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Optimization of surface roughness of mild steel (EN-8) using Taguchi and ANOVA

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Abstract - *For many years considerable research work has been carried out in industrial and academic perspective to monitor the CNC machines. Still works are going on to improve its accuracy and make it precise and flexible. Every manufacturing industry is working towards improving the surface finish of their product. As surface finish of the product improves, the cost of the product goes on increasing. Many research has been carried out in this field and is well documented. In this project, work has been carried out to find the optimum conditions for surface roughness using suitable methods like Taguchi and ANOVA (Analysis of Variance) for Mild Steel (EN-8 grade) material. The experiment is conducted in an industry 'Galaxy Machinery Pvt. Ltd.' on MIDAS 10 CNC turning machine. The machining parameters like Cutting speed, feed and depth of cut are optimized by measuring the Surface Roughness of the material. The surface roughness of materials is checked using a device called Surtronic S128 which is Taylor Hobson AMETEK make. The results showed that for Mild steel material feed is the significant parameter influencing the surface roughness.*

Key Words: **cutting speed, feed, depth of cut, Surface roughness, taguchi, ANOVA.**

1. INTRODUCTION

CNC machines have high accuracy and takes less time to complete tasks assigned to it, but during machining the CNC machine experiences many problems like force generated at the tool tip increases the surface roughness and also reduces tool life, vibrations produced during machining, acoustic emission, thermal problem etc. which affects the performance of the machine. So it is necessary to monitor these problems during machining which helps to increase the performance and accuracy of the machine. Surface roughness is nothing but the deviation of the surface from the flat ideal surface. Friction depends on the surface texture. Considerable study has been carried out to find the effect of surface texture on friction and wear during sliding conditions. There are many processes to modify the initial texture like grinding, honing, lapping, abrasive blasting, electrical discharge machining, laser etching etc. The surface with high roughness usually wear faster and have higher friction as compared to smooth surface. So to control the surface roughness is one of the main objective of every manufacturing company.

Many Researches were carried out in the field of CNC machines. M Sadilek *et.al.* [1] Investigated the problems with increase in the efficiency of turning centers. They proposed roughing turning cycles by applying variable depth of cut. They found that by utilizing this technique increases durability of cutting tool and efficiency during turning. They worked on two strategies, first is carrying machining process with roughing cycle having constant depth of cut and second with roughing cycle having variable depth of cut. They found that the cutting force generated during constant depth of cut is more compared to force generated during variable depth of cut. By using variable depth of cut strategy, increases tool life, reduces energy load of the machine and reduces cutting force almost by 10%. Anil Gupta *et.al.* [2] used hybrid taguchi fuzzy approach to optimize the CNC turning conditions of material AISI P-20 tool steel. They monitored performance characteristics of CNC turning machine like surface roughness, cutting force and power consumption. They used full factorial design to find the optimum point of cutting parameters by using minimum number of trials. The experimental design used orthogonal arrays L_{27} for the cutting parameters such as cutting speed, depth of cut, feed rate, nose radius and environment with levels 1, 2, 3. As there are three types of the performance characteristics for the analysis of signal to noise ratio like lower the better, nominal better and higher the better out of which they used lower the better because of the reason that effect of performance characteristics has to be reduced. Then they used ANOVA (Analysis of Variance) to find the most effective parameter which influencing the performance characteristics of the machine. K. Venkat Rao *et.al.* [3] Reviewed about monitoring of cutting tool conditions by investigating workpiece vibration, surface roughness, and volume of metal removed for the material AISI 1040 steel in boring. For online data acquisition they used a device called Laser Doppler Vibrometer and a high speed FFT analyzer is used to process the AOE signals for workpiece vibrations. They prepared DOE with eight experiments having two levels of cutting parameters and three factors such as tool nose radius, feed rate and spindle rotational speed. Then with the help of Taguchi method, Analysis of variance and Regression analysis found the effect and contribution of cutting parameter. Finally they concluded that nose radius is the significant parameter for affecting the amplitude of workpiece of vibrations, Feed rate is the significant parameter for affecting the surface roughness and Feed rate is the significant parameter for affecting the volume of metal removed.

In the present work, the experiment is conducted on MIDAS 10 turning center with coated CVD Ti(C,N)+Al203+TiN insert for the machining of mild steel (EN-8 grade). L_9 orthogonal array is used to find the optimum cutting parameters using taguchi and ANOVA. The cutting parameters used are cutting speed, feed and depth of cut.

2. EXPERIMENTAL DETAILS

The experiment is conducted on MIDAS 10 turning machine for mild steel (EN-8) bar, which is 50mm length and 44mm diameter. The Chemical and Mechanical properties of mild steel material is shown below.

Table -1: Mechanical properties of mild steel (EN-8)

Material	Density	Yield stress	Hardness (Hot rolled)	Tensile stress	Young's modulus
Mild steel (EN-8)	7850 kg/cm³	280 MPa	240 BHN	660 MPa	200 GPa

Table -2: Chemical Properties of mild steel (EN-8)

Material	Composition in Wt %				
	C	Si	Mn	S	P
Mild steel (EN-8)	0.41	0.204	0.70	0.02	0.026

Inserts WNMG080408 PM 4325 Sandvik make is used to machine mild steel coated with CVD Ti(C,N)+Al203+TiN having nose radius 0.794mm. The cutting parameters used to conduct experiment is given in Table 3.

Table -3: Cutting parameters and levels

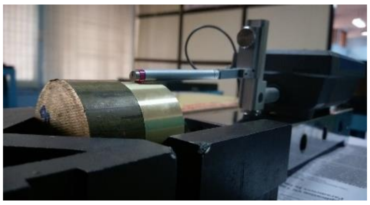
Cutting Parameter	Notation	Units	Level of factor		
			1	2	3
Cutting Speed	v	m/min	150	200	250
Feed	f	mm/rev	0.12	0.15	0.18
Depth of cut	d	mm	0.5	0.75	1

Based on L_9 orthogonal array, 9 experiments were conducted. The experimented is conducted on MIDAS 10 CNC turning machine by keeping chuck pressure 25kg/cm², coolant pressure 5bar and cutting length 25mm during machining. Surface roughness is measured for effective length 2.5 mm using a device called Surtronic S128 which is Taylor Hobson AMETEK make. The surface roughness factors measured are arithmetic mean (Ra), root mean square (Rq) and mean roughness depth (Rz).

The experimental setup to measure surface roughness Ra, Rq and Rz factor.

(a) 

(b) 

(c) 

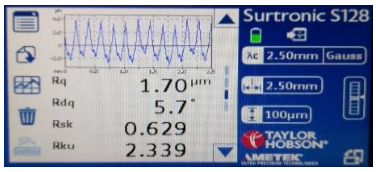
(d) 

Fig -1: (a) (b) (c) (d) setup to measure the surface roughness

The experimental results for mild steel is shown in table 4.

Table -4: Experimental results and S/N ratios for Mild steel

Run No	Parameter Level			Surface Roughness			S/N Ratio		
	V (m/min)	f (mm/rev)	d (mm)	Ra (µm)	Rq (µm)	Rz (µm)	Ra (dB)	Rq (dB)	Rz (dB)
1	1	1	1	0.997	1.267	6.933	0.02610	-2.05553	-16.8184
2	1	2	2	0.997	1.266	6.533	0.02610	-2.04867	-16.3023
3	1	3	3	1.387	1.667	7.400	-2.84153	-4.43871	-17.3846
4	2	1	2	0.733	1.400	4.500	2.69792	-2.92256	-13.0643
5	2	2	3	1.110	1.367	6.533	-0.90646	-2.71537	-16.3023
6	2	3	1	1.427	1.667	7.700	-3.08848	-4.43871	-17.7298
7	3	1	3	0.747	0.933	4.867	2.53359	0.60237	-13.7452
8	3	2	1	1.293	1.666	8.233	-2.23197	-4.43350	-18.3112
9	3	3	2	1.440	1.733	7.467	-3.16725	-4.77597	-17.4629

The S/N ratios for Ra, Rq and Rz is calculated using software MINITAB 17 software and is also calculated by using equation (1).

3. ANALYSIS OF RESULTS

In Taguchi for three level of factors and three cutting parameters, L_9 orthogonal arrays is used. The objective function in taguchi is S/N ratio where 'S' represents signal and 'N' represents noise. There are three characteristics of S/N ratio i.e. smaller the better, nominal the better and higher the better. To monitor the cutting force, surface roughness, tool wear etc. we have to use smaller the better S/N ratio.

$$\frac{S}{N} = -10\log\frac{1}{n}\left(\sum y^2\right) \quad \text{------------ (1)}$$

Where,

y = Mean square deviation for output characteristics

n = Number of observations

Average S/N ratios of level of experiments are calculated for Ra, Rq and Rz factor based on the experimental values using MINITAB 17 software. Total mean S/N ratios for Ra, Rq and Rz factor of mild steel is shown table 5, 6, 7 respectively.

Table -5: Response Table of Signal to Noise Ratio for 'Ra' factor of mild steel

Level	Cutting Speed (v) m/mm	Feed (f) mm/rev	Depth of Cut (d) mm
1	-0.9298	1.7525	-1.7648
2	-0.4323	-1.0374	-0.1477
3	-0.9552	-3.0324	-0.4048
Delta	0.5229	4.7850	1.6170
Rank	3	1	2

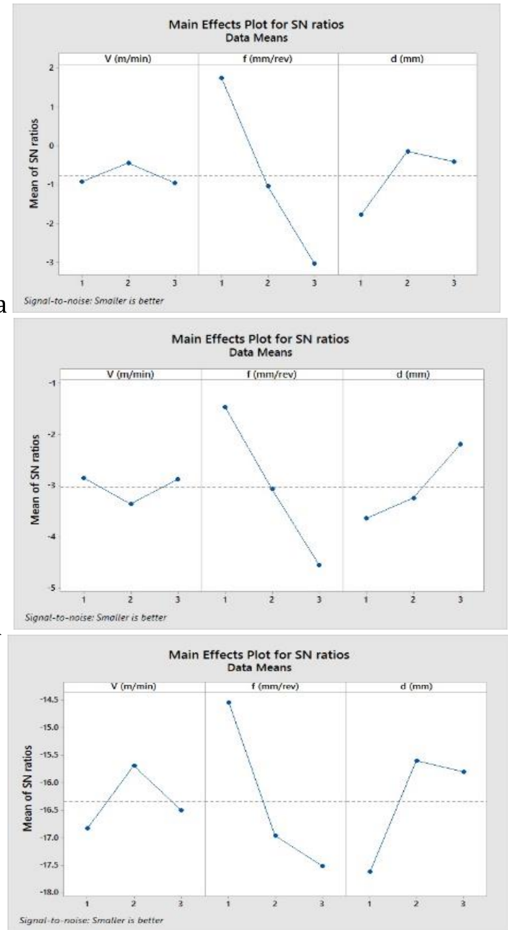
Table -6: Response Table of Signal to Noise Ratio for 'Rq' factor of mild steel

Level	Cutting Speed (v) m/min	Feed (f) mm/rev	Depth of Cut (d) mm
1	-2.848	-1.459	-3.643
2	-3.359	-3.066	-3.249
3	-2.869	-4.551	-2.184
Delta	0.511	3.093	1.459
Rank	3	1	2

Table -7: Response Table of Signal to Noise Ratio for 'Rz' factor of mild steel

Level	Cutting Speed (v) m/min	Feed (f) mm/rev	Depth of Cut (d) mm
1	-16.84	-14.54	-17.62
2	-15.70	-16.97	-15.61
3	-16.51	-17.53	-15.81
Delta	1.14	2.98	2.01
Rank	3	1	2

Difference between maximum and minimum S/N ratios is calculated and rank is allotted for each cutting parameter. According to the rank in response table 5, 6, 7 it is found that feed is the significant parameter and next is depth of cut. Optimum cutting parameters is found out by plotting graph for Table 5, 6, 7 as shown below.



Ra

Rq

Rz

Fig -2: Mean of S/N ratio v/s cutting parameters for Ra, Rq and Rz factor of mild steel

From the fig 1 the optimum cutting conditions for Ra and Rz factor is cutting speed 200m/min, feed 0.12 mm/rev and depth of cut 0.75 mm (2 1 2 orthogonal array). For Rq factor the optimum cutting condition is cutting speed 150m/min, feed 0.12 mm/rev and depth of cut 1 mm (1 1 3 orthogonal array).

ANOVA is used to find the significant cutting parameter which is affecting the performance characteristics. In this project ANOVA is solved for Ra, Rq and Rz factors of mild steel material considered for experimentation. The analysis was carried out with confidence level 95%. With the help of ANOVA, interpretation of S/N ratio and cutting parameters is calculated using MINITAB 17 software. From the table below DOF represents degree of freedom, SS–sum of squares, MS–mean squares, F value–variance ratio and P value–significant factor.

Table -8: Interpretation of S/N ratio and cutting parameters for Ra factor of mild steel

Cutting Parameters	DOF	SS	MS	F-Value	P-Value
Cutting Speed	2	0.5215	0.2607	0.25	0.798
Feed	2	34.6597	17.3299	16.78	0.056
Depth of cut	2	4.5305	2.2652	2.19	0.313
Error	2	2.0654	1.0327		
Total	8	41.7770			

Table -9: Interpretation of S/N ratio and cutting parameters for Rq factor of mild steel

Cutting Parameters	DOF	SS	MS	F-Value	P-Value
Cutting Speed	2	0.5018	0.2509	0.08	0.922
Feed	2	14.3533	7.1767	2.42	0.292
Depth of cut	2	3.4172	1.7086	0.58	0.634
Error	2	5.9319	2.9660		
Total	8	24.2042			

Table -10: Interpretation of S/N ratio and cutting parameters for Rz factor of mild steel

Cutting Parameters	DOF	SS	MS	F-Value	P-Value
Cutting Speed	2	2.051	1.0257	1.52	0.397
Feed	2	15.107	7.5537	11.18	0.082
Depth of cut	2	7.353	3.6766	5.44	0.155
Error	2	1.352	0.6759		
Total	8	25.864			

From the Table 8 and 9 for Ra, Rq and Rz factor the significant parameter is feed, depth of cut and then cutting speed. So as feed increases the surface roughness also increases.

4. CONCLUSIONS

Taguchi design is used to find the optimum cutting parameters for CNC turning center. Experimental results were analyzed by using ANOVA. L9 orthogonal array is used to solve the three levels of cutting speed, feed and depth of cut. In taguchi the first step is to find the S/N ratios for each experimental values. The second step is to find the optimum cutting parameters from calculated level values. Then ANOVA is used to find the significant factor which affects the surface roughness. After the study following conclusions are made:

1. The optimum cutting parameters for Ra and Rz factor of mild steel (EN-8) is cutting speed 200 m/min, feed 0.12 mm/rev and depth of cut 0.75 mm and for Rq factor cutting speed 150 m/min, feed 0.12 mm/rev and depth of cut 0.5 mm.
2. The results obtained from ANOVA showed that feed is the significant parameter for Ra, Rq and Rz factor of mild steel (EN- 8).

The number of experiments were reduced in taguchi to find the optimum cutting conditions and satisfactory results were obtained which can be used for further industrial studies.

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