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Productive Improvement and Cycle Time Reduction in CNC Machining- a Case study

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Abstract:
In present research work the effect of machining parameters including cutting speed, feed rate and depth of cut on material removal rate (MRR) and surface roughness(Ra) in a turning of EN-19 are investigated using the Taguchi method and ANOVA. A three level, three parameter design of experiment, L9 orthogonal array was used to perform experiment. The analysis of variance (ANOVA) is applied to study the contribution of each machining parameters while CNC turning of EN-19 material. The present investigation indicates that speed and feed rate are the most significant factors in case of material removal rate and surface roughness for turning of EN-19 material.

Keywords – CNC Turning, EN-19, ANOVA

1. INTRODUCTION

EN-19 is most widely used material in die and mold making industry. It has drawn special attention due to its excellent properties. From few years, the technology of CNC turning machine has been advanced significantly, in order to meet the advance requirements in various manufacturing fields, particularly in the precision turning metal cutting industry. It is widely used for a variety of products to manufacturing in the industries. Material removal rate (MRR) and Surface roughness (Ra) are an important responses of machining operation. MRR and Ra contribute to machining cost and quality of the machining component respectively. In order to reduce the machining time and characteristics, effort to maximize the value of MRR and to minimize Ra by selecting optimal machining process parameters like cutting speed, feed rate, depth of cut are required to be study in details.

Ranganath M.S, Vipin and R.S.Mishra [1] investigated the parameters affecting the surface roughness produced during the turning process for the material aluminium 6061 with speed, feed rate and depth of cut as process parameters. They employed Taguchi design for optimization of process parameters and characterized the main factors affecting surface roughness by ANOVA. It observed that the feed rate and cutting speed are the most influential process parameters on surface roughness in case of aluminium 6061 metal. M. Nalbant, H. Gokaya, G. Sur [2] showed that the Taguchi method is used to find the optimal cutting parameters for surface roughness in turning. Three cutting parameters namely, insert radius, feed rate, and depth of cut, are optimized with considerations of surface roughness. S.V. Alagarsamy and N. Rajakumar [3] investigated the influence of turning process parameters on material removal rate and surface roughness of material AA7075 using Taguchi method and Response Surface Methodology. They used L27 orthogonal array and Minitab16 statistical software for to generate the array. They have considered three machining parameters as cutting speed, feed rate and depth of cut in their work. They found that feed is most influencing factor for surface roughness and depth of cut is most influencing factor for material removal rate. G. Akhyar, C.H. CheHaron, J.A. Ghani [4] investigated that Taguchi optimization methodology is applied to optimize cutting parameters in turning Ti-6%Al-4%V extra low interstitial with coated and uncoated cemented carbide tools under dry cutting condition and high cutting speed. Zhang Xuepinga, et. al. investigate the process parameters of cutting speed, depth of cut, and feed rate on inducing subsurface compressive residual stress. Using a designed experiment based on a Taguchi L9 array, they varied process parameters over a feasible space. The resulting residual stresses were examined and evaluated by X-ray diffraction. Using the smaller-is-betterobjective function for residual stress, and then identified the optimal set of process parameters. S. S. Mahapatra, Amar PatnaikPrabina Ku. Patnaik [6] stated that In order to enable manufacturers to maximize their gains from utilizing hard turning, an accurate model of the process must be constructed. Several statistical modeling techniques have been used to generate models including regression and Taguchi methods for that. T. S. Lan and M.-Y. Wang [7] were selected L9 orthogonal array of a Taguchi experiment for four parameters as cutting speed, feed rate, depth of cut and tool nose runoff with three levels in optimizing the finish turning parameters on an ECOCA-3807

CNC lathe. The surface roughness (Ra) and tool wear ratio (mm) are primarily observed as independent objectives for developing two combinations of optimum single-objective cutting parameters. Additionally, the levels of competitive orthogonal array are then proposed between the two parameter sets. Therefore, the optimum competitive multi-quality cutting parameters can then be achieved. They found that both tool wear ratio and MRR from their optimum competitive parameters are greatly advanced with a minor decrease in the surface roughness in comparison to those of benchmark parameters.

In this paper, effect of process parameters in CNC turning of En-19 is described. The key parameters are cutting speed and feed. Machining cost become bigger with increase in machining time thus appropriate selection of the cutting parameters can provide a minimum machining cost.

2. EXPERIMENTAL SET-UP

During this study, series of experiments on the En-19 were conducted on CNC lathe (shown in Fig 1) to examine the effect of input machining parameters, such as cutting speed, Feed and depth of cut on material removal rate and surface roughness.

Fig. 1: CNC LATHE

In this experimental work the ISO Grade-TNMG 160408 MC inserts (Composition- TiCN,Al_2O_3,TiN; Coat- MTCVD) was used as tool material. MRR was measured with digital weighing machine shown in fig: 2and surface roughness was measured with surface tester of Mitutoyo SJ-400 seriesis used shown in fig: 3.

Fig. 2: Weighing machine

Fig. 3:surface roughness tester

On the basis of preliminary experiments conducted by using one variable at a time approach the range of input parameters are selected. Machining parameters and their level chosen for this study are presented in Table 1.

Table 1: Machining parameters and their levels

Parameter	UNIT	LEVELS		
		1	2	3
SPEED	rpm	1753	1984	2215
DOC	mm	0.7	1.2	1.7
FEED	mm/rev	0.017	0.028	0.04

3. RESULT AND DISSCUSSION

In this study the machining parameter Speed, Feed and Depth of cut were studied to evaluate MRR and quality of machine surface.

3.1 Analysis of electrode wear

Main effect plot for MRR is shown in Fig 4. The results show that with the increase in the feed and depth of cut there is a continuous increase MRR that means the MRR is an increasing function of feed and depth of cut. However, with the increase in speed there is a decrease in MRR up to 1984 rpm and increase in MRR was observed. A feed 0.04 mm/rev gives a highest MRR and 0.02mm/rev show the lowest MRR. Based on the analysis using Fig. 2, high MRR was obtained at cutting speed (2215 rpm), depth of cut (1.7 mm) and feed (0.04 mm/rev).

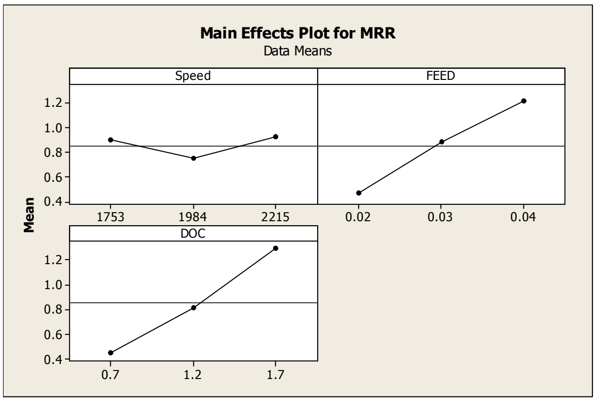

Fig. 4:Main effects plot for MRR

Table 2 show the analysis of variance (ANOVA) for MRR, which used for identifying the factors significantly affecting the performance measures. This analysis was carried out for significance level of α=0.05 i.e. for a confidence level of 95%. Table 2 shows that the significant parameter for the MRR is feed followed by the next largest contribution comes from depth of cut and then speed which is not statistically significant.

Table 2:Analysis of variance for MRR

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	1.89698	0.63233	22.05	0.003
Residual Error	5	0.14342	0.02868		
Total	8	2.04040			

Predictor	Coef	SE Coef	T	P
Constant	-1.2086	0.6424	-1.88	0.119
Speed	0.0000649	0.0002993	0.22	0.837
FEED	32.319	6.012	5.38	0.003
DOC	0.8433	0.1383	6.10	0.002

S = 0.169362 R-Sq = 93.0% R-Sq(adj) = 88.8%

The regression equation is
MRR = - 1.21 + 0.000065 Speed + 32.3 Feed + 0.843 DOC

3.2 Analysis of surface roughness

Main effect plot for surface roughness (Ra) is shown in Fig 5. Result shows increase in surface roughness with decreasing cutting speed. The surface roughness appears to be an almost linear increasing function of feed. According to this main effect plot, the conditions for good surface finish are: cutting speed at (2215 rpm), feed at (0.03 mm/rev) and depth of cut at (0.7 mm).

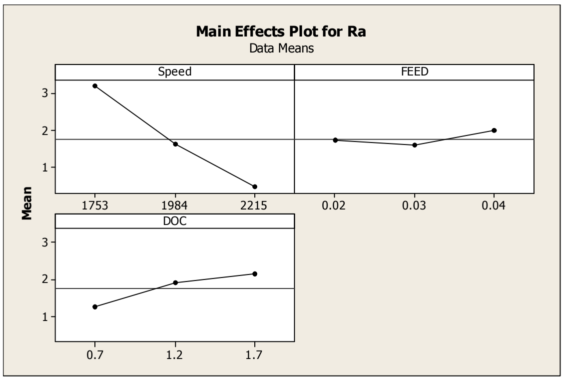

Fig. 5:Main effects plot for surface roughness

Table 3 shows the results of ANOVA for surface roughness. It was observed that, the cutting speed is the most significant parameter followed by the DOC. However, the insignificant parameter (feed) has the least effect in controlling the surface roughness.

Table 3: Analysis of variance for Ra

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	3	12.4217	4.1406	12.11	0.010
Residual Error	5	1.7098	0.3420		
Total	8	14.1314			

Predictor	Coef	SE Coef	T	P
Constant	12.065	2.218	5.44	0.003
Speed	-0.005894	0.001033	-5.70	0.002
FEED	11.46	20.76	0.55	0.605
DOC	0.8927	0.4775	1.87	0.120

S = 0.584765 R-Sq = 87.9% R-Sq(adj) = 80.6%

The regression equation is
Ra = 12.1 - 0.00589 Speed + 11.5 Feed + 0.893 DOC

CONCLUSION

1. The study shows that Taguchi experimental design method is an effective way of determining the optimum cutting parameters to achieve maximum MRR and good surface finish by Taguchi parameter design process.
2. The MRR is highly influenced by the Feed followed by DOC and smallest influencing by speed. In order to maximize the MRR, the high level of the feed (o.o4 mm/rev), high level of depth of cut (1.7 mm) and speed (2215 rpm) should be preferred.
3. The significant factors for the surface roughness were cutting speed and DOC. Although not statistically significant, the feed has a physical influence.
4. The Ra is highly influenced by the speed followed by DOC and smallest influencing by feed. In order to minimize the Ra, the high level of the feed (0.03 mm/rev), low level of depth of cut (0.7 mm) and speed (2215 rpm) should be preferred.

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