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Analysis of Optimal Selection of Machining Parameters on MRR and Surface Roughness using Taguchi Method

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ABSTRACT: The project work aims to investigate the cutting parameters in machine. In this study, a powerful approach to streamline the turning parameter, depending upon Taguchi strategies are displayed. The venture examines the utilization of Taguchi technique for limiting required surface roughness [Ra] and maximizing material removal rate [MRR] after machining. Experiments were conducted on the basis of L9 orthogonal array. Feed rate, speed and depth of cut were the three process parameters selected during machining. Orthogonal array, signal to noise ratio and the ANOVA [analysis of variance] were utilized to consider the presentation attributes in machining activities. Optimal values or ideal estimations of procedure parameters for desired performance characteristics are obtained by Taguchi design of experiments. The major aim of this study is to reduce power, machining time as well as to increase the productivity during machining.

KEYWORDS: machining, surface roughness [Ra], material removal rate [MRR], Taguchi method, ANOVA [analysis of variance].

I. INTRODUCTION

Mostly, manufacturing processes are used to increase the rate of productivity and to decrease cost. The most commonly used process in industry is turning process. This process maintains the surface finish and the quality of the product onto which the machining is carried out.

The motivation to choose this topic came from the literature review. MS carbon EN08 is one of the most commonly and widely used material in the field of manufacturing due to its cost, availability as well as its mechanical and physical properties. Due to its vast use in field of the engineering products, shafts, bolt and studs, and other automotive parts there is a need to optimize the machining parameters on MRR and surface roughness of MS carbon EN08 in turning operations to minimize time and cost and to increase the production rate. It is also very important to select the process parameters to achieve best performance characteristics in the plain turning process operation. There are various optimization techniques used for optimization out of which taguchi method and anova are mostly preferred. ANOVA approach helps to identify the most significant parameter for the given input process parameter whereas the taguchi method is helpful to determine the best optimal conditions with lesser number of experiments. Basically, taguchi method is a straightforward system utilized for the examination and enhancement of the process parameters. In this strategy, the fundamental parameters are accepted to have effect on process results are situated at various sections in a structured symmetrical array. Taguchi method generally consist of three stage process which are system design, choice of autonomous factors and the plan of symmetrical array.

II. LITERATURE SURVEY

Alagarsamy et al. [2014], studied the Taguchi method and Response surface methodology was applied to get a minimum surface roughness and maximum material removal rate for turning process of Aluminium Alloy 7075 using CNC machine via considering three influencing input parameters- Speed, Feed and Depth of Cut. The L27 orthogonal array is used in his design of expt.

Irfan et al. [2019], studied the Taguchi method and regression analysis were used to optimize the machining parameters for CNC turning of EN-45 spring steel by using the plain carbide cutting tool. L-18 orthogonal array was used for experimentation by which optimization was done. Feed rate, speed and depth of cut were considered as machining parameters on the basis of which the optimization process was carried out. ANOVA was obtained using MIMNITAB

software. The results shows that the speed and feed rate were directly proportional and the depth of cut were inversely proportional for the surface roughness whereas, for MRR all the three parameters were found to be proportional. Palaniappan et. al [2019] investigated the machining of aluminium 6082 alloy to identify the optimal parameters for CNC turning process. L27 orthogonal array was selected and optimization was done using Taguchi method. During experimentation parameters selected were speed, feed rate and depth of cut. His experiments resulted that the speed is most significant parameter for MRR whereas the feed rate was most significant for surface roughness. Mukherjee et al. [2014], carried out a study to optimize the process parameters viz. Cutting Speed, Feed rate and Depth of Cut with respect to material removal rate (MRR) in CNC Lathe of SAE 1020 steel using Taguchi method. Also, the effect of process parameters on material removal rate was investigated. L25 orthogonal array was used to conduct the experiments. The analysis showed that Depth of Cut had the most significant effect on MRR followed by Feed rate. With an increase in Depth of Cut MRR increased in the studied range. Optimum cutting parameter combination was found out for maximum MRR and this study will be useful in computer aided process planning. Sawant et al. [2018], investigated the effect of process parameters on material removal rate and surface roughness using CNC machine and aluminium as the work material. L-9 orthogonal array was employed to conduct the experimentation by varying three process parameters which were speed, feed rate, and depth of cut. The results obtained were analysed and verified using Minitab software. Thereafter he concluded the optimal solution amongst the many feasible solutions. Khare et al. [2018], conducted a study on “analysis of surface roughness during turning operation”, in which optimisation of machining parameters were done. This optimization was done on the basis of Taguchi’s design of experiments. The AA6061 material was used for the machining operation. After conducting the experiments it was observed that the rake angle is the dominant factor on the surface roughness and the optimization technique is more reliable and efficient tool used for the optimization of the machining parameters. Kumar et al. [2017], machined EN9 stainless steel using CNC turning process to investigate the affecting parameters while machining. The parameters such as feed rate, depth of cut, speed and lubrication were selected and carbide tip tool was used for the machining operation. The optimization was done using Taguchi’s L18 mixed type orthogonal array and ANOVA was applied to know significance of process parameters on response variable. On the basis of his study it was concluded that the MRR increases and surface roughness decreases with increase in feed, speed and depth of cut. It was also concluded that the feed rate and spindle speed has a significant effect on both the MRR and surface roughness. Yang et.al [1997], studied S/N ratio and ANOVA were used to find the cutting characteristics of S45C steel bar and the tungsten carbide tool was used for machining. L9 array was employed for the optimization of machining parameters and on the basis of the experiments performed optimal cutting parameters were verified.

III.EXPERIMENTATION

In this work firstly a long bar of MS Carbon EN8 was cut into 9 different bars having equal length. Then the input machining parameters such as speed, feed rate, and depth of cut were varied for the turning operation. MS Carbon EN8 is used in form of round bar of diameter 45 mm and 125 mm long. In this test the HSS tool is mounted on a tool holder and then employed for the experimentation. The experiments were designed according to the 3³ full factorial design. Formation of orthogonal array using 3 input parameters and considering 3 levels for operations L9 orthogonal array was selected.

The turning operation was carried out in order to obtain experimental output data in dry condition on lathe machine. Lathe machine was selected having spindle speed which ranges from 50 rpm to 1500 rpm respectively. Prior to actual machining operation the actual layer was of the work piece was removed by HSS tool to make the job true. The machined job was maintained to 44 mm diameter and a length of 124 mm. Then the actual machining operation with the various combinations using L9 array was done. The output variables like MRR and surface roughness were then determined. MRR was determined using standard formula and the surface roughness was determined using roughness tester in terms of arithmetic average value. The results obtained were then inserted in Minitab software to determine the effect of parameter on MRR and Surface roughness. Similarly, ANOVA module was used to determine the effect of individual parameter was determined. By analysing these results a best combination for turning operation is suggested.

IV.MATERIAL SELECTION

The machining operation were conducted on the lathe machine selecting material as MS carbon EN08 and high speed steel tool which is commonly known as HSS tool. MS Carbon EN8 is one of the mostly used manufacturing material to manufacture bolt, nut, studs, gears, shaft, axle, automotives and other engineering components. This material has vast applications because of its magnificent properties, low cost, and easy availability.

The information related to the chemical compositions and the properties of the MS Carbon EN8 are mentioned in tabular form below.

Table 1 chemical compositions of MS Carbon EN8

Composition	C	SI	Mn	P	S
Values (%)	0.41	0.3	0.78	0.03	0.025

Table 2 properties of MS Carbon EN8

Physical properties	values	Mechanical properties	Values
Poisson ratio	0.3	Max stress	700-800 N/m ²
Density	7800 kg/m ³	Yield stress	465 N/m ²
Thermal conductivity	37.5 W/mk	Hardness	201-205 BHN

The HSS tool used during the machining is maintained with the specific tool geometry as the tool geometry have high influence on the values of the surface roughness. The values of the various angles in the tool geometry were found using optical profile projector. These values obtained are presented in tabular form in table 3. The diagram represents the tool geometry of the HSS tool.

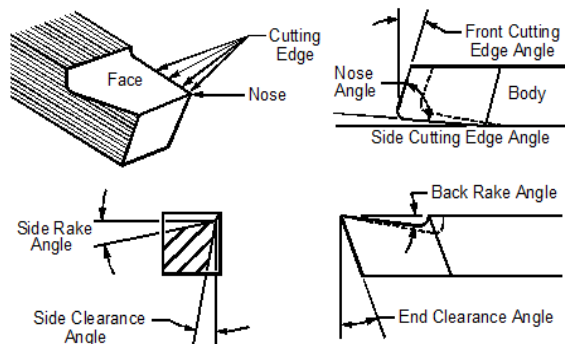


Figure 1 Various angles of HSS Tool

Table 3 Angles of HSS Tool selected

Sr.No.	Angle	Readings In degree
1	End cutting edge	12
2	Side cutting edge	7
3	Back rake	15
4	Side rake	5
5	End relief	6
6	Side relief	7

ADJUSTABLE CUTTING FACTORS IN TURNING

The most essential factors considered during the machining processes are speed, feed, depth of cut, rake angle, coolant, type of the tool used etc. From the above mentioned factors the most influencing factors on turning process are speed, feed, and depth of cut. Based on these parameters the overall analysis of the lathe machine was conducted to find the



values of the input parameters. The values obtained after detailed specification of lathe machine were listed in tabular form as shown below in the table 4.

Table 4 level of cutting parameters

Parameters	Unit	low	medium	High
Speed	Rpm	500	1000	1500
Feed rate	mm/rev	0.09	0.105	0.12
Depth of cut	mm	0.05	0.1	0.15

V. RESULT AND DISCUSSION

This section involves the general results obtained after machining operation on the selected work piece. Table 5 shows orthogonal array formed using three levels of operation for three input parameters, along with this data it contains results of surface roughness which are founded for each workpiece after machining by SJ Mitutoyo- portable surface roughness tester and MRR using standard formula [1] specified below.

$$MRR = \frac{(D^2 - d^2) \cdot \frac{\pi}{4} \cdot L}{\text{MACHINING TIME}}$$

Where,

D= diameter of the work piece before machining in mm.

d= diameter of the work piece after machining in mm.

L= length of work piece machining in mm.

Table 5 Orthogonal array and calculations for the response variables

sr.no	speed	feed	Depth of cut	S/F Roughness	MRR
1	500	0.09	0.05	8.66	151.94
2	1000	0.09	0.1	9.89	514.4
3	1500	0.09	0.15	6.77	1011.31
4	500	0.105	0.1	5.67	443.36
5	1000	0.105	0.15	5.51	877.93
6	1500	0.105	0.05	5.11	434.6
7	500	0.12	0.15	5.55	716.04
8	1000	0.12	0.05	8.27	315.26
9	1500	0.12	0.1	6.35	898.49

From the overall review of the literature survey it can be stated that Taguchi method cannot judge the effect of individual parameter on the whole process. In order to find the effect of individual parameter on the process Minitab software of ANOVA module is be employed.

Response table for surface roughness and MRR.

S/N ratio of the parameter can be categorised in to three types mainly, smaller the better, nominal the better, larger the better. In order to minimise surface roughness, smaller the better criteria is preferred.

Table 6 S/N ratios of surface roughness, smaller is better

Level	Feed Rate	Speed	Depth of cut
1	-1.42	-16.24	-17.09
2	-14.69	-17.69	-17.01
3	-16.43	-15.61	-15.44
Delta	3.73	2.08	1.65
Rank	1	2	3



Table 6 Shows that feed rate is more significant on surface roughness as compare to other parameters, and depth of cut is less significance on surface roughness. Theory suggests that surface roughness is function of feed rate [2].

Table 7 S/N ratios of MRR, larger is better

Level	Feed rate	speed	Depth of cut
1	52.65	51.22	48.79
2	54.86	54.36	55.41
3	55.38	57.31	58.69
Delta	2.73	6.09	9.9
Rank	3	2	1

Table 7 Shows that depth of cut is more significant on material removal rate as compare to other parameters and feed rate is less significant on material removal rate. As a result depth of cut is straight forwardly related to the material removal rate [2].

Response table for surface roughness

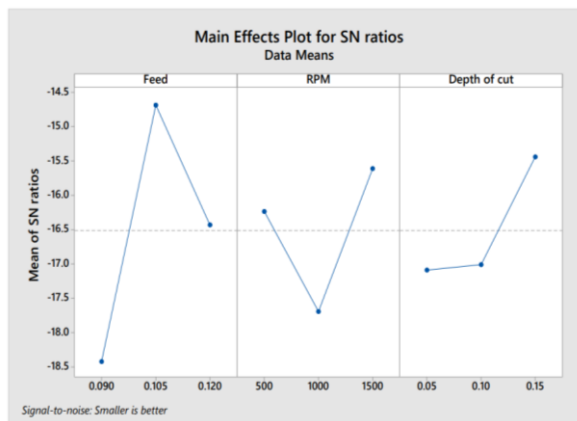


Figure 2

Significance of machining parameters of surface roughness indicates that feed is drastically contributing towards the machining performance. Plot for S/N ratio shown in Figure 2 explains that there is a smaller amount of variation for change in depth of cut where as there is considerable variation for change in feed rate.

Response plot for MRR

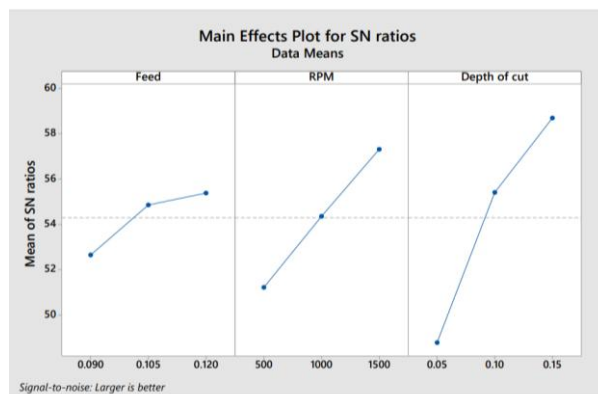


Figure 3

Significance of machining parameters of material removal rate indicates that depth of cut is significantly contributing towards the machining performance. Plot for S/N ratio shown in Figure explains that there is a smaller amount of variation in feed rate where as there is major variation for depth of cut.

Analysis of variance for S/N ratios of s/f roughness

Table 8 surface roughness analysis

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Feed	2	13.6798	6.83988	1966.74	0.001
Speed	2	5.1867	2.59334	745.69	0.001
Depth of cut	2	3.8208	1.91041	549.32	0.002
Error	2	0.0070	0.00348		
Total	8	22.6942			

Table 6 & 7 shows S/N ratios for responses. Now from surface roughness analysis (table 8), F value (1966.74) of parameter indicates that feed rate is extensively contributing towards surface finish & machining performance. F value (549.32) of parameter indicates that depth of cut is contributing less towards surface finish. It can be observed from rough surface for the specimen No. 2 (cutting speed:- 1000 rpm; depth of cut:- 0.1 mm; feed :- 0.09 mm/rev) and smooth surface for the specimen No. 6 (cutting speed:- 1500 rpm; depth of cut:- 0.05 mm; feed :- 0.105 mm/rev) as shown in Table 3.

Analysis of variance for S/N ratios of material removal rate.

Table 9 Material Removal Rate Analysis

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Feed	2	11104	5552	0.95	0.513
Speed	2	181084	90542	15.46	0.061
Depth of cut	2	485985	242992	41.48	0.024
Error	2	11715	5858		
Total	8	689888			

From MRR analysis (table 9), F value (41.48) of parameter indicates that Depth of Cut is extensively contributing towards MRR & machining performance. F value (0.95) of parameter indicates that Feed Rate is contributing less towards Material removal rate. The specimen No. 3 (cutting speed – 1500 rpm; depth of cut – 0.15 mm; feed – 0.09 mm/rev) has highest Material removal rate and the specimen No. 1 (cutting speed – 500 rpm; depth of cut – 0.05 mm; feed – 0.09 mm/rev) has lowest MRR as shown in table 5.

VI. CONCLUSION

On the basis of scope and limitations of the present work, the following conclusions can be drawn from the results of the experiments and analysis of the experimental data in connection with turning of MS carbon EN08. Taguchi method of experimental design has been applied for optimizing multi response process parameter for turning are optimized with L9 orthogonal array. Results obtained from Taguchi method matches with results obtained from ANOVA. Within the range of parameters selected, following conclusions can be drawn.

- 1] Minimum surface roughness are found at cutting speed – 1500 rpm; depth of cut – 0.05 mm; feed – 0.105 mm/rev. The results from ANOVA for surface roughness specify Feed is most influencing parameters corresponding to the quality characteristics of surface roughness.
- 2] Maximum MRR are found at cutting speed - 1500 rpm; depth of cut – 0.15 mm; feed – 0.09 mm/rev. The results from ANOVA for MRR specify Depth of cut is most significant parameter on MRR.

3] By observing table 5, the surface roughness value corresponding to highest MRR of specimen no. 5 is $5.511\mu m$. This value of surface roughness is nearer to the surface roughness value of smooth surface. Hence Combination of parameters of specimen no. 5 gives optimum MRR with smooth surface finish. Desired values of parameters are cutting speed - 1000 rpm; depth of cut – 0.15 mm; feed – 0.105 mm/rev. As a result, the optimisation of complicated multiple performance characteristics can be greatly simplified using this approach.

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