Experimental Analysis on Turning parameters for Surface roughness and MRR

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***Abstract*—The objective of this paper is to obtain an optimal setting of turning parameters (Spindle speed, Feed rate and Depth of Cut) which results in an optimal value of Surface Roughness and MRR while machining AISI 1018 steel alloy with Titanium coated Carbide Inserts (TN4000). Also an attempt has been made to optimize the process parameters using Taguchi Technique. S/N ratio and ANOVA analysis were also performed to obtain significant factors influencing Surface Roughness and MRR.**

***Keywords*—Turning process, Surface roughness, MRR, Taguchi Method, ANOVA**

I. INTRODUCTION

Turning processes are replacing grinding for finishing various mechanical components of hardened steels such as transmission shafts, bearings and gears for the automotive industry, as well as landing gear struts for the aerospace industry. It is characterized by development of high temperatures at the cutting zone, which impairs the surface quality of the final product. Turning with multilayer coated carbide tool has several benefits over grinding process such as, reduction of processing costs, increased productivities and improved material properties [1]. Several researchers have established that hard coatings deposited on tool and machine parts by different physical vapour decomposition methods can improve the performance of the parts. These coated materials not only help reducing the wear and increasing the tool life but also improve strength and chemical inertness, reduce friction, and make the parts more stable at high temperatures. **Noordin et al** [2] introduced hard turning to manufacture parts made from hardened steels. TiAlN coated carbide tool was selected to finish machine hardened steel. Performing hard turning dry at various cutting conditions, that is, cutting speed and feed rate, revealed that satisfactory tool life values and surface finish values that meet the strict range of finish machining were obtained when finish machining hardened steel of 47–48 HRC hardness. R. Suresh et al [3] have analyzed the effects of process parameters on machinability aspects by using multilayer hard coatings (TiC/TiCN/Al2O3) on cemented carbide substrate for machining of hardened AISI 4340 and have found that the optimal combination of low feed rate and low depth of cut with high cutting speed is beneficial for reducing machining force. Higher values of feed rates are necessary to minimize the specific cutting force. Kyung-Hee Park et al [4] have analyzed the flank wear on the multi-layer (TiCN/Al2O3/TiCN) coated carbide inserts while turning AISI 1045 steel using advanced microscope and image processing techniques including wavelet transform, they have obtained the flank wear profiles and analyzed the surface roughness and groove sizes on the coating layers. D.I. Lalwani et al [5] investigated the effect of cutting parameters (cutting speed, feed rate and depth of cut) on cutting forces (feed force, thrust force and cutting force) and surface roughness in finish hard turning of MDN250 steel using coated ceramic tool. Noordin et al [6] presented hard turning of martensitic stainless steel using wiper coated carbide tool at various cutting speeds and feeds. The main purpose of this paper is to investigate the effects of machining parameters such as spindle speed, feed rate and depth of cut on the surface roughness and MRR of Turning operation AISI 1018 steel. Experiments were planned according to Taguchi's L_9 orthogonal array with 3 levels for each parameter.

II. EXPERIMENTATION

In the present investigation, AISI 1018 (42 mm diameter, 250 mm long) steel is selected. It has good strength, ductility, hardness, fatigue strength. AISI 1018 steel is used in industrial carburized parts that include worms, gears, pins, non-critical components of tool and die sets tool holders, pinions, machine parts, ratchets, dowels and chain pins. The chemical composition of AISI 1018 steel is shown in Table 1. The cutting tool selected were titanium coated carbide inserts (TN4000) of corner radius 0.800 mm. Figure 1 shows the schematic diagram and the setup of Turning process.

Table 1 Chemical composition of work-piece

Element	C	Si	Mn	Cr	Mo	Ni	Cu	p	S	V	Fe
Weight	0.298	0.176	0.46	0.012	0.002	0.010	0.027	0.058	0.097	0.005	98.81

There are various process parameters of CNC lathe affecting the material removal rate and surface roughness. On the basis of pilot run investigations, the following process parameters have been selected for study. Their levels are given in Table 2.

Table 2 Process parameters with their levels

Parameters	Unit	Levels		
		Level 1	Level 2	Level 3
Spindle speed	rpm	280	710	1120
Feed rate	mm/rev	0.35	0.45	0.56
Depth of cut	mm	0.5	0.6	0.7

Fig. 1. Experimental setup Turning process

2.1 Taguchi's Methodology

Taguchi method was developed by Dr. Genchi Taguchi this technique powerful tool for parameter design of performance characteristics, for the purpose of designing and improving the product quality [7]. This approach has been built on tradition Design of Experiments (DOE), such as full factorial, fractional factorial design and orthogonal array based on signal to noise ratio. In the Taguchi method, process parameters which influence the products are separated into two main groups: control factors and noise factors. The control factors are used to select the best conditions for stability in design or manufacturing process, whereas the noise factors denote all factors that cause variation. According to Taguchi based methodology, the characteristic that the larger value indicates better machining performance, such as material removal rate (MRR) and smaller value indicates the better machining performance, such as surface roughness is addressed as the larger-the-better and smaller-the-better type of problem respectively. The S/N Ratio, i.e. η, can be calculated as shown below:

S/N ratio for Material removal rate (MRR):

$$\eta = -10 log \frac{1}{n} \sum_{i=1}^{n} \frac{1}{Y_{MRR}^2} \qquad (1)$$

S/N ratio for Surface roughness (R_a):

$$\eta = -10 log \frac{1}{n} \sum_{i=1}^{n} Y_{Ra}^2 \qquad (2)$$

The value or parameter setting for these criteria is obtained by the process of trial and error for giving the most optimal result that is expected from this study.

Table 3 Design matrix and Experimental results

Run	Spindle speed (rpm)	Feed rate (mm/rev.)	Depth of cut (mm)	MMR (g/min)	S/N Ratio (db)	R_a (µm)	S/N Ratio (db)
1.	1	1	1	4644.9436	-15.1535	5.58	-14.9327
2.	1	2	2	9776.3949	-14.9275	5.89	-15.4023
3.	1	3	3	14248.354	-16.9551	6.84	-16.7011
4.	2	1	2	14748.409	-19.2026	8.86	-18.9487
5.	2	2	3	15436.708	-20.1423	9.91	-19.9215
6.	2	3	1	17736.886	-22.0673	13.40	-22.5421
7.	3	1	3	19205.094	-15.6080	6.37	-16.0828
8.	3	2	1	21978.022	-16.4451	6.45	-16.1912
9.	3	3	2	23234.445	-17.3070	7.15	-17.0861

III. RESULT AND DISSCUSSION

After all tests are conducted, decision made confirming which machining parameters affect the performance of a product or process, which level is optimum of each process parameters. S/N ratios selected based on their characteristics irrespective of the characteristic a higher S/N ratio value always represents the better performance. Therefore among the levels of each parameter the higher S/N ratio corresponds to optimal level (Table 4 and 5). The S/N ratio calculations were done for all the experiments in L_9 orthogonal array and the optimal MRR and Surface roughness was obtained at 1120 rpm spindle speed, 0.56 mm/rev feed rate and 0.7 mm depth of cut and 280 rpm spindle speed, 0.35 mm/rev feed rate and 0.6 depth of cut respectively. Fig. 2 draws plot of main parameters effect on MRR and Surface roughness. This plot is used to visuliaize the relation between parameters ant output response. Since analysis of the results the parameters at spindle speed (level 3), feed rate (level 3), depth of cut (level 3) gives the maximum MRR and spindle speed (level 1), feed rate (level 1), depth of cut (level 2) gives the minimization of surface roughness.

Table 4 S/N ratio response table for MRR

Parameters/Levels	Level 1	Level 2	Level 3	Delta	Rank
Spindle speed	78.74	84.04	86.61	7.87	1
Feed rate	80.79	83.47	85.13	4.33	2
Depth of cut	81.72	83.50	84.17	2.45	3

Table 5 S/N ratio response table for Surface roughness

Parameters/Levels	Level 1	Level 2	Level 3	Delta	Rank
Spindle speed	-15.68	-20.47	-16.45	4.79	1
Feed rate	-16.65	-17.17	-18.78	2.12	2
Depth of cut	-17.89	-17.15	-17.57	0.74	3

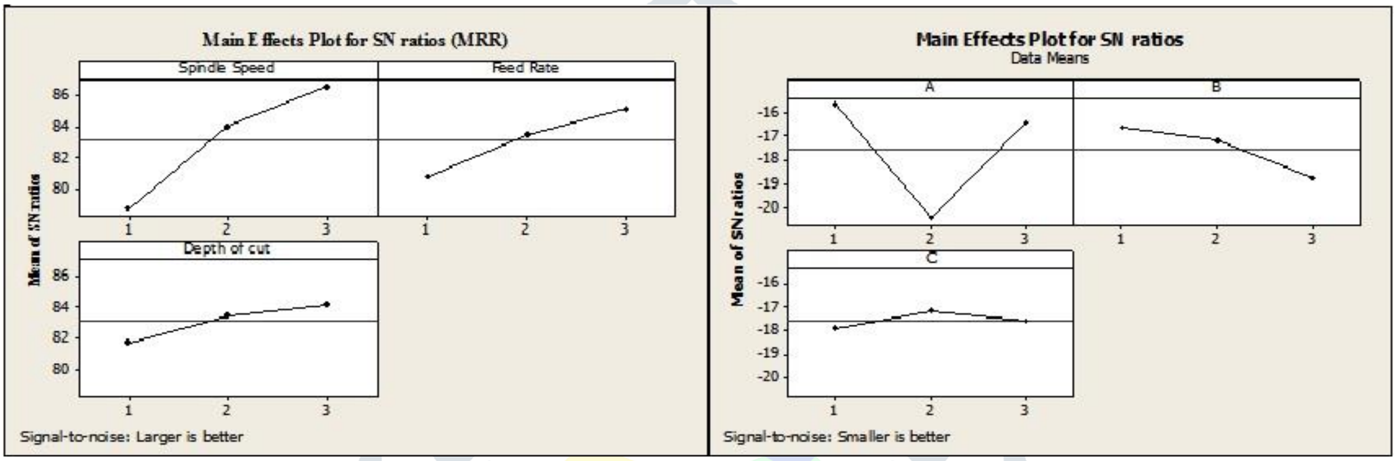

Fig. 2 Main effect plot for MRR and Surface roughness (Ra)

Table 5 ANOVA table for MRR

Parameters	DOF	Sum square	Mean square	F-ratio	Percentage
Spindle speed	2	21340722	106703611	21.74	78.173
Feed rate	2	46061940	23030970	4.69	16.873
Depth of cut	2	3706501	1853251	0.38	1.358
Error	2	9816448	4908224		3.597
Total	8	27299211			100

Table 6 ANOVA table for Ra

Parameters	DOF	Sum square	Mean square	F-ratio	Percentage
Spindle speed	2	38.188	19.094	15.85	75.297
Feed rate	2	7.977	3.988	3.31	15.728
Depth of cut	2	2.143	1.071	0.89	4.226
Error	2	2.409	1.204		4.749
Total	8	50.717			100

Analysis of variance (ANOVA) is a statically based, objective decision making tool for detaching any differences in average performance of groups of items tested. An ANOVA table consists of sum of squares, corresponding degree of freedom, the F-ratio corresponding to the ratios of two mean squares, and contribution proportions from each of control factors. Analysis of variance (ANOVA) was employed to find the significance of the parameters effect based on a 95% confidence interval and α risk equal to 0.05 is chosen. F-ratio values for MRR and Surface roughness that are shown in Table 5 and 6. From table 5 and table 6 find the most powerful parameters for the material removal rate (MRR) and surface roughness (Ra) of AISI 1018 (low carbon steel) is spindle speed respectively.

IV. CONFIRMATION EXPERIMENTS

A confirmation experiments is performed by conducting a test using a specific combination of the parameters and levels. The sample size of confirmation experiments is larger than the sample size of any specific trial in the previous factorial experiments. The final step of the Taguchi's parameters design after selecting the optimal parameters is to be predicted any verifying the improvement of the performance characteristics with the selected optimal machining parameters [Table 8]. The predicted S/N ratios using the optimal level of machining parameters can be calculated with the help of following prediction equation 3.

$$\eta_{opt} = \eta_m + \sum_{j=1}^{k} \left(\eta_j - \eta_m \right) \tag{3}$$

Here, η_{opt} is the predicted optimal S/N ratio, η_m is the total mean of the S/N ratios, η_j is the mean S/N ratio of at optimal levels and k is the number of main design parameters that affect the quality characteristics.

Table 8 Results of confirmation experiments for MRR and Ra

Response	Factor	Spindle speed (µs)	Feed rate (µs)	Depth of cut (A)	Predicted S/N ratio (db)	Experimental S/N ratio (db)
MRR (g/min)	Level	3	3	3	25359.23	24840.4
	values	1120	0.56	0.7		
Ra (µm)	Level	1	1	2	4.8085	4.6844
	Values	280	0.35	0.6		

V. CONCLUSSION

The following conclusions can be drawn from this investigation on turning of hardened AISI 1018 steel using titanium coated carbide inserts at different cutting parameters:

1. The investigated optimal process parameters, spindle speed (1120 rpm), feed rate (0.56 mm/rev.) and depth of cut (0.7 mm) are preferred for MRR of machined AISI 1018 steel.
2. The investigated optimal process parameters, spindle speed (280 rpm), feed rate (0.35 mm/rev.) and depth of cut (0.6 mm) are preferred for Surface roughness of machined AISI 1018 steel.
3. Based on analysis of variance (ANOVA); Spindle speed were found to be significant parameters for MRR and surface roughness with regression p-value less than 0.05.
4. It was found from the analysis that the parameters which affect the MRR and surface roughness in descending order are as follows: spindle speed, feed rate and depth of cut.

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