Optimize Process Parameters for Comparative Study of MRR on Turning using HSS and Carbide Tool using Taguchi and ANOVA

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ABSTRACT

The present work concerned an experimental study of turning on EN8 steel of grade SAE (AISI) 1040 by a carbide insert tool and HSS tool. The primary objective of the ensuing study was to use the Taguchi method in order to determine the effect of machining parameters viz. cutting speed, feed, and depth of cut, on the material removal rate of the machined material. The objective was to find the optimum machining parameters so as to maximize the material removal rate for the selected tool and comparative study for cutting tool. L9 orthogonal array was selected and S/N ratios were analyzed to study the MRR characteristics. The relationship between the machining parameters and the response variables (MRR) were modeled and analyzed using the Taguchi method. Analysis of Variance (ANOVA) was used to investigate the significance of these parameters on the response variables Main effects plots from the ANOVA were obtained and studied. The quadratic models were found to be significant with a p-value of 0.057, 0.059 and 0.089. Results showed that feed is the most significant and cutting speed least significant factor affecting MRR using carbide tool, p-value of 0.042, 0.043 and 0.232. Results showed that feed is the most significant and depth of cut is least significant factor affecting MRR using HSS tool.

Keyword: - *Taguchi, EN8, Orthogonal array, carbide, HSS tool etc….*

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1. INTRODUCTION

In present industrialization world in engineering applications a number of materials are in use An unalloyed medium carbon steel is one of among all the materials, EN8 also known as 080M40, containing 0.36 % to 0.44 % of carbon (e.g. AISI 1040 steel).

A manufacturer focuses on the quality, quantity and product dimensional accuracy during the manufacturing. They always try to reduce manufacturing time, wear rates (of machine and tool used), high productivity to reduce cost of manufacturing and maintenance cost. From the number of machining operations turning is the one of the common machining process and is widely used in variety of manufacturing industries. Productivity and quality of the product depends upon the input parameters selected during the fabrication of the part. Generally the MRR depends upon the cutting speed, feed and depth of cut input parameters. The use of EN8 steel are in Automotive parts, Connecting rods, Studs, bolts, Axles, spindles, General engineering components made up of this. EN8 is a medium strength steel, good tensile strength. Suitable for shafts, stressed pins, studs, keys etc

For the machining of metals Selection of Insert for machining of part depends upon the strength and hardness of material to be machined. In the present study AISI 1040 is selected for machining because of sufficient strength and low wear rate for machining EN8 and also it is cost effective.

2. MATERIALS AND METHOD

EN8 is a medium strength steel, good tensile strength and machined in any condition. EN8 or 080m40 can be tempered at a heat of between 550°C to 660°C (1022°F-1220°F), heating for about 1 hour for every inch of thickness, then cool in oil or water. Normalizing of EN8 bright Mild Steel takes place at 830-860°C (1526°F-

1580°F) then it is cooled in air. Quenching in oil or water after heating to this temperature will harden the steel. EN8 is a medium strength steel, good tensile strength. Suitable for shafts, stressed pins, studs, keys etc

Fig -1: EN8 material work piece after machining

Table -1: Chemical Composition of EN8 steel

Grade	C	Mn	P	S	Si
EN8	0.36-0.44	0.60-1.00	0.05	0.005	0.10-0.40

Table -2: Physical Properties of EN8 steel

Tensile Strength (psi)	Yield Strength (psi)	Elongation In 2in. %	Reduction In Area %	Brinell Hardness
76000	42000	18	40	149

2.1 Weighing Machine

The material removal rate (MRR) of work piece was calculated by measuring the weight of work piece after machining period. For this, weighing machine was used with an accuracy of 0.001 gram is as shown in figure 3.1. Precision balance was used to measure the weight of the work piece and tool. Precision balance was used to measure the weight of the work piece This machine capacity is 300 gram and accuracy is 0.001 gram and Brand: SHINKO DENSHI Co. LTD, JAPAN, Model: DJ 300S

Fig -2: Weighing Machine

2.2 Cutting Tool

For the machining of EN8 steel two types of single point tool were used: carbide and HSS Tool.

Cemented carbides or sintered carbides tool have high hardness over a wide range of temperatures, high thermal conductivity, high Young's modulus making them effective tool and die materials for a range of applications. The two types of carbide tool used for machining are tungsten carbide and titanium carbide. A wide range of grades are available for different applications. Sintered carbide tips are the dominant type of material used in metal cutting. The proportion of cobalt (the usual matrix material) present has a significant effect on the properties of carbide tools. 3 - 6% matrix of cobalt gives greater hardness while 6 - 15% matrix of cobalt gives a greater toughness while decreasing the hardness, wear resistance and strength. Tungsten carbide tools are commonly used for machining steels, cast irons and abrasive non-ferrous materials. Titanium carbide has a higher wear resistance than tungsten but is not as tough. With a nickel-molybdenum alloy as the matrix, TiC is suitable for machining at higher speeds than those which can be used for tungsten carbide. Typical cutting speeds are: 30 - 150 m/min or 100 - 250 when coated.

High Speed Steel is a high carbon tool steel, containing a large dose of tungsten. A typical HSS composition is: 12-18% tungsten, 4% Chromium, 1-5% Vanadium, 0.7% carbon and the rest, Iron. HSS tools have a harness of 62-64 Rc. The additions of 5 to 8% cobalt to HSS impart higher strength and wear resistance. Typical cutting speeds 10 – 60 m/min.

Fig -3: Figure (a) carbide tool & figure (b) HSS tool

3. EXPERIMENTATION

Experiment was performed on centre lathe machine made by OSWAL MACHINERY & TOOLS CORPORATION LUDHIANA PUNJAB. This is an automatic feed centre lathe with manual depth of cut. Turning operation was performed for machining "Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece and to produce a smooth finish on the metal"

Fig -4: Centre lathe machine used for turning

Table -3: Turning Parameters and Their Levels

Response Parameters	**MRR (mm^3/min)**		
Control Parameters	Levels		
	A	B	C
Cutting speed	20	40	60
Feed Rate	0.1	0.2	0.3
Depth of Cut	0.3	0.6	0.9

3.1 Taguchi Method

Taguchi method is the process of engineering optimization in a three step approach namely system design, parameter design and tolerance design. In the system design, a basic functional prototype design will be produced by applying scientific and engineering knowledge. In parameter design, independent process parameter values will be optimized and where as in tolerance design, tolerances will be determined and analyzed for optimal values set by parameter design. Taguchi method is a powerful design of experiments (DOE) tool for optimization of engineering processes.

The parameter design of the Taguchi method consists of following steps [9]:

1. Identify the performance characteristics and select process parameters to be evaluated.
2. Determine the number of levels for the process parameters and possible interactions between the process parameters.
3. Select the appropriate orthogonal array and assignment of process parameters to the orthogonal array.
4. Conduct the experiments based on the arrangement of the orthogonal array.
5. Calculate the total loss function and the S/N ratio.
6. Analyze the experimental results using the S/N ratio and ANOVA.
7. Select the optimal levels of process parameters.
8. Verify the optimal process parameters through the confirmation experiment.

Signal-to-Noise ratio of the quality characteristics is divided into the Larger the Better, Nominal the Better, and the Smaller the Better in the definition of Taguchi Method. This study aims to increases the material removal rate of work piece. Higher the MRR, Higher the productivity will be. In this case, the Larger the Better (LTB) is used to compute the Signal-to-Noise ratio of the MRR, as shown in equation (1).

$$S/N_{LTB} = -10\log_{10}\left(\frac{1}{n}\sum\frac{1}{yi^2}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where yi is the performance response to the ith setting of the parameter combination, and n is the number of samples. L9 orthogonal array was used for the experimentation. Following the analysis of variance (ANOVA), the experimental results are acquired by independently extracting the main effects of these factors and determining the statistically significant factors. This process identifies the controlling factors and optimizes the magnitude of the effects accordingly. The design of experiments is shown in Table 4.

Table -4: L9 Orthogonal Array

S. no.	Cutting Speed	Feed Rate	Depth of Cut
1	20	0.1	0.3
2	20	0.2	0.6
3	20	0.3	0.9
4	40	0.1	0.9
5	40	0.2	0.3

6	40	0.3	0.6
7	60	0.1	0.6
8	60	0.2	0.9
9	60	0.3	0.3

3. RESULT AND DISSCUSSION

After performing the experiments, the output responses (MRR) values were calculated by equation 2. and the results were tabulated for carbide and HSS tool.

$$MRR\ (mm^3/min) = \frac{[\text{Initial Weight of Work piece (gm)} - [\text{Final Weight of Work piece (gm)}]}{\text{Density } (gm/mm^3) \times \text{Machining Time (min)}} \quad \ldots\ldots (2)$$

The density of the mild steel is taken as 7.87 x 10^{-3} gm/mm^3

Table -5: Experimental data for carbide tool

S. no.	Cutting Speed	Feed Rate	Depth of Cut	MRR	S/N Ratio
Unit	(m/min)	(mm/rev)	(mm)	gm/mm^3	db
1	20	0.1	0.3	86173.25	98.707
2	20	0.2	0.6	74500.64	97.443
3	20	0.3	0.9	93011.46	99.371
4	40	0.1	0.9	114649.68	101.187
5	40	0.2	0.3	18048.41	85.129
6	40	0.3	0.6	21569.43	86.677
7	60	0.1	0.6	83731.72	98.458
8	60	0.2	0.9	52738.85	94.443
9	60	0.3	0.3	5847.13	75.339

Table -6: Response table of S/N Ratio for carbide tool

Level	Cutting speed	Feed Rate	Depth of Cut
1	98.51	99.45	98.33
2	91.00	92.34	86.39
3	89.41	87.13	94.19
Delta	9.09	12.32	11.94
Rank	3	1	2

Table -7: Response table of mean for carbide tool

Level	Cutting speed	Feed Rate	Depth of Cut
1	84562	94852	86800
2	51423	48429	36690
3	47439	40143	59934
Delta	37123	54709	50110
Rank	3	1	2

Table -8: Experimental data for HSS tool

S. no.	Cutting Speed	Feed Rate	Depth of Cut	MRR	S/N Ratio
Unit	(m/min)	(mm/rev)	(mm)	gm/mm^3	db
1	20	0.1	0.3	67070.06	96.531
2	20	0.2	0.6	75592.36	97.570
3	20	0.3	0.9	32038.85	90.114
4	40	0.1	0.9	54649.68	94.752
5	40	0.2	0.3	21974.52	86.838
6	40	0.3	0.6	8141.40	78.214
7	60	0.1	0.6	29205.86	89.309
8	60	0.2	0.9	12707.01	82.081
9	60	0.3	0.3	2382.17	67.539

Table -9: Response table of S/N Ratio for HSS tool

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Table -10: Response table of mean for HSS tool

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Delta	37123	54709	50110
Rank	3	1	2

Table -11: Analysis of Variance for SN ratios with carbide tool

Source	DF	Seq SS	Adj MS	F	P	% of Contribution
Cutting speed	2	141.60	70.802	10.20	0.089	23.38
Feed Rate	2	229.56	114.782	16.54	0.057	37.90
Depth of Cut	2	220.61	110.305	15.90	0.059	36.43
Residual Error	2	13.88	6.938			2.29
Total	8	605.65				100

Table -12: Analysis of Variance for SN ratios with HSS tool

Source	DF	Seq SS	Adj MS	F	P	% of Contribution
Cutting speed	2	342.47	171.234	22.14	0.043	45.19
Feed Rate	2	348.54	174.272	22.53	0.042	45.99
Depth of Cut	2	51.32	25.658	3.32	0.232	6.77
Residual Error	2	15.47	7.734			2.04
Total	8	757.80				100

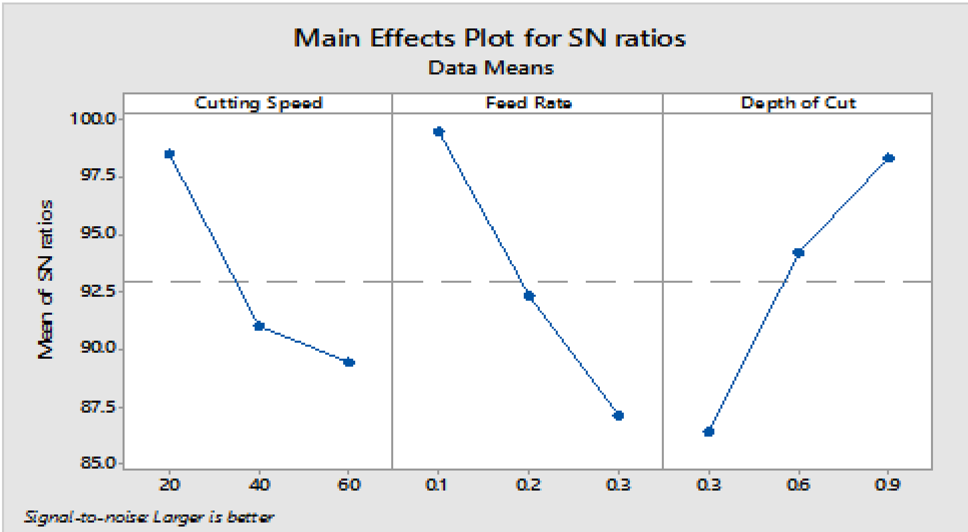

Chart -1: Main effect plot for SN Ratio of MRR (for Carbide tool)

This graph is between SN ratio of MRR verses the three different levels (A1,B2,C3) of the input parameters i.e. Cutting Speed, Feed and Depth of Cut A greater value of S/N ratio is always considered for better performance regardless of the category of the performance characteristics. This graph shows that which level of the parameter results in maximum material removal rate. According to this graph, first level of Cutting Speed results in maximum material removal rate. Similarly, the first level of feed rate, third level of Depth of cut results in maximum material removal rate.

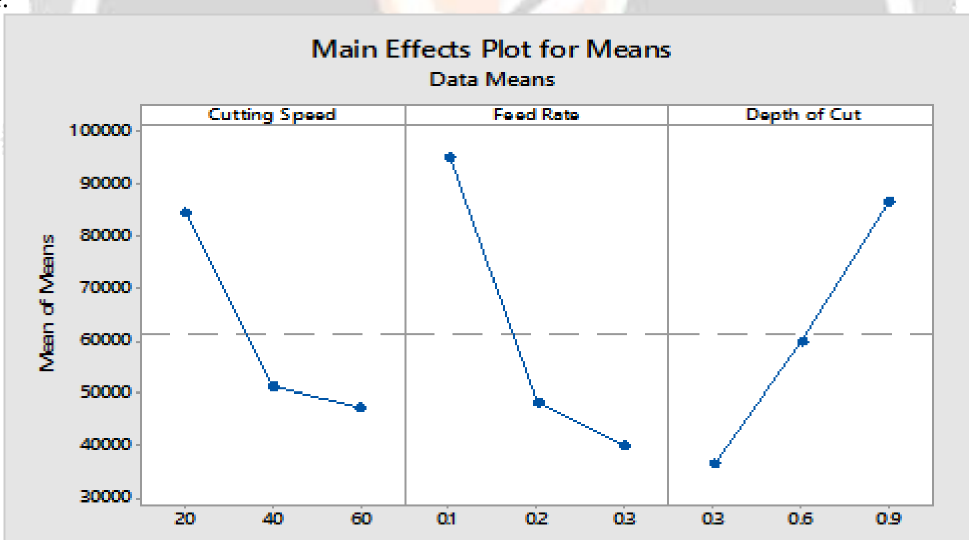

Chart -2: Main effect plot for Means of MRR (for Carbide tool)

This graph is between the means of MRR verses the three levels (A1, B2, C3) of input parameters i.e. cutting speed, feed rate, and depth of cut. This graph shows that maximum value of the means results in maximum material removal rate. Hence, first level of cutting speed, first level of feed rate and third level of depth of cut results in maximum material removal rate.

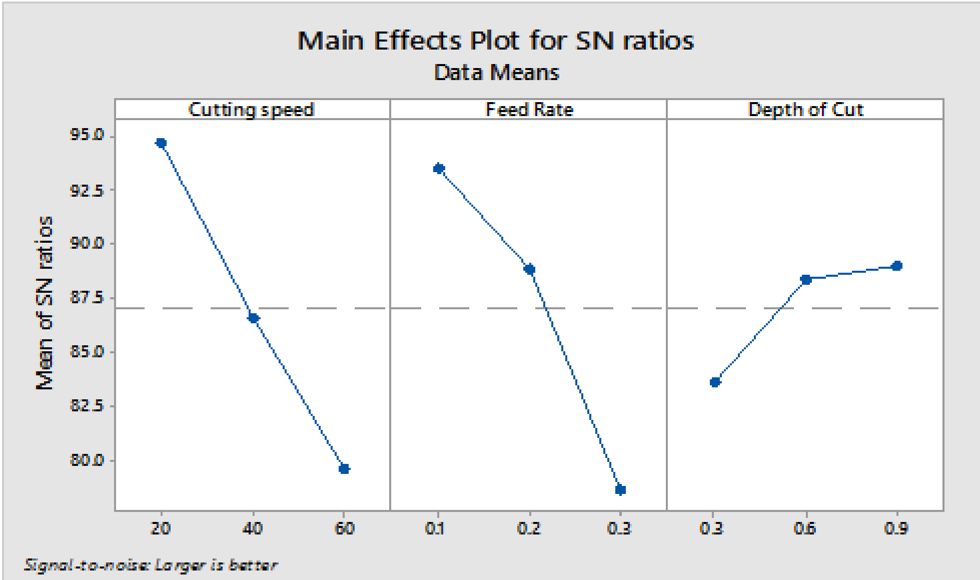

Chart -3: Main effect plot for SN Ratio of MRR (for HSS tool)

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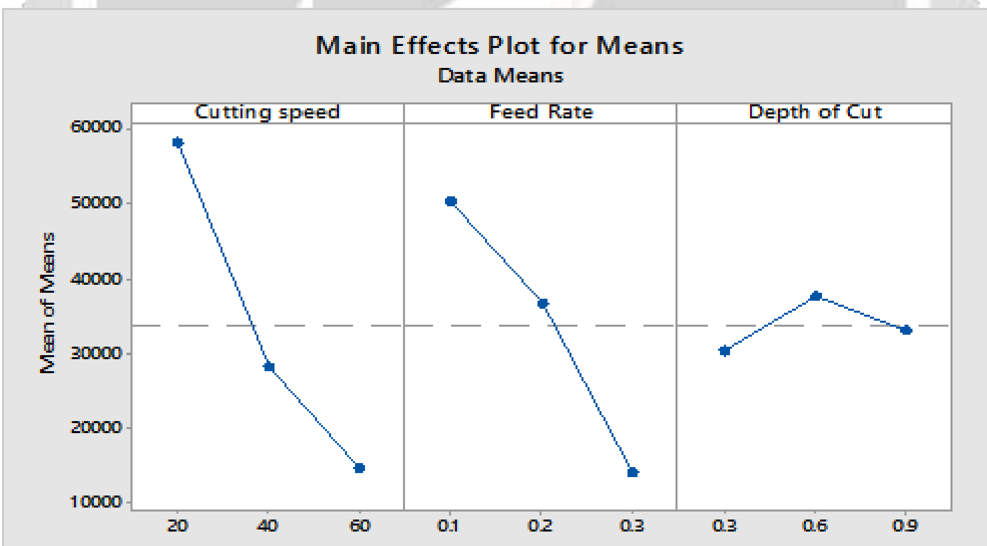

Chart -4: Main effect plot for Means of MRR (for HSS)

This graph is between the means of MRR verses the three levels (A1,B2,C3) of input parameters i.e. cutting speed, feed rate, and depth of cut. This graph shows that maximum value of the means results in maximum material removal rate. Hence, first level of cutting speed, first level of feed rate and third level of depth of cut results in maximum material removal rate.

Optimal setting for material removal rate when carbide tool was used in the experiment level is as
Cutting Speed = 20 m/min
Feed Rate = 0.10 mm/rev

Depth of Cut = 0.9 mm

Optimal setting for Material Removal Rate when HSS tool was used in the experiment level is as
Cutting Speed = 20 m/min
Feed = 0.10 mm/rev
Depth of Cut = 0.9 mm

4. CONCLUSIONS

The experimental study has focused an application of the Taguchi method for the optimization of process parameters of turning operations. As discussed earlier, the parameter design of the Taguchi method provides a simple, systematic, and efficient methodology for the optimization of the cutting parameters. Except machining time, cutting parameters such as cutting speed, feed rate, and Depth of cut mainly influenced the MRR of EN8 steel rod. The optimal combination of turning parameters and their levels for the MRR of the turning process are A1B1C3 (i.e. cutting speed- 20 m/min, feed rate- 0.10 mm/rev and depth of cut- 0.9 mm). The percentage contributions of cutting speed, feed rate and depth of cut for carbide tool are 23.28%, 37.90% and 36.43% respectively.

The percentage contributions of cutting speed, feed rate and depth of cut for HSS cutting tool are 45.19%, 45.99% and 6.77% respectively.

Hence, significant improvements in MRR can be obtained using this approach. Finally, it can be a very useful technique for use to the industries to optimize the machining performance with minimum cost and loss of time.

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