Method. Their work reflects in the optimized values of turning parameters on the E8 material work piece.

Rama Rao et al. have expressed the Applications of Taguchi Methods and ANOVA in optimization of process parameters for metal removal rate in electro- chemical machining of Al/5%sic composites. Electro- chemical machining is one of the non conventional process in the field of metal cutting. They had calculated maximum MRR by using Analysis of variance and Taguchi method.

Sujit Kumar Jha et al. had Experiment to Analyze the CNC Turning using Taguchi

Method. The proceedings utilized by this project had taken the analysis over Taguchi method and turning parameters are optimized by using Taguchi method.

Cho. S. S. Komvopoulos, K. had expressed the Wear Mechanisms of Multi-layer Coated Cemented Carbide Cutting tools, he has done his project on tool wear rate. To get the optimized values of tool wear rate he had done his experiment on cemented carbide cutting tools.

J. A. Ghani et al. have completed the Wear Mechanism of Tin coated carbide and Un- coated cements tools at high cutting speed applications. Tool wear rate plays a key role in this study. They proved that at high cutting speed, the tool rate would be maximum. Tool wear rate is directly proportional to cutting speed.

Yong Huang et al. had made his study on Effect of Cutting Conditions on Tool Performance in CBN hard Turning. turning operation is employed in this experiment. They observed the cutting conditions which affects the output response parameters. They also calculated the input parameter values which are optimized.

Chetan Bhardwaj investigated the Parameters Influencing AL6351 Surface Finish and Material Removal Rate By CNC wire EDM. Wired EDM is a non conventional method used in cutting or machining processes. In this WEDM high current is utilized to generate spark which cuts the material. Aluminium tends to cut in the required and easy manner.

Ramesh et al. had done experiment to Optimization of MRR and surface Roughness for turning of AL6061 using Taguchi method. in this study they express that MRR and surface roughness are output characteristic. MRR should be Larger the better and surface roughness should be smaller. They had optimized all of the input parameters and got optimized levels of response parameters.

PROBLEM DESCRIPTION

CNC lathe is programmed by speed, feed rate, depth of cut by depending on the type of the job, here it is turning. However, the performance of the machine and characteristics of the product are not constant. Therefore, the optimum turning conditions are needed to calculate. Here, 9 experiments are done by taking 9 work pieces of same dimensions. Initially before the experiment weight of the tool and work piece is calculated by using highly

sensitive weighing machine. After the operation, again weights of the tool and work piece are noted down. Time is noted for every operation of removing 10mm of work piece material in the turning process by using stop watch. After 9 operations, MRR and TWR values calculated. These values are tabled in MINTAB19 software to calculate S/NOISE ratios and values are tabulated. By using ANOVA variance values are calculated and tabulated.

PARAMETER IDENTIFICATION

The input parameters which effects the output characteristics of the turning parts are

- Cutting speed
- Depth of cut
- Feed rate
- Work piece and tool cutting material
- Working condition
- Operator
- Type of CNC machine

From the above SPEED, FEED, DEPTH OF CUT are considered as input parameters. The range of the input parameters is

General OUTPUT parameters available are

1. MATERIAL REMOVAL RATE
2. TOOL WEAR RATE

3. SURFACE ROUGHNESS

4. CUTTING FORCES

5. POWER CONSUMPTION etc.

MRR and TWR are considered as output parameters for this work

Work piece material

Aluminium is used as a work piece material to optimize the Material Removal Rate in the Turning process. The measurements of the pieces are length- 60mm and diameter- 40mm. here, AL-2024 ALLOY is used as work piece material the composition of this AL-2024 are as follows:

Table 1: AL-2024 Composition

ELEMENT	PERCENTAGE
COPPER	3.8% - 4.9%
MEGNISIUM	1.25% - 1.85%
MANGANESE	0.5% - 0.6%
SILICON	0% - 0.5%
IRON	0% - 0.5%
CHROMIUM	0.1%
ZINC	0.25%
TITANIUM	0.15%

DESIGN OF EXPERIMENT

Taguchi's Orthogonal Array

Orthogonal array of L9 (3) was selected for the parameters (speed, feed, depth of cut) the experiment consists of three factors, then total no of experiments is 27.

But by using this Taguchi method no of
TOOL WEAR RATE.

experiments reduced to 9 instead of 27 with same accuracy.

Following table 2 indicates the process parameters taken at different levels for the experimentation.

Table 2: Process Parameters

S. No.	Spindle Speed (RPM)	Feed Rate (mm/min)	Depth of Cut (mm)
1	920	3	0.3
2	1100	5	0.5
3	1220	10	1.0

The experimental design chosen for the investigation to get optimal levels for M.R.R. during the turning operation is based on L9.

RESULTS

For the MAXIMUM REMOVAL RATE, the solution is LARGER THE BETTER. The S/N ratio is determined by the following equation.

$$S/N = -10 \log_{10} \{n-1 \sum y^2 - 2\}$$

Where,

S/N ratio = signal to noise ratio.

n = no of measurements

y = measured value

The influence of input parameters such as speed, feed, depth of cut on the response MRR is observed from the experiment as per pre- designed L9 orthogonal array, are listed in the below table 3.

Table 3 Indicates the S/N Ratios for M.R.R

S. No.	SPEED (rpm)	FEED\ (mm/rev)	DEPTH OF CUT (mm)	S/N RATIO
1	920	3	0.3	80.77
2	920	5	0.5	84.53
3	920	10	1.0	86.99
4	1100	3	0.3	82.57
5	1100	5	0.5	86.54
6	1100	10	1.0	88.84
7	1220	3	0.3	84.73
8	1220	5	0.5	85.05
9	1220	10	1.0	88.87

The results show us that controlled parameters FEED and SPEED have most significant influence on optimization of MATERIAL REMOVAL RATE. On the other hand, DEPTH OF CUT has some shared effect on the response.

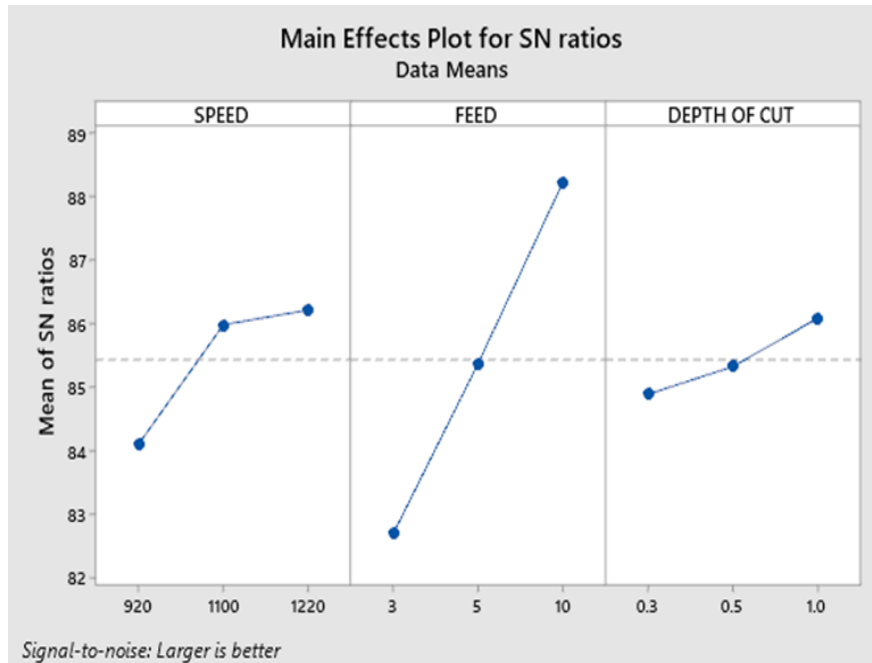


Fig. 1

The above graph indicates the main effects for S/N Ratios of MRR

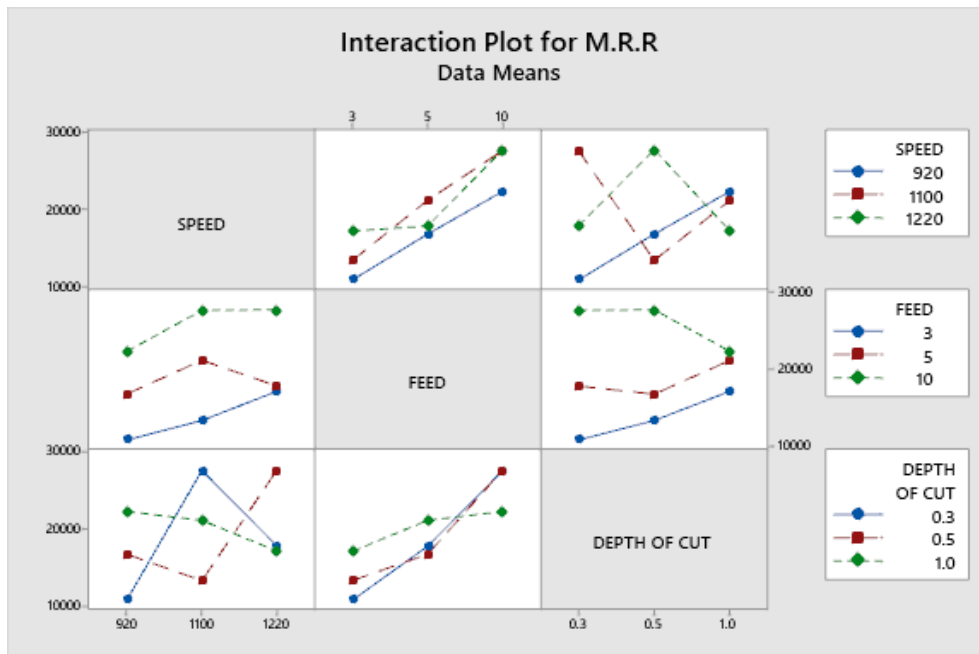


Fig. 2

The above plot indicates the interactions of Input variables over MRR.

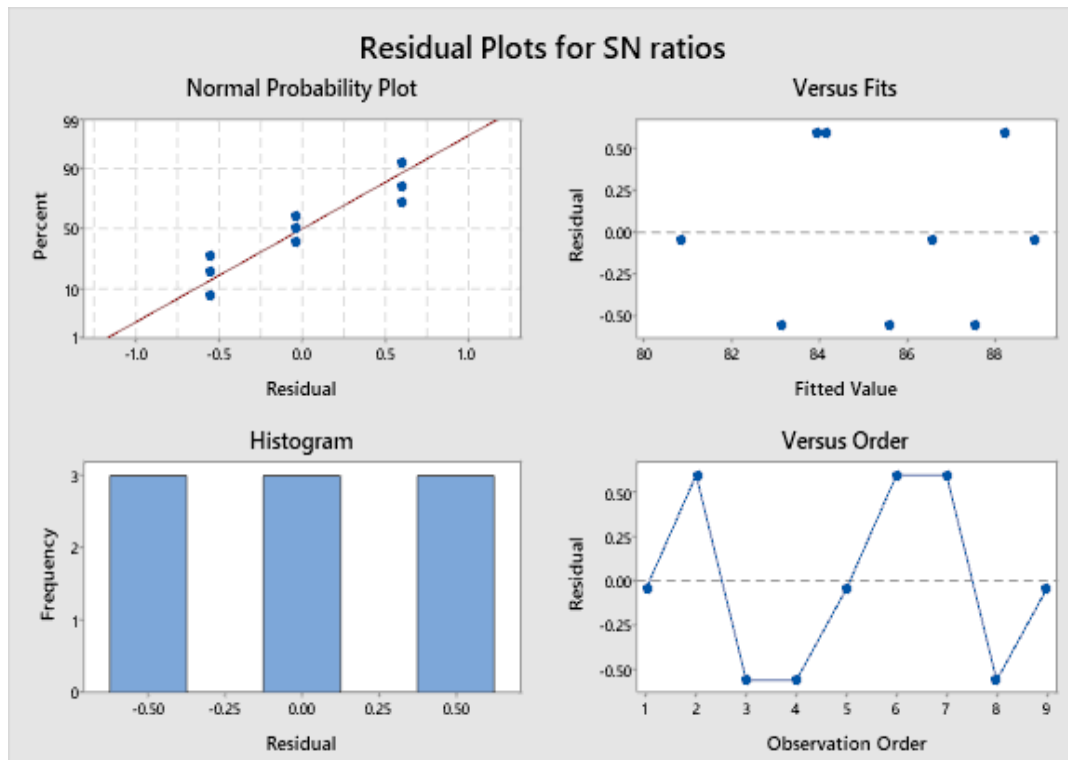


Fig. 3: Four in one plots for residual ratios of S/N ratios

From the figure 2 and 3 optimized levels of input parameters for maximum material removal rate are third level of speed (1220) rpm, third level of FEED (10) mm and the third level of Depth of Cut (1.0) mm.

The Material Removal Rate increases with an increase of Feed and Speed.

For this project we use both S/N ratio and ANOVA for analyzing the result and make it fast to reach the optimum levels of parameters for maximum MRR and to give flawless result.

ANOVA finds out the ratio between the Regression mean square and mean square error and it is known as F- ratio or variance ratio.

Regression Equation

M. R. R	=	-7758 + 14.81 SPEED + 1672 FEED + 2028 DEPTH OF CUT
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Table 4 shows us that percentage contribution of each of the parameter. It is observed that parameters FEED (mm/rev) and speed (rpm) had the most significant influence on MRR and the other parameter Depth of Cut (mm) was not significant with the specific experimental range.

Figs: 4, 5, 6, 7, 8, and 9 had shown us the counter and response plots for MRR with respect to the selected input parameters.

From the plots it is clear that the Material Removal Rate increase with an increase of Feed rate and Speed.

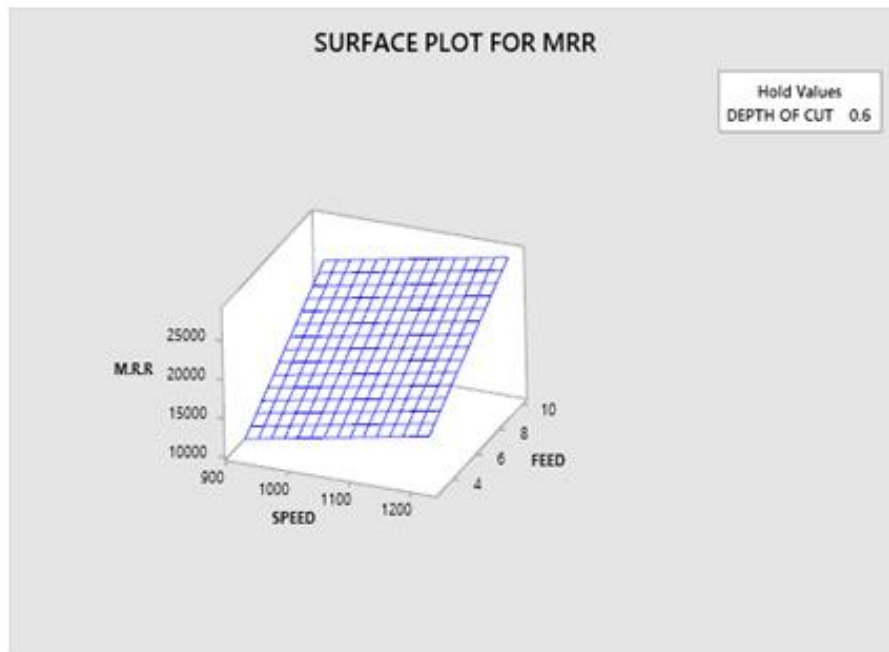


Figure: 4

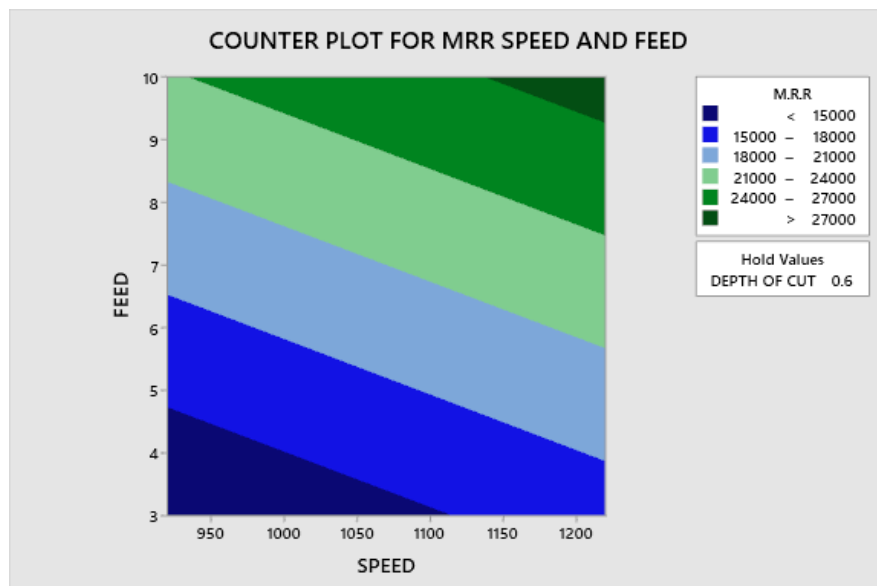


Figure: 5

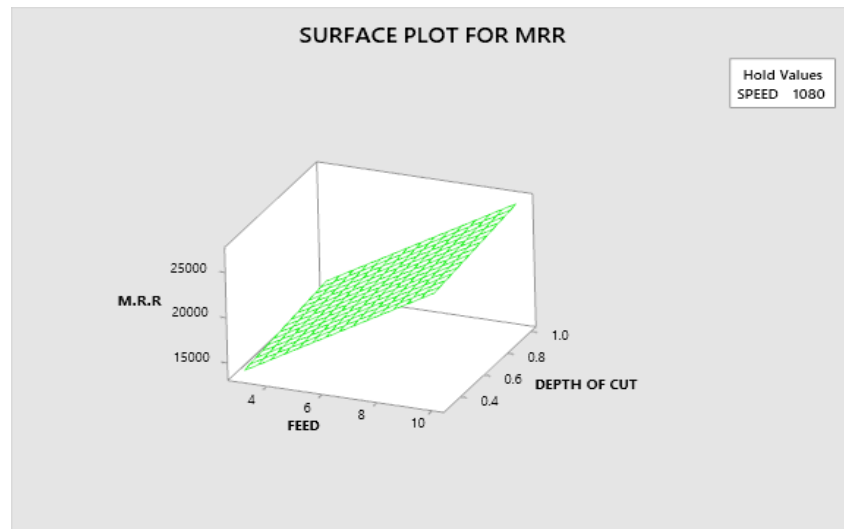


Figure: 6

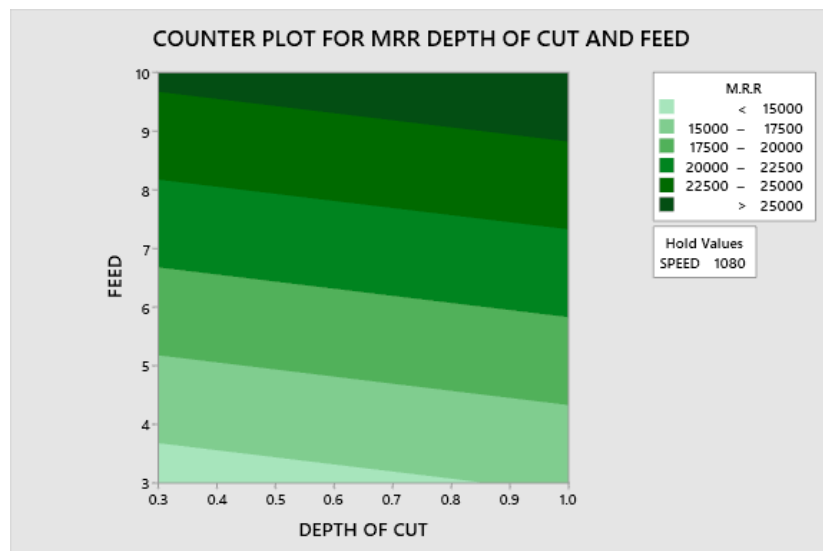


Figure: 7

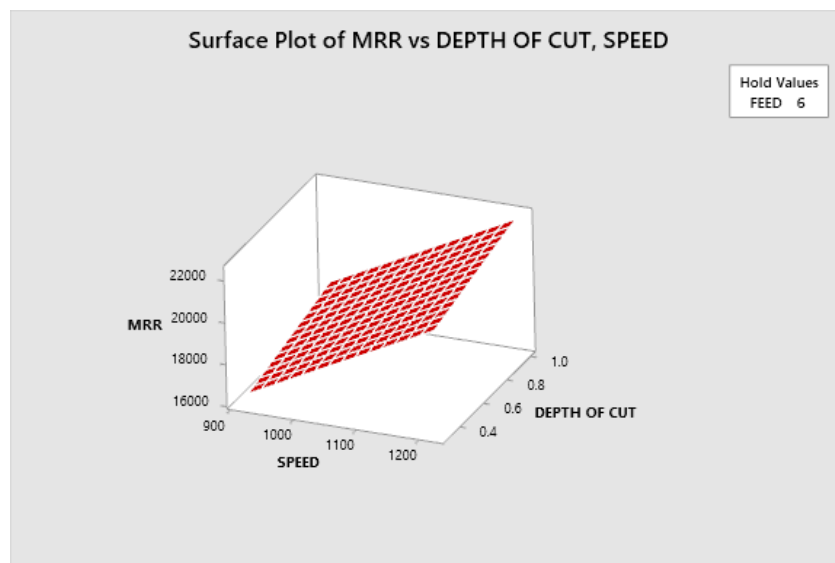


Figure: 8

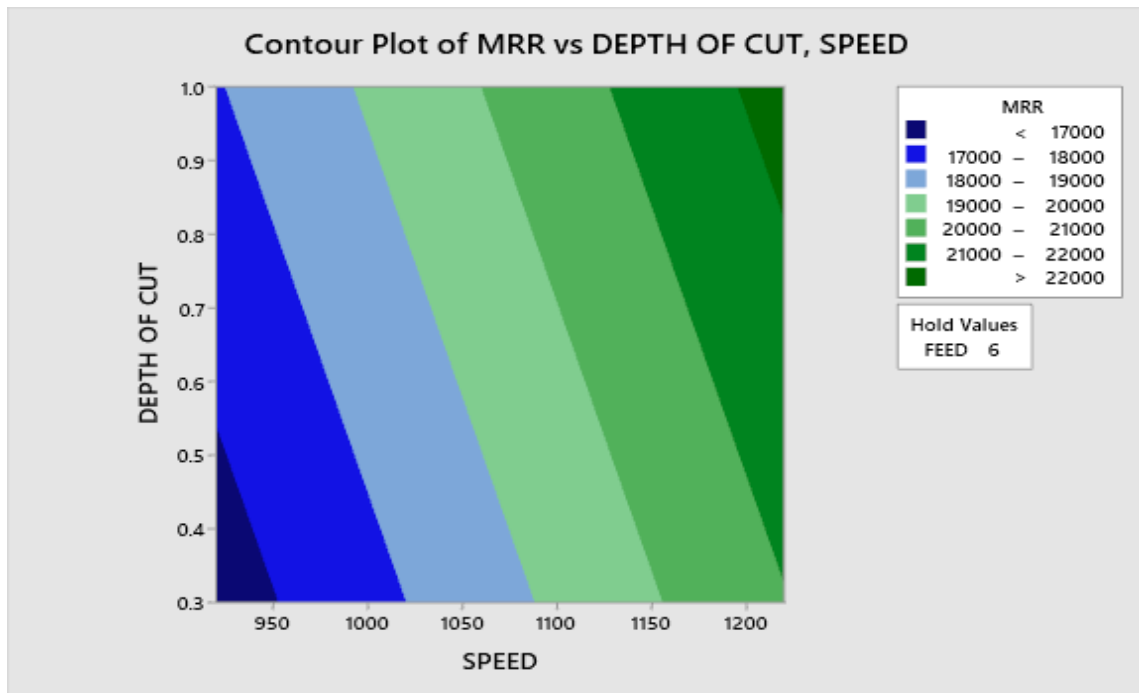


Fig 9

Analysis of Variance

Table 4

Source	DF	Contribution	Adj SS	Adj MS	F-Value	P-Value
FEED	2	81.69%	221350282	110675141	13.39	0.006
Error	6	18.31%	49611051	8268509		
Total	8	100.00%				

The above table indicates the analysis of variance of MRR with respect to Feed.

Here, from the table 4, shows that the MINITAB19 assigns the first rank to highest delta value for FEED RATE (mm/rev). The second rank for SPEED (rpm), and the third to DEPTH OF CUT (mm).

The results show us that controlled parameters FEED and SPEED have most significant influence on optimization of TOOL WEAR RATE. On the other hand, DEPTH OF CUT has some shared effect on the response.

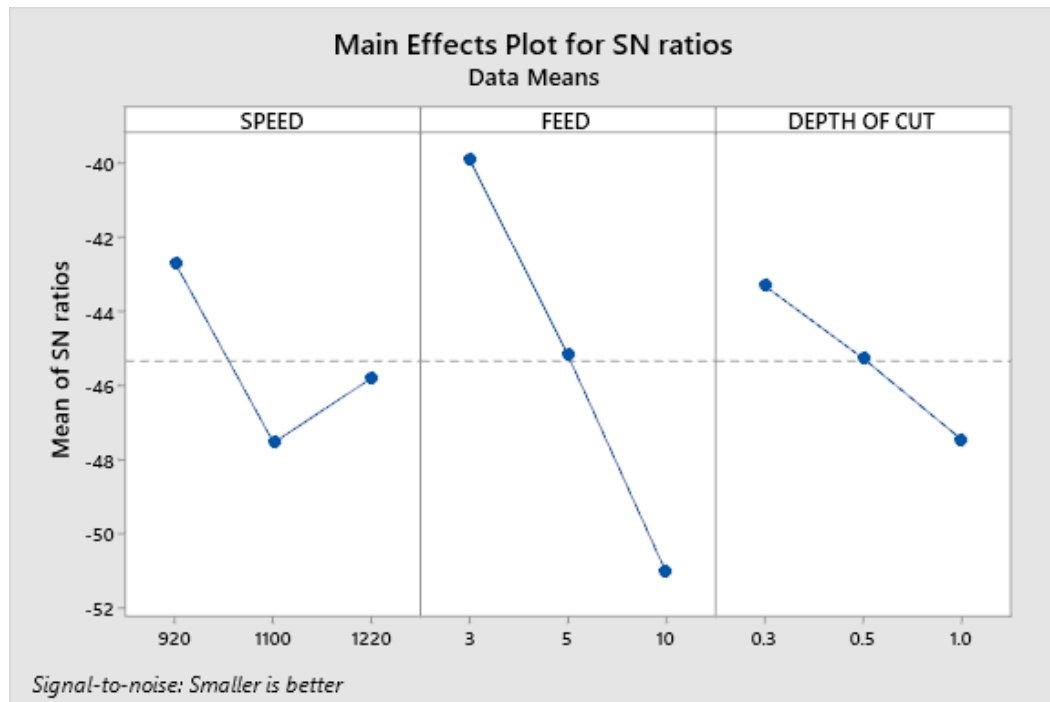


Figure: 10

The above fig indicates main effects Plots for S/N Ratios of TWR

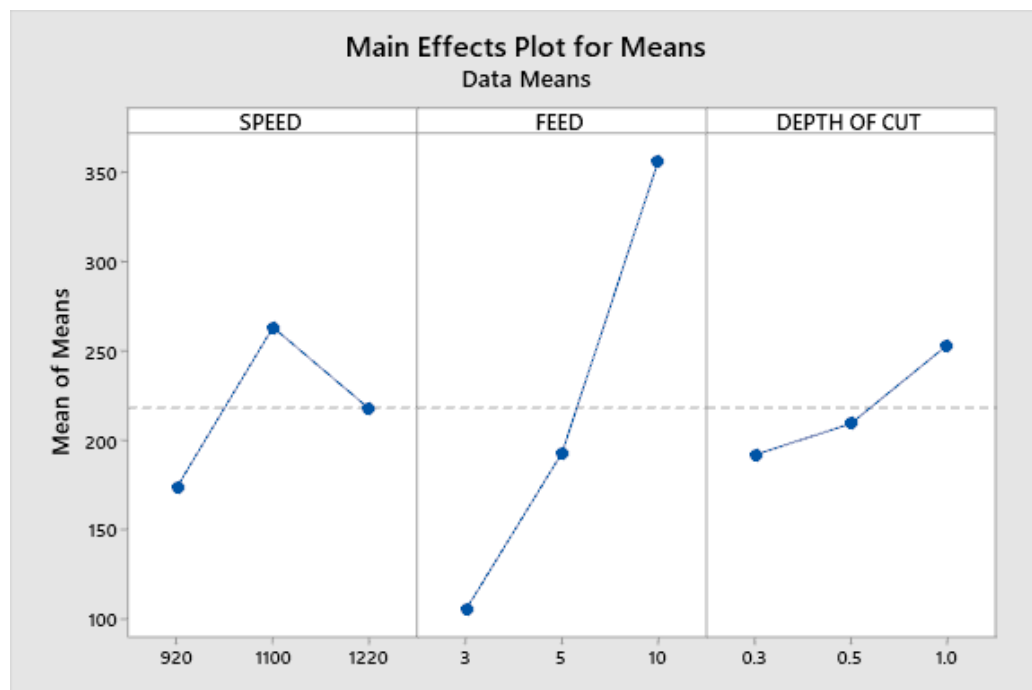


Figure: 11

The above Fig Indicates main effects plots for Data means for TWR

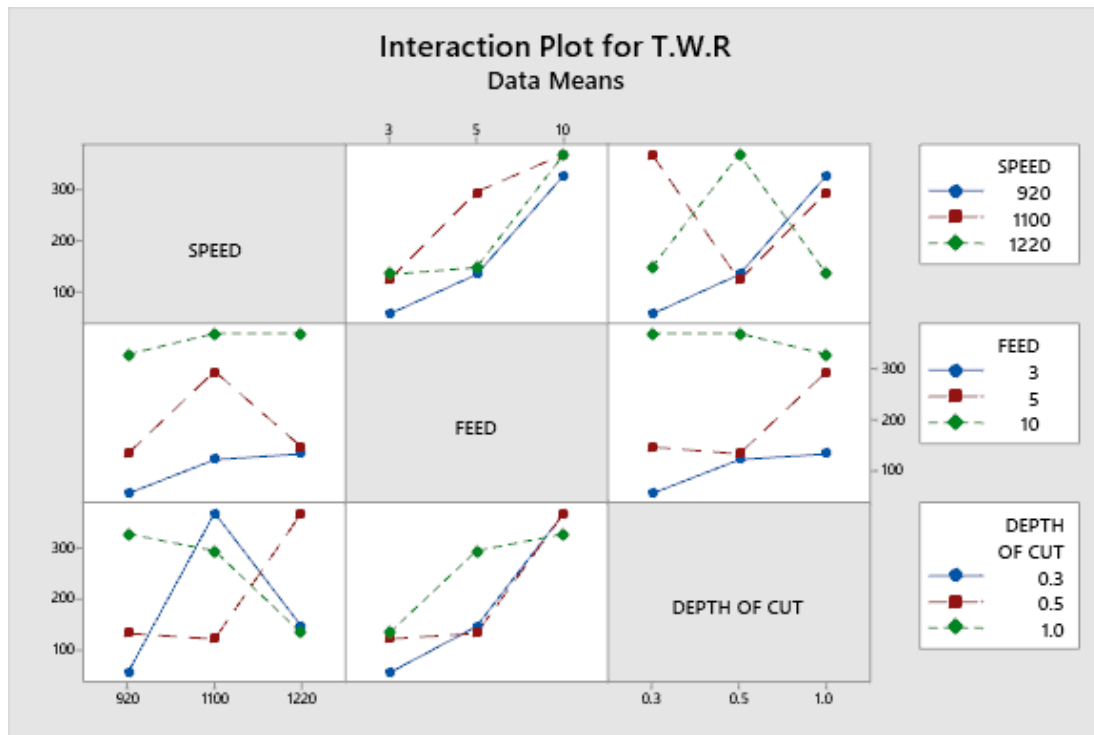


Figure: 12

The above Fig indicates Interaction plots of TWR

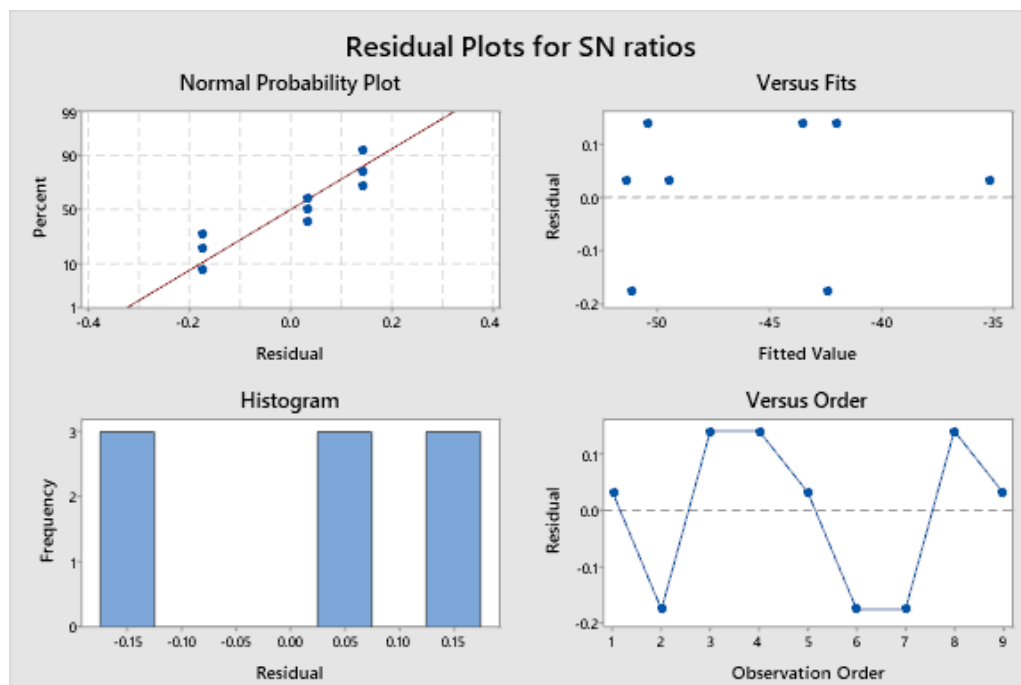


Figure: 13

The above fig Indicates Residual plots for S/N ratios of TWR.

From the figs 10,11,12, and13 shows the optimized levels of input parameters for MINIMUM TOOL WEAR RATE are second level of speed (1100) rpm, THIRD level of FEED (10) mm/rev and the third level of DEPTH OF CUT (1.0) mm.

The TOOL WEAR RATE Decreases within decrease of FEED and SPEED. For this project we use both S/N ratio and ANOVA for analyzing the result and make it fast to reach the optimum levels of parameters for minimum TOOL WEAR RATE and to give flawless result.

ANOVA finds out the ratio between the Regression mean square and mean square error and it is known as F- ratio or variance ratio.

Regression Equation		
T W. R	=	-235 + 0.175 SPEED + 35.33 FEED + 87.9 DEPTH OF CUT

Tables 5 show us that percentage contribution of each of the parameter. It is observed that parameters FEED (mm/rev) and speed (rpm) had the most significant influence on TWR and the other parameter DEPTH OF CUT (mm) was not significant with the specific experimental range.

Analysis of Variance

Table 5

Source	DEGREES OF FREEDOM	Seq SUM OF SQUARES	Contribution	Adj SS	Adj MEAN SQUARES	F- Value	P- Value
Regression	3	107542	90.70%	107542	35847	16.26	0.005
SPEED	1	4179	3.52%	4179	4179	1.90	0.227
FEED	1	97333	82.09%	97333	97333	44.16	0.001
DEPTH OF CUT	1	6029	5.09%	6029	6029	2.74	0.159
Error	5	11021	9.30%	11021	2204		
Total	8	118562	100.00%				

The above Table indicates the Analysis of Variance of TWR with respect to the Input variables.

Figs: 14, 15, 16, 17, 18, 19 show the counter and response plots for TWR with respect to the selected input parameters. From the plots it is clear that the TOOL WEAR RATE increase with an increase of FEED rate and SPEED.

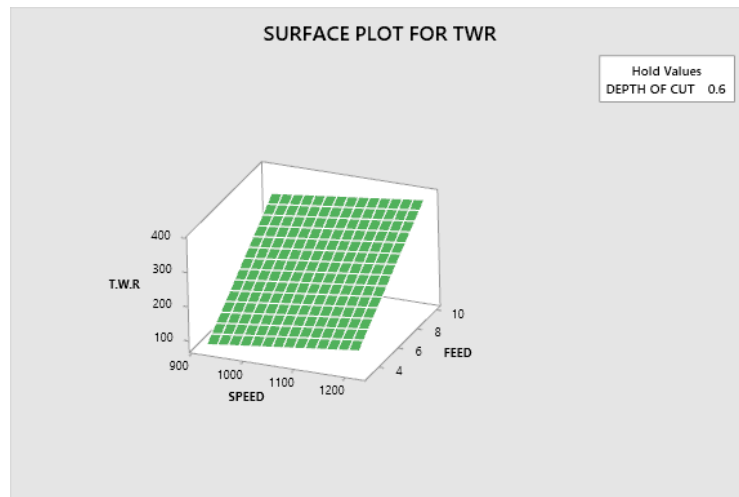


FIG 14

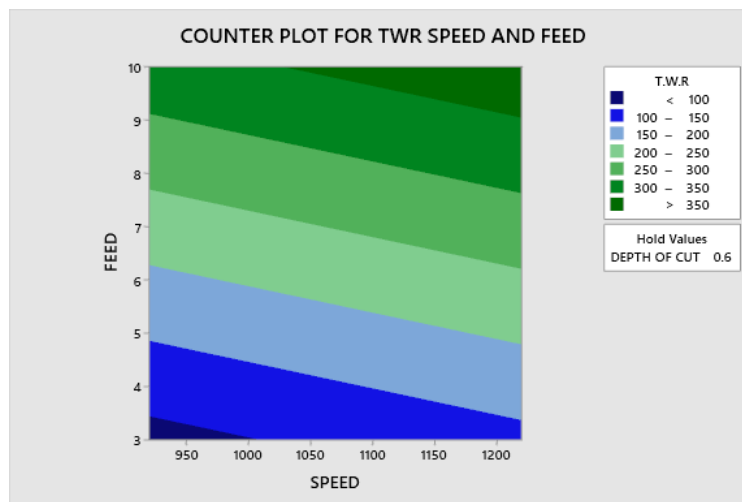


Fig 15

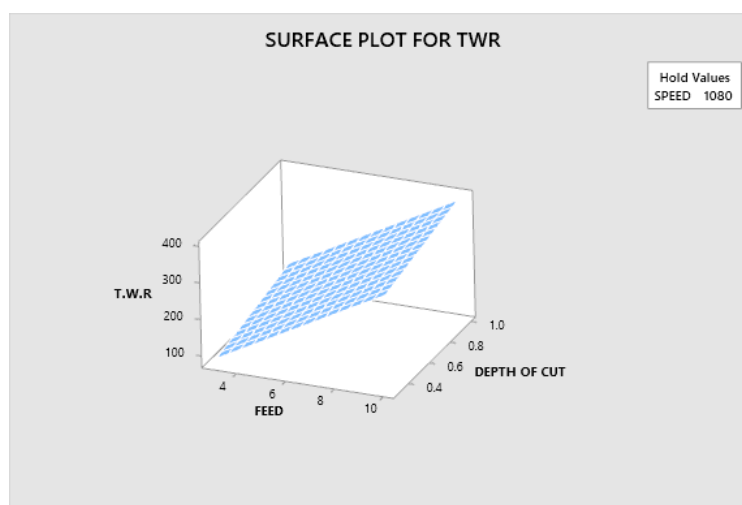


Fig 16

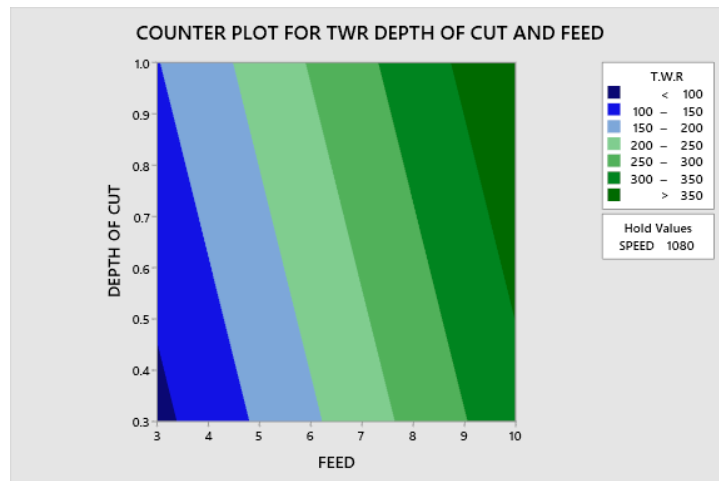


Fig 17

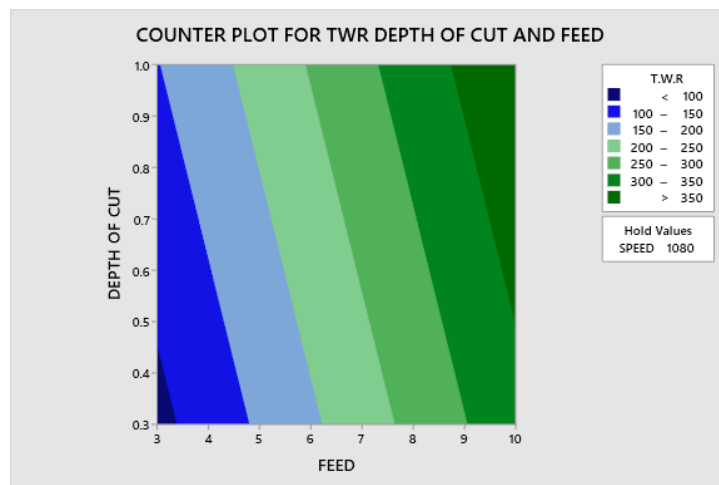
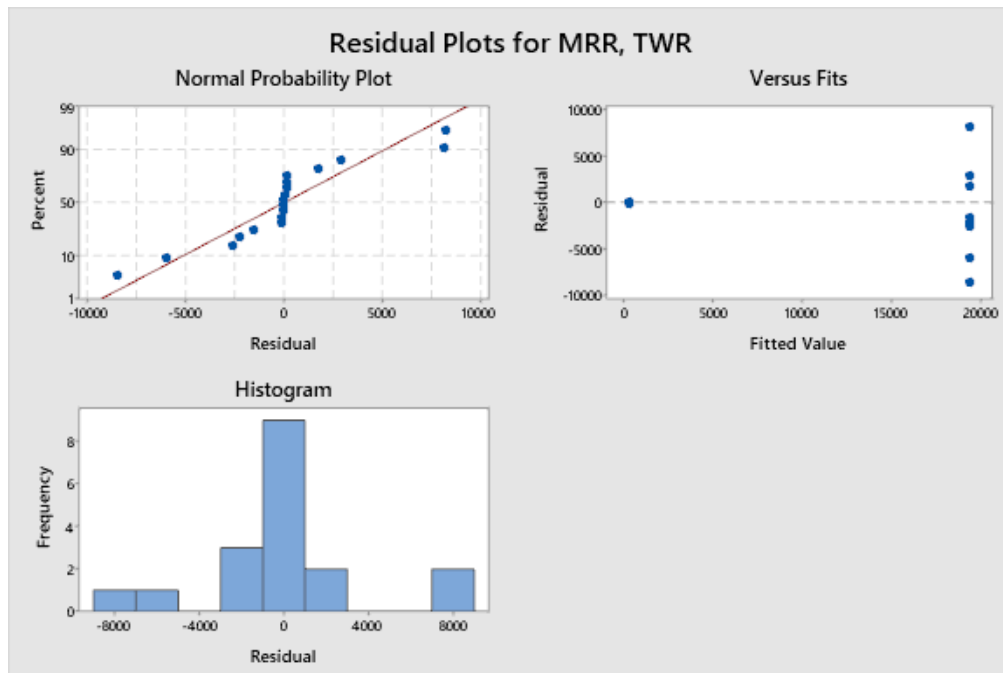


Fig 18



Fig 19

The above table indicates the analysis of variance of TWR with respect to Depth of Cut.



CONCLUSION

Taguchi method gives the optimal parameters in the CNC lathe turning process using High Speed Steel tool. The optimum set of speed, feed, depth of cut and the effect of machining parameters on Material Removal Rate. From S/N as the following:

Spindle speed: Material Removal Rate is increasing with increase in the spindle speed up to 1220 rpm. So, the optimum spindle speed is level 3

Feed rate: Material Removal Rate is increasing with increase in feed rate; the optimum level of feed rate is (10 mm/min) level 3.

Depth of cut: Material Removal Rate is increasing with increase in depth of cut; optimized depth of cut is 1.0mm (level 3).

In this paper of optimization of design parameters that effects the Tool Wear Rate on weight of the HSS tool used here has Presented by using Taguchi method. Some optimized values had summarized depending on the experimental results. The input parameters used to optimize were speed(mm), feed(mm/rev), depth of cut(mm). This analysis indicates speed and feed has significant influence on Tool Wear Rate (mm³/min). The optimized combination of levels are as follows, speed at level 2, (1100) rpm, feed at level 3, (10) mm/rev and depth of cut at level 3, (1.0) mm. The same results are shown from ANOVA also.

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