Optimization and Analysis of Dry Turning of EN-8 Steel for Surface Roughness

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Abstract- Dry machining has gained a lot of importance in at the moment in manufacturing industries because possibilities of health hazards due to use of coolants while machining. Many industries are now using dry environment whenever it suitable during machining of various metal alloys. This paper presents a detailed analysis and optimization of surface roughness in dry turning of EN-8 which is widely used material for general-purpose axles, shafts, gears, bolts and studs. ANOVA is used for studying influence of various cutting parameters on surface roughness. For optimization Taguchi methodology is used. The optimized parameters are selected on basis for smaller is better signal to noise ratio criterion. During the analysis it is found that feed is the most significant parameter while dry turning of EN-8 steel. The optimized parameters are 180 m/min of speed, 0.2 mm/rev. feed and 1 mm depth of ct which gives surface roughness value of 1.21 µm.

Keywords: DryMachining, SurfaceRoughness, TaguchiMethodology, Turning, Analysis, Optimisation, EN-8

1.INTRODUCTION

Dry machining is a practice in which no coolant is used while cutting process. Coolants in many machining processes are used because of their capability to assist to improve the surface finish. But In the past years the cost of cutting fluids has risen from just 3% of the overall cost of the machining process, to that of more than 15% of a production shop's cost. In several countries 'spent' cutting fluids have been re-classified as either 'toxic-' , or 'hazardous-waste' ,moreover, if they have been found to have machined certain alloyed and exotic material workpieces, they are under even harsher disposal regulations [1]. Health professional around the world has pointed out numerous health hazards due to long term exposure of lubricants and coolants [2]. Recently dry and near dry cutting conditions are more popular developments in machining because of concern about coolant costs and environmental problems from large quantity cutting fluid applications [3].Due the latest advancement in manufacturing and cutting technology many of metal alloys can be cut without or very less use of coolant.

Numerous parts are machined to produce explicit surface characteristics because they have features such as bearing, locking, or gasketing surfaces which necessitate a consistent surface finish. In many applications, particularly finishing operations, the surface finish requirement restricts the range of tool geometries and feed rates which can be used. Furthermore, since the machined surface finish becomes rougher and less consistent as the tool wears, stringent finish requirements may also limit tool life and thus strongly influence machining productivity and tooling costs[4].Raykar et al.[5] investigated dry machining of EN-8 steel using regression models their analysis showed that feed has greatest influence on surface finish. They also found very less difference between surface roughness values obtained dry machining and machining with coolant therefore recommended use of dry machining conditions when situation is favorable. Asilturk et al. [6] reported significant effect of feed rate on the surface topology parameters Ra and Rz while optimization of cutting parameters to minimize surface roughness during turning of hardened AISI 4140 steel (51 HRC) with coated carbide tools. Diniz and Micaroni [7] reported increases in surface roughness with increase in feed while dry maching but for wet cutting this increase roughness was greater than for dry cutting.Asiltürk and Neseli [8] presented a combined approach of Taguchi method and the RSM for optimization of CNC turning parameters. They found feed rate is the most significant factor on the work piece surface roughness (Ra and Rz) with the percent contribution of 85.5% in bringing down the average roughness values.

2. Details of Experiment

2.1 Experimental Set up

The experimental studies were carried out on a CNC turning center. All the experiments were conducted under dry cutting conditions Work pieces of EN-8 steel were used with size of 40mm in length and 40 mm in diameter. The turning length was 30mm which also permit holding of workpiece with a length 5mm. The cutting insert was TNMG 06 04 04 M3 for the insert tool holder used was MTLNR 25 25 M 06 W. The experiments were carried out on 27 specimens for every experimental run a fresh insert side was used for making suitable analysis and comparison. The surface roughness was measured using a Mitutoyo SJ-201 sampling length of 0.8mm. Fig. 1 shows the specimens. After every turning operation specimen were cleaned and surface roughness was measured with a suitable clamping arrangement. The surface roughness was measured at three points on the specimen and average of there was taken as final roughness value.

Fig.1 Machined Workpieces and Workpiece with cutting tool during machining

2.2 Design of Experiment

Taguchi methodology is used for design of experiment. Speed, feed and depth of cut are the three process parameters are selected for this investigation. The levels these parameters are selected on basis of some trial experiment and from tool manufacture's catalogue. Each parameter is kept at three levels high low and medium. Therefore experiment consists of three factors at three levels. For this purpose L_{27} Taguchi array is used to design the experiment. The three process parameters with their levels are shown in Table 1.Table 2 indicates details L_{27} array with actual values of all process parameters and the measured value of surface roughness parameter R_a after experiment.

Table 1 Process Parameters and Their Levels

Levels	Process Parameters		
	Speed 'V' (m/min.)	Feed 'f' (mm/rev.)	Depth of Cut 'd' (mm)
Low	125.60	0.2	0.2
Medium	150.72	0.25	0.4
High	175.84	0.3	0.6

Table 2.Taguchi L27 array with Process parameters, Surface roughness and Signal to Noise Ratio for Surface Roughness

EN	Speed 'V' (m/min.)	Feed 'f' (mm/rev.)	Depth of Cut 'd' (mm)	Surface Roughness 'Ra' (μm)	SNR for Roughness 'db'
1	125.6	0.2	0.2	4.1527	-12.3666
2	125.6	0.2	0.4	3.884	-11.7856
3	125.6	0.2	0.6	4.322	-12.7137
4	125.6	0.25	0.2	7.0147	-16.9202
5	125.6	0.25	0.4	5.8123	-15.287
6	125.6	0.25	0.6	6.1787	-15.8179
7	125.6	0.3	0.2	8.5757	-18.6654
8	125.6	0.3	0.4	8.384	-18.469
9	125.6	0.3	0.6	9.3137	-19.3824
10	150.72	0.2	0.2	3.7507	-11.4822
11	150.72	0.2	0.4	3.87	-11.7542
12	150.72	0.2	0.6	4.131	-12.3211
13	150.72	0.25	0.2	5.7883	-15.251
14	150.72	0.25	0.4	6.408	-16.1345
15	150.72	0.25	0.6	5.7337	-15.1687
16	150.72	0.3	0.2	8.0542	-18.1204
17	150.72	0.3	0.4	8.377	-18.4618
18	150.72	0.3	0.6	8.7917	-18.8815
19	**175.84**	**0.2**	**0.2**	**3.6503**	**-11.2466**
20	175.84	0.2	0.4	3.8543	-11.7189
21	175.84	0.2	0.6	3.85	-11.7092
22	175.84	0.25	0.2	6.015	-15.5847
23	175.84	0.25	0.4	5.986	-15.5427
24	175.84	0.25	0.6	5.9207	-15.4475
25	175.84	0.3	0.2	9.0097	-19.0942
26	175.84	0.3	0.4	8.811	-18.9005
27	175.84	0.3	0.6	9.0937	-19.1748

3 Analysis of Results

Analysis of the experimental data obtained through Taguchi experimental design was carried out using MINITAB 16. Analysis of variance (ANOVA) and analysis of means (AOM) were performed to determine the influence of process parameters on the surface roughness. The statistical significance of process parameters were evaluated by corresponding P values. When P-value is less than 0.05 (or 95% confidence) the parameter is said to statistically significant on the surface roughness. Main effects plot were used in conjunction with ANOVA to visualize the effect of the process parameters on surface roughness.

Table 3. Analysis of Variance for Roughness (μm), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Speed 'V' (m/min)	2	0.416	0.416	0.208	1.79	0.193
Feed ' f' (mm/rev)	2	102.784	102.784	51.392	442.46	0.000
DoC 'd'(mm)	2	0.220	0.220	0.110	0.95	0.405
Error	20	2.323	2.323	0.116		
Total	26	105.742				
S = 0.340807 R-Sq = 97.80% R-Sq(adj) = 97.14%						

From ANOVA table and AOM plot shown in Figure 2 it is clear that feed is the most significant parameter which affects the surface roughness at 95% confidence with P value of 0.000 which is less than 0.05.This trend follows the general machining system. Because surface roughness is directly proportional to feed rate used during the machining. During the investigation it is found that surface roughness increases with increases with increase in feed from 0.2 to 0.25 and also from 0.25 to 0.3.The other two parameters that is speed and depth of cut do have a significant effect on surface roughness. Surface roughness marginally decreases with increase in speed from 125.8 to 150.72 but thereafter it slightly increases when speed increase to 175.84.When depth of cut changes from 0.2 to 0.4 surface roughness remains unchanged but a slight increase in surface roughness is noticed when depth up further increase to 0.6 mm.

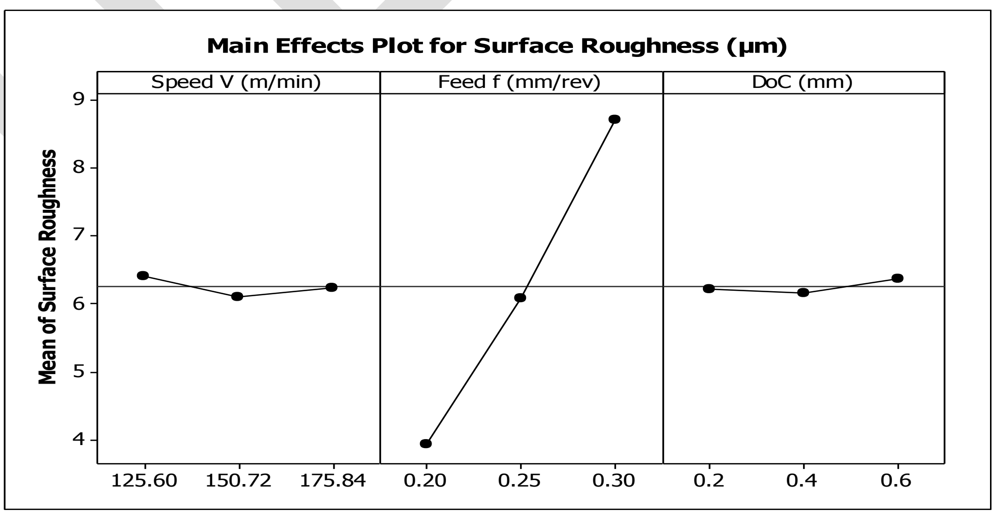

Figure 2 Main Effect Plot for Surface Roughness

For optimization Taguchi methodology is used. The optimized process parameters are selected on basis for smaller is better signal to noise ratio criterion because for any maching process smaller values of roughness are preferred. From signal to noise ratio shown in Table 2 it is clear that optimum combination of process parameter for dry turning of EN-8 are 175.84 m/min speed, 0.2 mm/rev feed and 0.2 mm depth of cut. At these process parameters the signal to noise ratio is -11.2466 and surface roughness is 3.6503 µm.

4 Conclusions

Optimization and analysis of dry turning of EN-8 steel is presented in this investigation. Taguchi methodology and ANOVA techniques are used for optimization and analysis purpose. Based on analysis following conclusions can be drawn.

- Feed has greatest influence on surface roughness. Feed affects the surface roughness at 95% confidence with P value of 0.000 for the parameters under investigation.
- The Cutting Speed and depth of cut do not show significant effect on surface roughness fro parameters under study.
- The optimized parameters for dry turning of EN-8 steel for this investigation are 175.84 m/min speed, 0.2 mm/rev feed and 0.2 mm depth of cut. At these process parameters the signal to noise ratio is -11.2466 and surface roughness is 3.6503 µm.

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