Turning Parameter Optimization for Surface Roughness Of AISI 4140 Alloy Steel By Taguchi Method

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Abstract- *In this research work machining of the AISI 4140 Alloy steel with the help of coated carbide insert of TNMG 432 PD M400 C7 CVD Al_2O_3 is performed. Analysis of the surface roughness is done experimentally with specific input values of feed, depth of cut and speed and gradually the optimal condition is found out. A relation between the inputs and the output is determined and thereafter, the analysis is done how the inputs affected the output. First using the full factorial composite design a layout of the experiment is made after which it is conducted. With the help of ANOVA (Analysis of Variance), the most effective or the optimal parameters and possible conclusions are made at the end.*

Keywords- AISI 4140 Alloy steel, CVD, ANOVA.

I. INTRODUCTION

CNC machining has become an indispensable part of the machining industry. The accuracy and precision achieved through the CNC cannot be achieved by the conventional manufacturing machines. Although the results of a CNC machining are not free from errors, these errors depend on the skill, experience and the cutting parameters used by the worker and hence can be rectified with practice. The main objective of manufacturing industries is to produce low cost, high quality products in short time for which the selection of optimal cutting parameters is a very important issue [1].

Surface roughness is an important measure of product quality because it greatly influences the performance of mechanical parts as well as the production cost. Surface roughness is a significant design specification of machine parts, which has a considerable effect on mechanical properties, such as wear resistance and fatigue strength. Surface quality is an important factor in evaluating machine tool productivity. Hence, achieving a consistent surface finish and tolerance is significant. Turning is the most common method for cutting and especially for finishing machined parts. In a turning operation, selecting the cutting parameters is necessary to achieve high cutting performance because cutting parameters affect surface roughness [2] Orthogonal arrays are three dimensional arrays of numbers which possess the interesting quality that by choosing any two columns in the array you receive an even distribution of all the pair-wise combinations of values in the array [3].

Zahia Hessainia et al [4] research work concerns the elaboration of a surface roughness model in the case of hard turning by exploiting the response surface methodology (RSM). The main input parameters of this model are the cutting parameters such as cutting speed feed rate, depth of cut and tool vibration in radial and in main cutting force directions. The machined material tested is the $42CrMo_4$ hardened steel by Al_2O_3 /TiC mixed ceramic cutting tool under different conditions. Mustafa Gunay et al[5], paper is focused on optimizing the cutting conditions for the average surface roughness (Ra) obtained in machining of high-alloy white cast iron (Ni-Hard) at two different hardness levels (50 HRC and 62 HRC). Machining experiments were performed at the CNC lathe using ceramic and cubic boron nitride (CBN) cutting tools on Ni-Hard materials. Cutting speed, feed rate and depth of cut were chosen as the cutting parameters

II. EXPERIMENTAL SET UP AND CUTTING CONDITIONS

Machining of the AISI 4140 Alloy steel with the help of coated carbide insert of TNMG 432 PD M400 C7 CVD Al_2O_3 is performed. The experiment was carried out with a Smarturn linear tool CNC lathe machine. The experiment was carried out in dry condition without using cutting fluid. The cutting condition of alloy steel rod in the turning operation is spindle speed, feed rate, and depth of cut parameters taken on the basis of optimizes the output value with the given input. The cutting condition also include the cutting insert and the turning operation take place in the absence of cutting fluid.

Table 1. Domain of experiment

SI No	Factor	Symbol	Unit	Level 1	Level 2	Level 3
1	DOC	d	mm	0.5		
2	FEED	f		0.1	0.6	0.7
3	SPEED	v	mm/rev			
			rpm	1900	0.2	0.3
					2000	2100

IV. RESULTS AND DISCUSSIONS

The experiment was conducted with a plan developed to analyse the effects of input parameters speed (V), feed (F) and depth (D) on the surface roughness parameters (Ra). Table 1 shows the results of the experiments for surface roughness and SN ratio Test no. 03 gave the minimum values Ra and test no.18 gave the maximum values for Ra

Table 2. Experimental Detail

S.No.	V	F	D	Ra(µm)	SN Ratio
1	1900	0.1	0.5	0.438	7.1705
2	2000	0.1	0.5	0.483	6.3211
3	2100	0.1	0.5	0.401	7.9371
4	1900	0.2	0.5	1.473	-3.3641
5	2000	0.2	0.5	1.514	-3.6025
6	2100	0.2	0.5	1.570	-3.9180
7	1900	0.3	0.5	3.063	-9.7229
8	2000	0.3	0.5	3.224	-
9	2100	0.3	0.5	3.255	10.1679
10	1900	0.1	0.6	0.717	-
11	2000	0.1	0.6	0.481	10.2510
12	2100	0.1	0.6	0.429	2.8896
13	1900	0.2	0.6	1.461	6.3571
14	2000	0.2	0.6	1.536	7.3509
15	2100	0.2	0.6	1.530	-3.2930
16	1900	0.3	0.6	3.056	-3.7278
17	2000	0.3	0.6	3.222	-3.6938
18	2100	0.3	0.6	3.334	-9.7031
19	1900	0.1	0.7	0.498	-
20	2000	0.1	0.7	0.485	10.1625
21	2100	0.1	0.7	0.442	-
22	1900	0.2	0.7	1.409	10.4593
23	2000	0.2	0.7	1.521	6.0554
24	2100	0.2	0.7	1.534	6.2852
25	1900	0.3	0.7	3.094	7.0916
26	2000	0.3	0.7	3.230	-2.9782
27	2100	0.3	0.7	3.217	-3.6426
					-3.7165
					-9.8104
					-
					10.1841
					-
					10.1490

The results of the ANOVA with surface roughness Ra are shown in Table 3. The significance level α=1.15, and confidence level of 95% for Surface roughness is taken. The sources which are having a P-value less than 0.15 can be said as the significant parameters.

1. Analysis of Variance for Means (surface roughness Ra)

Table 3. ANOVA for Ra

Source	DF	Seq SS	Adj SS	Adj MS	F	P
V	2	0.0182	0.0182	0.0091	2.42	0.151
F	2	33.5224	33.5224	16.7612	4461.39	0.000
D	2	0.0086	0.0086	0.0043	1.14	0.366
V*F	4	0.0865	0.0865	0.0216	5.75	0.018
V*D	4	0.0068	0.0068	0.0017	0.45	0.768
F*D	4	0.0101	0.0101	0.0025	0.67	0.631
R-Error	8	0.0301	0.0301	0.0038		
Total	26	33.6826				

Response Table for Means of Ra is obtained which is shown below

Table 4: Response Table for means of Ra

Level	V	F	D
1	1.6899	0.4860	1.7134
2	1.7440	1.5053	1.7518
3	1.7458	3.1883	1.7144
Delta	0.0559	2.7023	0.0383
Rank	2	1	3

Figure 1. Main effects plot for means

From response table of means of Ra it is found that feed is the most important factor among all the parameter selected and depth of cut is least important. The Fig.1 shows the average outcome for each value of each variable, combining the effects of the other variables as if all variables were independent. Main effect plot show the relation between independent variable and mean.

2. Analysis of Variance for S/N ratios for Ra

Table 5. ANOVA for S/N ratios for Ra

Source	DF	Seq SS	Adj SS	Adj MS	F	P
V	2	0.60	0.60	0.299	0.54	0.604
F	2	1235.50	1235.50	617.748	1111.35	0.000
D	2	1.37	1.37	0.687	1.24	0.341
V*F	4	6.98	6.98	1.745	3.14	0.079
V*D	4	1.99	1.99	0.497	0.89	0.510
F*D	4	2.62	2.62	0.654	1.18	0.390
R-Error	8	4.45	4.45	0.556		
Total	26	1253.49				

Response Table for Signal to Noise Ratios is obtained ANOVA for S/N ratios for Ra

Table 6. Response Table for S/N ratios for Ra

Level	V	F	D
1	-2.528	6.384	-2.178
2	-2.503	-3.549	-2.716
3	-2.201	-10.068	-2.339
Delta	0.328	16.452	0.538
Rank	3	1	2

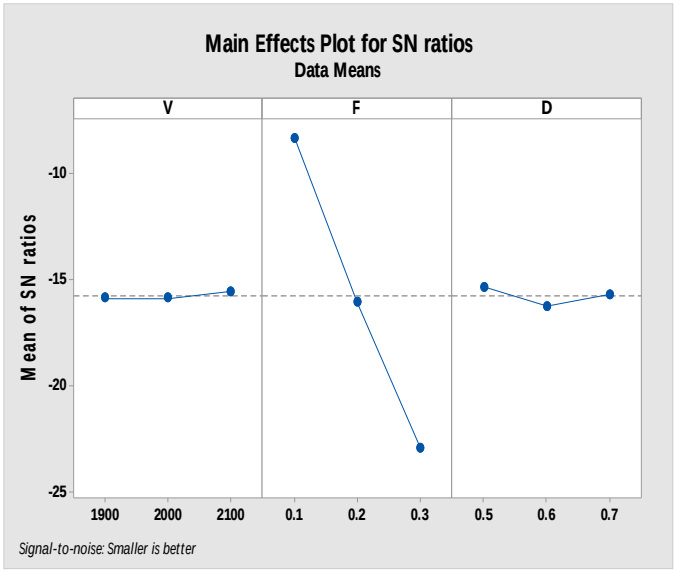

Figure 2. Main effects plots for SN ratios

From the response table of signal to noise ratio we found that feed is the most important factor and velocity is less important. The above fig shows the main effect plot for the SN ratio in which mean of SN ratio is on y-axis and velocity, feed and depth of cut on x-axis respectively.

3. Contour plot for Ra

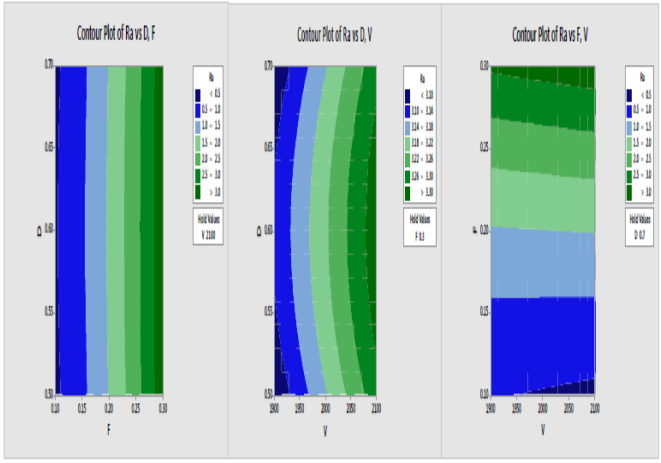

Figure 3. Contour plot for Ra

The fig.3 show contour plot for Ra for variable of speed, feed and depth. The contour plot show the value of Ra on different area with given input variable. As from the above contour plot we see surface roughness is lower for blue colour and higher for dark green colour. Thus we can say the value of Ra Increase from blue to green colour.

IV. CONCLUSION

The following conclusions are found from the performed experiment:

1. Taguchi orthogonal array design was used to evaluate the influence, the input parameters (speed, feed and depth) had on the response or the output parameter which is the surface roughness and the optimal machining conditions were determined to minimize the surface roughness during turning operation.
2. From response table of means of Ra it is found that feed is the most important factor among all the parameter selected
3. From the response table of signal to noise ratio we found that feed is the most important factor and velocity is less important
4. From the analysis, it was found that, the multilayer coated carbide inserts have performed well and provide us with an optimal operating condition when at a combination of speed of 2100 rpm, feed of 0.10 mm/rev and depth of 0.5 mm.

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