Process Monitoring for The Estimation of Surface Roughness Characteristics of Alloy Steel

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Abstract

In this research work the surface roughness of material E0300 steel was optimized by varying the cutting speed, feed rate, and depth of cut during the turning. The turning operation was carried out on HMT lathe. The influence of cutting parameters on surface roughness was studied and analyzed by using Taguchi methods and then followed by the analyzed by using Taguchi methods and then followed by Analysis of variance (ANOVA) The ANOVA is used to optimize the experimental results i.e. to find the minimum surface roughness. L27 orthogonal array design has been used for conducting the experiments in Taguchi design. The cutting tool used in this research work is carbide inserts DNMX150608WM1525 and CCMT09308PM4225 in dry environment, Talysurf instrument was used to measure the Surface Roughness (Ra)Ra parameter is used to determine the surface roughness. Taking the significant parameters in to consideration and using the multiple linear regression analysis the mathematical model relating to surface height Ra is established to investigate the effect of cutting parameters during turning.

KeyWords:ANOVA, Talysurf, E0300, Depth of Cut

DOI Number: 10.14704/nq.2022.20.2.NQ22332 **NeuroQuantology2022; 20(2):416-423**

Introduction

Turning is very important machining process in which a single point cutting tool removes material from the surface of a work piece. In turning metal is removed from the outer diameter of a rotating cylindrical work piece to a specified dimension and it gives good finish. Surface finish as a performance evaluation criteria can be obtained by appropriate selection of machining parameters i.e. speed, feed, depth of cut etc. In obtaining the good surface finish engineers come across many challenges to find out the optimal parameters for the desired product quality and to maximize the performance of manufacturing using the available resources.

Anselmo Eduardo Diniz et al. [1] investigated on ABNT1045 steel during turning using different cutting tools with and without use of coolant. Author concluded that the wet turning is expected to be better for longer tool life but dry turning could not be used with large depth of cut. Arrazola P. J. et al.[2] studied micro-scale temperature fields in the cutting of two AISI 4140 steels with different machinability ratings. For this, they constructed a custom infrared microscope and used it to investigate the behaviour of the certain critical regions of the thermal field. Blais Carl et al. [3] studied on the optimization of machining parameters. Author presented new approaches to improve the P/M machinability. Author suggested that the presence of MnS in P/M part improve the machinability. Chen M. C. et al.[4] studied the extensive attention regarding optimization of machining conditions for turning cylindrical stocks into continuous finished profiles. Authors developed a machining model and claimed that the developed model is usefulness for turning of cylindrical work-piece on CNC machine. Childs T. H. C. et al. [5] studied on surface finishes during turning and facing by round nosed tools. Author concluded that the minimum roughness can be achieved by cemented carbide but also with single crystal diamond round nosed tools.Choudhury I. A. et al.[6] carried out a series of turning tests on Inconel 718 using coated and uncoated carbide tools. Author described the effects of cutting variables (speed, feed and depth of cut) on cutting forces and tool life.

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Author concluded that an uncoated carbide tool gives better results as compared to that of the coated tools. Dragos, A. Gindy et al. [7] studied the process monitoring to asses the work piece surface quality in machining. Author made an attempted to correlate the quality of the machined surface after broaching and the output signal obtained from the multiple sensors. Hui Y. V. et al. [8] studied the optimal machining conditions based on costs of quality and tool maintenance in turning. Author developed a time dynamic economic model for single pass turning. Kopac J. et al. Kishawy H. A. et al. [9] described the results of the applications of different coolants during high speed milling of A356-aluminium alloy. The work investigated the effect of tool floods coolant, dry cutting and minimum quantity of lubricant (MQL) technologies on tool wear, surface roughness, and cutting forces. Author concluded that the main wear mechanism encountered are abrasive at the tool tip region and the adhesive wear on the flank and rake face of the tool tip.

[10] presented a reviewed result from available published work of some recently used cutting tool materials and coatings in machining. Authors concluded that Tool life is depending on certain technological parameters such as cutting tool material, tool materials etc. Manna A. et al. [11] experimental investigated the influence of cutting conditions on surface finish during turning of AL/SiC-MMC. In this study, author used the Taguchi method based experiment design to optimize the cutting parameters for effective turning of AL/SiC-MMC by rhombic insert. Petropolous Georgios et al. [12] studied on the longitudinally and faced turned surface generated during turning of Ck60 steel over a wide range of feed and cutting speed. The correlations of each parameter considered were examined with the machining condition and statistical regression models with varying correlation coefficient were developed. Suresh P. V. S. et al. [13] studied on the genetic algorithm approach for optimization of surface roughness model. This approach was used for prediction of optimal machining conditions for good surface finish and dimensional accuracy.

In this research work, analysis of surface roughness during turning of E0300 steel alloy steel using taguchi method is presented. In this study, the taguchi method a powerful tool for experiment design is also used to optimize the cutting parameters to achieve better surface finish.

Planning for Experimentations

The different sets of experiments have been performed by turning operation on a HMT Lathe with and without use of cutting fluid. Machined surfaces have been measured at different positions along the machined surface and average value is taken utilizing surface. SURFCOM 130 A –TSK manufactured by Seimitsu, Tokyo, Japan. According to the Taguchi method based robust design, an L 27 (313) orthogonal array is employed for the experimentation. Three machining parameters such as cutting speed, feed and depth of cut are considered as controlling factors and each parameter has three levels, namely small, medium and large are denoted by 1,2 and 3 respectively. Table 1. shows the cutting parameters and their levels considered for the experimentation.

Table1: Cutting parameters and their levels

Sl. No.	Machining parameters	Level		
		1	2	3
1	A: Cutting speed, m/min.	40	100	160
2	B: Feed, mm/rev.	0.16	0.32	0.48
3	C: Depth of cut, mm.	0.50	0.75	1.25

Table 2: Chemical composition of E0300 alloy steel

Specification	%C	%Mn	%P	%S	%Ni	%Cr	%V	%Mo	%Co	%Ti	%W
E0300 alloy steel	0.87	0.76	0.46	0.82	0.028	1.34	0.01	0.03	0.01	0.01	0.25

Table 3: Details of cutting tool used and environment for turning experiments

Cutting tool used	Cutting tool Specification	Rake angle	Clear-ance angle	Nose radius	Cutting edge angle	Environment
T-Max-P Positive insert	CCMT09T308 PM4225	00	70	0.8 mm	800	Wet and dry
T-Max-P Négative insert	DNMX150608 WM1525	- 60	00	0.8 mm	550	Wet and dry

Design of Experimental Plan based on Standard Orthogonal Array

The design of experimental plan is a methodology to study efficiently the effect of several control factors simultaneously through a matrix experimental plan called orthogonal array. An orthogonal array for a particular robust design project can be constructed from knowledge of the number of control factors, their levels and the desire to study specific interaction. Table 4 exhibits the planning for experimental design considered for the present investigation for developing mathematical models to achieve optimal surface finish , minimum flank wear, minimum cutting forces during turning of E0300 alloy steel and En31 steel. The first column, second column and sixth column of L 27 (313) array are assigned to the cutting speed (A), feed (B) and depth of cut (C) respectively. Initially, 27 sets of experiments have been performed according to the L 27 (313) orthogonal array, each set of experiment repeated three times and total 81 experiments have been conducted for the present investigation.

Table 4: Design experiment of Taguchi L 27(313) orthogonal array

Expt. No	Column					
	Coded level			Actual setting value		
	1	2	6	1	2	6
1	1	1	1	40	0.16	0.50
2	1	1	2	40	0.16	0.75
3	1	1	3	40	0.16	1.25
4	1	2	1	40	0.32	0.50
5	1	2	2	40	0.32	0.75
6	1	2	3	40	0.32	1.25
7	1	3	1	40	0.48	0.50
8	1	3	2	40	0.48	0.75
9	1	3	3	40	0.48	1.25
10	2	1	2	100	0.16	0.50
11	2	1	3	100	0.16	0.75
12	2	1	1	100	0.16	1.25
13	2	2	2	100	0.32	0.50
14	2	2	3	100	0.32	0.75
15	2	2	1	100	0.32	1.25
16	2	3	2	100	0.48	0.50
17	2	3	3	100	0.48	0.75
18	2	3	1	100	0.48	1.25
19	3	1	3	160	0.16	0.50
20	3	1	1	160	0.16	0.75
21	3	1	2	160	0.16	1.25
22	3	2	3	160	0.32	0.50
23	3	2	1	160	0.32	0.75

24	3	2	2	160	0.32	1.25
25	3	3	3	160	0.48	0.50
26	3	3	1	160	0.48	0.75
27	3	3	2	160	0.48	1.25

S/N Ratio, ANOVA and Mathematical model for surface finish by DNMX 150608WM1525 insert on E0300 alloy steel

Table5: Experimental results and S/N ratio of average surface finish (E0300, DNMX150608WM1525, Dry)

Expt. No	Column										
	Coded level			Actual setting values			Results				
	1	2	6				Surface Finish			Average Surface finish	S/N Ratio
1	1	1	1	40	0.16	0.50	1.52	1.61	1.49	1.54	-3.75517
2	1	1	2	40	0.16	0.75	1.63	1.69	1.72	1.68	-4.50833
3	1	1	3	40	0.16	1.25	1.97	1.96	2.01	1.98	-5.93382
4	1	2	1	40	0.33	0.50	2.31	2.33	2.29	2.31	-7.27245
5	1	2	2	40	0.33	0.75	2.48	2.43	2.47	2.46	-7.81903
6	1	2	3	40	0.33	1.25	2.87	2.81	2.78	2.79	-8.99563
7	1	3	1	40	0.48	0.50	2.77	2.73	2.78	2.76	-8.81844
8	1	3	2	40	0.48	0.75	2.95	2.91	2.96	2.94	-9.36718
9	1	3	3	40	0.48	1.25	3.24	3.27	3.33	3.28	-10.31804
10	2	1	2	100	0.16	0.75	1.37	1.34	1.28	1.33	-2.48046
11	2	1	3	100	0.16	1.25	1.64	1.68	1.69	1.67	-4.45505
12	2	1	1	100	0.16	0.50	1.16	1.21	1.14	1.17	-1.36646
13	2	2	2	100	0.33	0.75	2.27	2.29	2.31	2.29	-7.19693
14	2	2	3	100	0.33	1.25	2.65	2.64	2.66	2.65	-8.46495
15	2	2	1	100	0.33	0.50	2.14	2.1	2.09	2.11	-6.48610
16	2	3	2	100	0.48	0.75	2.72	2.76	2.71	2.73	-8.72352
17	2	3	3	100	0.48	1.25	3.09	3.08	3.04	3.07	-9.74298
18	2	3	1	100	0.48	0.50	2.61	2.57	2.59	2.59	-8.26616
19	3	1	3	160	0.16	1.25	1.44	1.42	1.46	1.44	-3.16780
20	3	1	1	160	0.16	0.50	0.87	0.92	0.91	0.9	0.91264
21	3	1	2	160	0.16	0.75	0.08	2.1	1.06	1.08	-2.66388
22	3	2	3	160	0.33	1.25	2.24	2.17	2.22	2.21	-6.88861
23	3	2	1	160	0.33	0.50	1.7	1.73	1.76	1.73	-4.76179
24	3	2	2	160	0.33	0.75	1.87	1.89	1.91	1.89	-5.52956
25	3	3	3	160	0.48	1.25	2.56	2.59	2.58	2.58	-8.23252
26	3	3	1	160	0.48	0.50	2.09	2.11	2.07	2.09	-6.40319
27	3	3	2	160	0.48	0.75	2.27	2.23	2.22	2.24	-7.00536

S/N Ratio for average surface finish while cutting of E0300 alloy steel by DNMX150608WM1525 insert in dry environment

Fig. 1. exhibits Signal to Noise (S/N) response graph for average surface finish It has been observed that the average surface finish decreases with the increase of cutting velocity and increases with the increase of machining time during machining of E0300 alloy steel. From the S/N Ratio graph Fig.4.15 it is clear that the parametric combination for higher surface finish is A3B1C1.

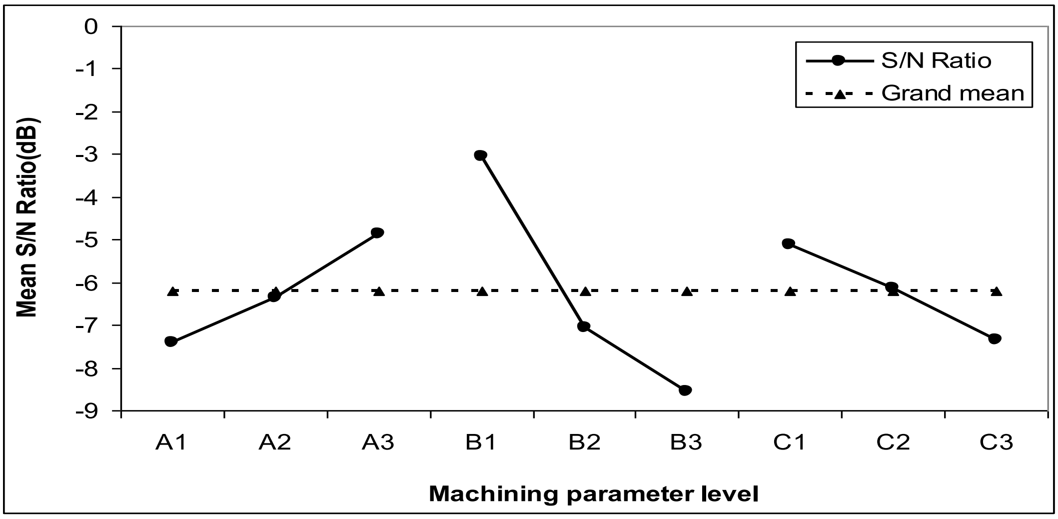

Fig. 1: S/N Ratiofor flank wear while cutting of E0300 steel by DNMX150608WM1525 insert in dry environment

Table 6. shows the Analysis of Variance (ANOVA) and 'F' test for average surface finish. It has been observed from Table 6. that the cutting speed and feed rate are the most significant and significant parameter respectively.

Table 6: ANOVA for flank wear while cutting of E0300 steel by DNMX150608WM1525 insert in dry environment

Parameters	Degree of freedom	Sum of square	Variance	'F' test value	% of contribution
X1	2	5.3445	2.6723	78.75	15.74
X2	2	22.8241	11.412	336.3	67.22
X3	2	3.5152	1.7576	51.79	10.35
X1.X2	4	0.161	0.0402	1.19	0.47
X1.X3	4	0.0008	0.0002	0.01	0
X2.X3	4	0.0008	0.0002	0.01	0
Error	62	2.1039	0.0339		6.19
Total	80	33.9503			100.00

Mathematical Model for average surface finish while cutting of E0300 alloy steel by DNMX150608WM1525 insert in dry environment

Considering most significant and significant parameters as identified from Table 6 and using the Gauss elimination method, the mathematical model for average surface finish has been developed with notation of X1, X2 and X3 which represent the cutting speed, feed rate and depth of cut respectively. The mathematical model for average surface finish while cutting of E0300 alloy steel by DNMX150608WM1525 insert in dry environment as follows

$$Y_{,E0300,15} = 0.03754163975791 - 0.00051101986975X1 + 8.62342692627787X2 + 0.55656609857737X3 - 0.00248278187160X1X2 + 0.00012962962963X1X3 + 0.01558404029146X2X3 - 0.00001995884774X12 - 6.87454611474217X22 + 0.05234567901234X32$$ ---------------Eq 1.

$R2 = 0.938$

S/N Ratio, ANOVA and Mathematical model for average surface finish by CCMT09308PM4225 insert on E0300 alloy steel

Table 7. shows the set of experiments of L27 (313) orthogonal array with experimental results of average surface finish and S/N ratio (dB) during turning of En31 alloy steel by CCMT09308PM4225 insert in dry environment.

Table7: Experimental results and S/N ratio of average surface finish (E0300,

CCMT09308PM4225,Dry)

Expt. No	Column										
	Coded level			Actual setting values			Results				
	1	2	6				Surface Finish			Average Surface finish	S/N Ratio
1	1	1	1	40	0.16	0.50	1.99	1.94	1.98	1.97	-5.88984
2	1	1	2	40	0.16	0.75	2.12	2.14	2.16	2.14	-6.60852
3	1	1	3	40	0.16	1.25	2.44	2.47	2.47	2.46	-7.81884
4	1	2	1	40	0.33	0.50	2.73	2.64	2.67	2.68	-8.56354
5	1	2	2	40	0.33	0.75	2.86	2.77	2.89	2.84	-9.06776
6	1	2	3	40	0.33	1.25	3.17	3.16	3.21	3.18	-10.04874
7	1	3	1	40	0.48	0.50	3.19	3.18	3.14	3.17	-10.02138
8	1	3	2	40	0.48	0.75	3.31	3.36	3.35	3.34	-10.47511
9	1	3	3	40	0.48	1.25	3.64	3.71	3.69	3.68	-11.31723
10	2	1	2	100	0.16	0.75	1.81	1.79	1.77	1.79	-5.05742
11	2	1	3	100	0.16	1.25	2.08	2.09	2.13	2.1	-6.44484
12	2	1	1	100	0.16	0.50	1.63	1.62	1.67	1.64	-4.29763
13	2	2	2	100	0.33	0.75	1.83	2.48	2.46	2.47	-7.14634
14	2	2	3	100	0.33	1.25	2.76	2.81	2.77	2.78	-8.88115
15	2	2	1	100	0.33	0.50	2.28	2.33	2.32	2.31	-7.27261
16	2	3	2	100	0.48	0.75	2.82	2.81	2.79	2.83	-8.96390
17	2	3	3	100	0.48	1.25	3.18	3.17	3.19	3.18	-10.04857
18	2	3	1	100	0.48	0.50	2.97	3.04	3.05	3.02	-9.60074
19	3	1	3	160	0.16	1.25	1.89	1.85	1.84	1.86	-5.39084
20	3	1	1	160	0.16	0.50	2.16	2.18	2.14	2.16	-6.68932
21	3	1	2	160	0.16	0.75	2.31	2.33	2.29	2.31	-7.27245
22	3	2	3	160	0.33	1.25	2.62	2.63	2.67	2.64	-8.43236
23	3	2	1	160	0.33	0.50	2.12	2.17	2.13	2.14	-6.60871
24	3	2	2	160	0.33	0.75	2.33	2.28	2.32	2.31	-7.27261
25	3	3	3	160	0.48	1.25	2.94	2.99	3.01	2.98	-9.48474
26	3	3	1	160	0.48	0.50	2.51	2.47	2.46	2.48	-7.88936
27	3	3	2	160	0.48	0.75	2.67	2.66	2.59	2.64	-8.43260

S/N Ratio for average surface finish while cutting of E0300 alloy steel by CCMT09308PM4225 insert in dry environment

Fig.2. exhibits Signal to Noise (S/N) response graph for average surface finish It has been observed that the average surface finish decreases with the increase of cutting velocity and increases with the increase of machining time during machining of E0300 alloy steel. From the S/N Ratio graph Fig.4.16 it is clear that the parametric combination for higher surface finish is A3B1C1

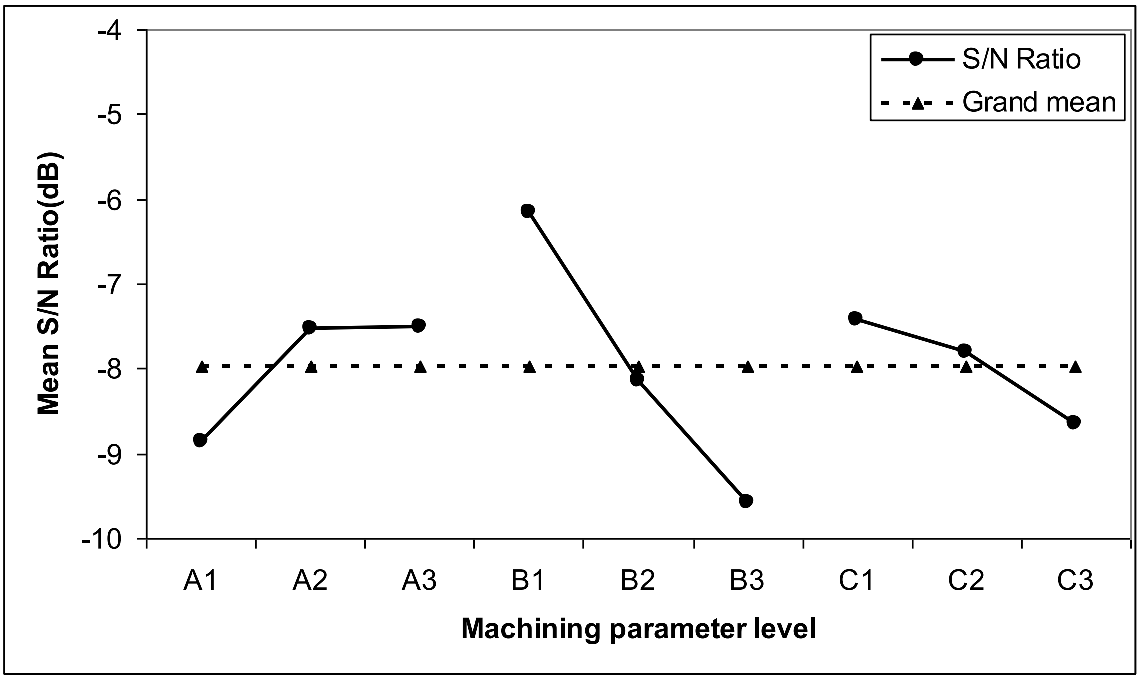

Fig. 2. S/N Ratiofor surface finish while cutting of E0300 steel by CCMT09308PM4225 insert in dry environment

Table 8. shows the Analysis of Variance (ANOVA) and 'F' test for average surface finish. It has been observed from Table 4.34 that the cutting speed and feed rate are the most significant and significant parameter respectively.

Table 8: ANOVA for average surface finish while cutting of E0300 alloy steel by CCMT09308PM4225 insert in dry environment.

Parameters	Degree of freedom	Sum of square	Variance	'F' test value	% of contribution
X1	2	3.1665	1.58324	100.44	15.06
X2	2	13.1095	6.55476	425.85	62.35
X3	2	1.944	0.97202	61.67	9.24
X1.X2	4	1.1227	0.28069	17.81	5.33
X1.X3	4	0.3704	0.0926	5.87	1.76
X2.X3	4	0.3343	0.08356	5.3	1.59
Error	62	0.9773	0.01576		4.64
Total	80	21.0247			100.00

Mathematical Model for average surface finish while cutting of E0300 alloy steel by CCMT09308PM4225 insert in dry environment.

Considering most significant and significant parameters as identified from Table 8 and using the Gauss elimination method, the mathematical model for average surface finish has been developed with notation of X1, X2 and X3 which represent the cutting speed, feed rate and depth of cut respectively. The mathematical model for average surface finish while cutting of E0300 alloy steel by CCMT09308PM4225 insert in dry environment as follows.

Y E0300,16 = 1.48967271298379-0.00570781797443X1+3.92329388300617X2 + 0.14693160681891X3-0.01616938785339X1X2-0.00317195767196X1X3 + 0.90765166057754X2X3 +0.00004963991770X12 +0.02314814814815X22 + 0.20839506172840X32 -----------------------------Eq. 2

R2 = 0.95

Conclusions

On the basis of experimental results, optimal parametric combinations for better surface finish using Taguchi design concept the following points can be concluded as listed below:

Most significant parameter influencing the surface finish (Ra) is cutting speed as compared to depth of cut and feed rate. For better surface finish the recommended parametric combination is A3B1C1 for E0300 alloy steel using DNMX 150608WM1525 andCCMT09308PM4225 insert in dry environment. The developed mathematical model for surface roughness height Ra is successfully proposed for proper selection of machining parameters. Mathematical model developed can be useful in evaluating the Ra value under various machining condition during turning.

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