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Research Article

Effect of Cutting Parameters on MRR and Surface Roughness in Turning EN-8

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Abstract

Surface finish is one of the prime requirements of customers for machined parts. The present paper presents an experimental study to investigate the effects of cutting parameters like spindle speed, feed and depth of cut on surface finish and material removal rate on EN-8. Taguchi methodology has been applied to optimize cutting parameters. The results showed that the spindle speed (the most significant factor) contributed 63.90%, depth of cut (second most significant factor) contributed only 11.32% and feed rate contribution was least with 8.33% for R_a. The contribution for feed and RPM was 60.91% and 29.83%.whereas the depth of cut contributed only 7.82% for material removal rate.

Keywords: *Taguchi design, EN-8, Surface roughness, Material removal rate*

1.1 Introduction

Surface finish is the method of measuring the quality of a product and is an important parameter in machining process. It is one of the prime requirements of customers for machined parts. Productivity is also necessary to fulfill the customers demand. For this purpose quality of a product and productivity should be high. In addition to the surface finish quality, the material removal rate (MRR) is also an important characteristic in turning operation and high MRR is always desirable. So the study of surface roughness and material removal rate and the interaction between them is now becoming an integral part of machining operations. In this study, EN-8 was selected as workpiece which used for manufacturing of parts such as general purpose axles and shafts, gears, bolts and studs.

Taguchi has developed a methodology for the application of factorial design experiments that has taken the design of experiments from the exclusive world of the statistician and brought it more fully into the world of manufacturing. His contributions have also made the practitioner's work simpler by advocating the use of fewer experimental designs, and providing a clearer understanding of the nature of variation and the economic consequences of quality engineering in the world of manufacturing. Taguchi introduces his approach to:

- Quality should be designed into a product, not inspected into it
- Quality is best achieved by minimizing the deviation from a target
- The cost of quality should be measured as a function of deviation from the standard and the losses should be measured system wide

Taguchi techniques have been widely used in engineering design. The main thrust of the Taguchi techniques is the use of parameter design, which is an engineering method for product or process design that focuses on determining the parameter (factor) settings producing the best levels of a quality characteristic (performance measure) with minimum variation. Taguchi designs provide a powerful and efficient method for designing processes that operate consistently and optimally over a variety of conditions. To determine the best design requires the use of a strategically designed experiment which exposes the process to various levels of design parameters.

1.2 Literature Review

John et al. (2001) demonstrated a systematic procedure of using Taguchi parameter design to optimize surface roughness performance with a particular combination of cutting parameters in an end milling operation. Kopac et al. (2002) described the machining parameters influence and levels that provide sufficient robustness of the

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machining process towards the achievement of the desired surface roughness for cold pre-formed steel work-pieces in fine turning. IhsanKorkut et al. (2004) carried turning tests to determine optimum machining parameters for machining of austenitic stainless steel. Ciftci (2006) investigated the machining characteristics of austenitic stainless steels (AISI 304 and AISI 316) using coated carbide tools. Zhang et al. (2007) have used Taguchi method for surface finish optimization in end milling of Aluminum blocks. G. Akhyar et al. (2008) optimized cutting parameters in turning Ti-6%Al-4%V extra low interstitial with coated and uncoated cemented carbide tools under dry cutting condition. Anirban Bhattacharya et al. (2009) estimated the effect of cutting parameters on surface finish and power consumption during high speed machining of AISI 1045 steel. SaeedZareChavoshi& Mehdi Tajdari (2009) developed a surface roughness model in hard turning operation of AISI 4140 using CBN cutting tool.Adeel H. Suhail et al. (2010) conducted experimental study to optimize the cutting parameters using two performance measures, work piece surface temperature and surface roughness. D. Philip Selvaraj and P. Chandramohan (2010) concentrated with the dry turning of AISI 304 Austenitic Stainless Steel.Nikolaoset al. (2010) developed a surface roughness model for turning of femoral heads from AISI 316L stainless steel. T.G Ansalam Raj and V.N Narayanan Namboothiri (2010) formed an improved genetic algorithm for the prediction of surface finish in dry turning of SS 420 materials. M. Kaladhar et al. (2011) constructed a multi-characteristics response optimization model based on Taguchi and utility concept. They optimized process parameters, such as speed, feed, depth of cut, and nose radius on multiple performance characteristics, namely, surface roughness and material removal rate during turning of AISI 202 austenitic stainless steel using a CVD coated cemented carbide tool.

2. Materials and Methods

2.1 Work piece material

The experimental investigation presented here was carried out on a HMT lathe with 5 kW power rating. The work piece material used for present work was EN-8 steel.

Fig. 1 View of the cutting zone

Table 1 Chemical composition of EN-8

Chemical Composition of EN-8				
C	Si	Mn	S	P
0.35/0.45	0.05/0.35	0.60/1.00	0.06Max	0.06Max

In this experiment, in order to investigate the surface finish of the machined workpiece and material removal rate, during cutting of the EN-8 steel, carbide tool was used. A view of the cutting zone arrangement is shown in Fig. 1. The surface roughness of the finished work surface was measured with the help of a surface roughness tester. The material, characteristics of tool and detail of experimental design set-up are listed in Table 2 and conditions are given in the Tables 3.

Table 2 Experimental set-up and conditions

Machine tool	**HMT Lathe, 5 kW power rating**
Work piece	EN-8 steel
Size	Φ28 mm x40mm
Cutting condition	Dry
Cutting tool	WIDIA Tool Bit CNMG120408
Tool holder	WIDIA PCLNR2020K12
Surface roughness tester	SURFTEST-4 (Mitutoyo Make)

Table 3 Process variables and their limits

Factors	**Units**	**Level-1**	**Level-2**	**Level-3**	**Level-4**
Spindle speed	N	1000	1260	1600	2000
Feed	mm/rev.	0.05	0.1	0.2	0.3
Depth of cut	mm	0.5	1	1.5	2

2.2 Experimental procedure

Turning is a popularly used machining process. The lathe machines play a major role in modern machining industry to enhance product quality as well as productivity. In the present work, four levels, three factors and sixteen experiments are identified. Appropriate selection of orthogonal array is the first step of Taguchi approach. According to Taguchi approach L16 orthogonal array has been selected. Cutting tests were carried out on HMT lathe machine under dry conditions. A pre-cut with a 1 mm depth of cut was performed on each work piece prior to actual turning. This was done in order to remove the rust layer or hardened top layer from the outside surface and to minimize any effect of in homogeneity on the experimental results. After that, the weight of each samples have been measured accurately with the help of a high precision digital balance meter. Then, using different levels of the process parameters sixteen specimens have been turned in lathe accordingly. Machining time for each sample has been calculated accordingly. After machining, weight of each machined parts have been again measured precisely with the help of the digital balance meter. Then surface roughness and surface profile have been measured precisely with the help of a portable Mitotoyo suftest-4. The results of the experiments have been shown in table 4

Table 4 Experimental results L16 orthogonal array

N	Feed	DOC	Ra(μm)	MRR (mm^3/sec.)
1000	0.05	0.5	5.48	19.23
1000	0.1	1	9.34	96.19
1000	0.2	1.5	5.74	104.36
1000	0.3	2	7.61	188.59
1260	0.05	1	5.01	44.56
1260	0.1	0.5	5.36	124.97
1260	0.2	2	1.75	346.39
1260	0.3	1.5	2.61	282.05
1600	0.05	1.5	3.22	34.21
1600	0.1	2	1.7	222.81
1600	0.2	0.5	2.54	157.79
1600	0.3	1	2.91	298.66
2000	0.05	2	2.89	176.56
2000	0.1	1.5	3.3	246.11
2000	0.2	1	2.74	383.65
2000	0.3	0.5	3.21	532.05

3. Results and Discussion

Experiment was conducted to assess the effect of cutting speed, feed rate and depth of cut on the surface finish and machine power consumption. Table 3 illustrates the experimental results of R_a and Material Removal Rate (MRR).

3.1 Analysis of variance (ANOVA)

The experimental results were analyzed using analysis of variance (ANOVA) for identifying the significant factors affecting the performance measures. The results of ANOVA for the surface roughness of R_a are shown in Tables 4 and the ANOVA result for the MRR is shown in table 5. This analysis was carried out for a significance level of a = 0.05 (confidence level of 95%). Tables 4 and 5shows the realized significance levels, associated with the F tests for each source of variation. The last columns of the tables show the percent contribution of significant source to the total variation indicating the degree of influence on the result.

In Tables 5 and 6, the ANOVA result shows that the F value for the factor spindle speed (factor A) is larger than that of the other two cutting parameters, i.e., the largest contribution to the workpiece surface finish is due to the spindle speed. Spindle speed (the most significant factor) contributed 63.90% for R_a. The percent contribution of the second most significant factor depth of cut (factor C) was found to be only 11.32% and feed rate contribution was least with 8.33%. The error contribution is 16.45%. Table 6shows the ANOVA results for the Material Removal Rate. The results of the F test clearly indicate that the feed is the most significant factor compared to the other two factors, and that the spindle speed was found to be the second most significant factor and depth of cut was found the least significant factor. The percent contribution gives for feed was 60.91%, percent contribution gives for spindle speed was 29.83, whereas the depth of cut contributes only 7.82%. The error contribution was 1.44%.

3.2 Main effect plot

The main effect plot for the three different surface parameters R_a has been shown in figure 2 and that for Material Removal Rate in figure 3. Figure 2 shows the main effect plot for work-piece surface roughness R_a for spindle speed, feed rate and depth of cut. The results show that with the increase in spindle speed there is a decrease in surface roughness value up-to 1600 RPM. A RPM of 800 produces the highest roughness and 1260 RPM shows the lowest one, i.e. the best surface finish. In the figure the optimum value for feed was 0.20 mm/rev. and for depth of cut was 2 mm. Figure 3 shows the main effect plot for work-piece MRR for spindle speed, feed rate and depth of cut.

The results show that with the increase in spindle speed, feed rate and depth of cut there was a continuous increase in Material Removal Rate. The high value of spindle speed, feed rate and depth of cut give high value of Material Removal Rate, i.e. high production rate. It was observed that the maximum MRR is obtained at the spindle speed 2000 RPM, 0.3 mm/rev of feed and 2 mm depth of cut.

Table 5 ANOVA result for workpiece surface roughness R_a [95% confidence level]

Source	Degree of freedom	Sum of square	Variance	F ratio	P	%Contribution
Spindle speed	3	175.44	58.481	7.77	0.017	63.9
Feed	3	22.87	7.622	1.01	0.45	8.33
DOC	3	31.09	10.364	1.38	0.337	11.32
Residual Error	6	45.15	7.525			16.45
Total	15	274.55				100

Table 6 ANOVA result for workpiece Material Removal Rate (MRR) [95% confidence level]

Source	Degree of freedom	Sum of square	Variance	F ratio	P	%Contribution
Spindle speed	3	287.64	95.881	41.33	0	29.83
Feed	3	587.37	195.79	84.41	0	60.91
DOC	3	75.38	25.126	10.83	0.008	7.82
Residual Error	6	13.92	2.32	2.32		1.44
Total	15	964.31				100.00

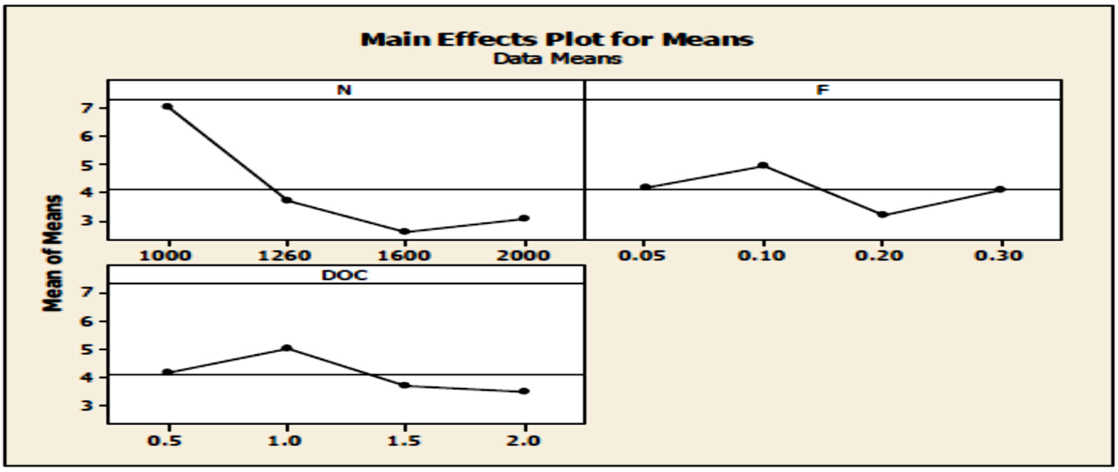

Fig. 2 Main effect plot for work-piece surface roughness R_a (μm)

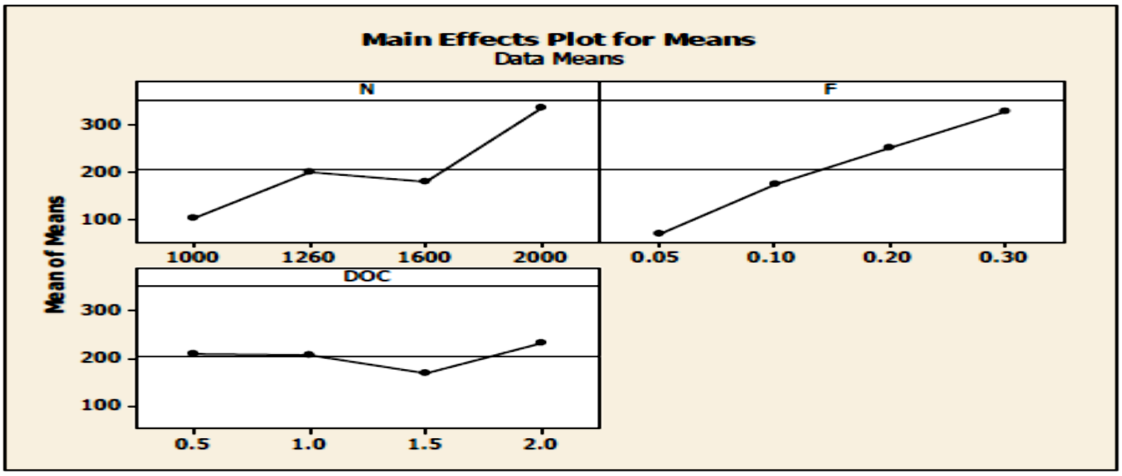

Fig. 3 Main effect plot for work-piece Material Removal Rate MRR (mm^3/sec.)

4. Conclusion

The effect of cutting parameters on surface roughness and MRR during machining of EN-8 was examined. Accordingly, the following drawn conclusions can be drawn: It was concluded that interesting to note that spindle speed and depth of cut a approximate decreasing trend. The feed has the variable effect on surface roughness. It is interesting to note that spindle speed, feed rate and depth of cut for Material Removal Rate have increasing trend.

Scope for future work

In this present study only three parameters have been studied in accordance with their effects. View of future scope, other factors like Nose Radius etc. can be studied. Also, the other outputs like power consumption, tool life, etc. can be added.

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