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Optimization of CNC Turning Parameter for EN 351 by using Taguchi Method

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Abstract—*The objective of this article is to manufacture low cost, high-quality products with maximum productivity in short time. Design of experiments has been used to study the effect of the main turning parameters such as tool nose radius, feed rate, cutting speed and depth of cut on the surface roughness of EN 351 steel. A mathematical prediction model of the surface roughness has been developed in terms of above parameters. The effect of these parameters on the surface roughness has been investigated by using Taguchi method. In the present investigation a single characteristic response optimization model based on Taguchi Technique is developed to optimize process parameters, such as feed, cutting speed, and depth of cut of single point cutting tool. Three machining parameters are chosen as process parameters: Cutting speed, Feed rate and Depth of cut. The experimentation plan is designed using design of experiment, L9 orthogonal array and Minitab-16 statistical software is used. Optimal value of process parameters for desired performance characteristics are obtained by analysis of variance. This paper also aims to determine parametric relationship and its effect on surface finish.*

Keywords*: orthogonal array, surface roughness, EN 351, MINITAB, CNC turning.*

1. INTRODUCTION

Metal cutting is one of the most important and widely used manufacturing processes in engineering industries and in today's manufacturing scenario, optimization of metal cutting process is essential for a manufacturing unit to respond effectively to severe competitiveness and increasing demand of quality which has to be achieved at minimal cost [1]. Machining is an essential finishing process by which jobs of desired dimensions and surface finish are produced by gradually removing the excess material from the performed blank in the form of chips with the help of cutting tools moved past the work surfaces [2]. This study helpful in evaluating optimum machining parameter like tool geometry, tool material, cutting speed, feed and depth of cut for cutting force for turning of EN 351 alloy steel on CNC Lathe machine. The selection of optimal cutting parameter like the number of passes, depth of cut for each pass, feed rate and speed is a very critical issue for every machining process. Surface finish in turning has been found to be influenced in varying amounts by a number of factors such as feed rate, work hardness, unstable built up edge, speed, depth of cut, cutting time, use of cutting fluids etc. The three primary process parameters in any basic Turning operation are speed, feed, and depth of cut. Speed always refers to the spindle and the work piece. Feed is the rate at which the tool advances along its cutting path. Depth of cut is the thickness of the material that is removed by one pass of the cutting tool over the work piece. After experimentally turning sample work pieces using the selected orthogonal array and parameters, this study produced a verified combination of controlled factors and a predictive equation for determining surface roughness with a given set of parameters.

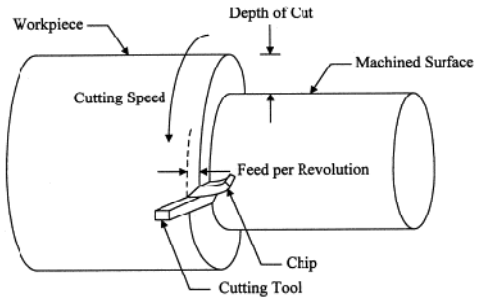

Fig. 1: Representation of turning process

2. LITERATURE REVIEW

Mr. Manoj Kumar Sahoo [3] reported the optimization of turning process by the effects of machining parameters applying Taguchi methods. Three machining parameters i.e., Spindle speed, Feed rate and Depth of cut. Experiments were done by varying one parameter and keeping other two fixed so maximum value of each parameter was obtained. Taguchi orthogonal array is designed with three levels of turning parameters with the help of software Minitab 16. Dr.S.S.Chaudhari et.al [4] investigated a single characteristic response optimization model based on Taguchi Technique was developed to optimize process parameters, such as speed, feed, depth of cut, and nose radius of single point cutting tool. Taguchi's L9 orthogonal array is selected for experimental

planning. The experimental result analysis showed that the combination of higher levels of cutting speed, depth of cut and lower level of feed is essential to achieve simultaneous maximization of material removal rate and minimization of surface roughness. W.H.Yang& Y.S[5],1998 Tang envisages that the Taguchi method is a powerful tool to design optimization for quality and is used to find the optimal cutting parameters for turning operations. An orthogonal array , the signal to noise ratios and ANOVA are employed to investigate the cutting characteristics of S45C steel bars using Tungsten carbide cutting tools. Through this study, not only optimal cutting parameters for turning operations obtained, but also the main cutting parameters that affect the cutting performance in turning operations are found. Ajay Mishra and Dr. Anshul Gangele [6] used Taguchi techniques to find out the optimum tool flank wear width in turning operation of AISI 1045 Steel. A L9 orthogonal array, S/N ratios and ANOVA are used to study the performance characteristics of cutting speed, feed rate and depth of cut as turning parameters with tool flank wear width as response variable. The result of the analysis show that the selected machining parameters affect significantly the tool flank wear width of Tungsten Carbide cutting tool while machining AISI 1045 steel and also indicate that the cutting speed is the most influencing parameter out of the three parameters under study. Harsimran Singh Sodhi and Harjot Singh [7] Discusses an investigation into the use of Taguchi Parameter Design for optimizing surface roughness generated by a conventional lathe. Control parameters being consider in this paper are cutting speed, feed rate and depth of cut. After experimentally turning sample workpieces using the selected orthogonal array and parameters, this study expected to produce an optimum combination of controlled parameter for the surface roughness. Prof. Atul dhale and Fahim khan [8] proposed AE as non-contact and indirect technique for in-process surface roughness assessment in turning. Three cutting conditions dry cut, cutting with water as coolant and normal coolant were used. The material used in study is EN8. Three cutting parameters namely feed rate, depth of cut, cutting speed are optimized with consideration with surface roughness. Taguchi method is used find optimal cutting parameters for surface roughness (Ra) in turning. R.K Suresh &G.Krishnaiah [9] investigated an optimal setting of process parameters in turning for maximizing material removal rate. In this work En 41B alloy steel has been taken as work material and cermet as tool. A number of experiments have been conducted as Taguchi DOE. By Taguchi analysis process parameters such as spindle spped, feed and depth of cut has been optimized for maximum MRR and by ANOVA the percentage contribution by each process parameters on response characteristic has been depicted. MeenuSahu and KomeshSahu [10] presents an optimization method of cutting parameters (cutting speed, depth of cut and feed) in dry turning of AISID2 steel to achieve minimum tool wear, low work piece surface temperature and maximum material removal rate. The experimental layout was designed based on Taguchi OA technique and ANOVA was performed to identify the effect of cutting parameters on the response variables. The results showed that depth of cut and cutting speed are the most important parameters influencing wear.

3. WORK MATERIAL & CUTTING TOOL

The experimental investigation presented here was carried out on a HMT STALLION 100 HS CNC lathe with 5.5 kW power rating. The work material selected in this investigation was EN351. The chemical composition of the EN351 tool steel includes:

Materials	C	Si	Mn	Cr	Mo	Ni
EN 351	0.10-0.20	0.35	0.60-1.0	0.40-0.80	0.08-0.10	0.60-1.0

Commercially available EN351 round bar of dia. 40 mm was used as work piece material. A commercially available single point CNMG 120408 GT cutting tool was used as cutting tool material.

Fig. 2: HMT STALLION 100 HS CNC lathe

4. DESIGN OF EXPERIMENTS

In this study, Taguchi method is used for single characteristics optimization has been used to establish correlation between the independent variables therefore; the experiments were performed according to a Taguchi design of experiments. To perform the experimental design, a total of three parameters namely RPM, feed rate and depth of cut were chosen for the controlling factor, and each parameter is designed to have two levels .The selected interactions were between RPM and feed rate , between RPM and depth of cut and between feed rate and depth of cut .

Table 1: Process parameters and their levels

Symbol	Factor	Unit	Level1	Level2	Level3
A	Speed	mm/min	135	180	225
B	Feed	mm	0.1	0.2	0.3
C	Doc	mm	0.5	1	1.5

5. RESULTS AND DISCUSSION

The surface roughness Ra was measured using the input factors namely cutting speed, feed rate and depth of cut. The response, surface roughness was measured by varying the machining parameters and the corresponding values is shown in table 2. The statistical analysis is done using MINITAB (version17) software for obtaining the main effect, interaction effect and graphs. The surface roughness plots for means and signal to noise ratio are given in table 3 and 4.

Experimental details:

Table 2: L9 Orthogonal Array

SR.NO	Cutting speed	Feed rate	Depth of cut	Surface roughness
1.	135	0.1	0.5	2.75
2.	135	0.2	1	2.73
3.	135	0.3	1.5	2.94
4.	180	0.3	0.5	3.24
5.	180	0.1	1	2.40
6.	180	0.2	1.5	2.55
7.	225	0.2	0.5	2.70
8.	225	0.3	1	2.44
9.	225	0.1	1.5	1.85

Table 3: Response table for means (Smaller is better)

Level	Cutting speed	Feed rate	Depth of cut
1.	2.80	2.41	2.94
2.	2.81	2.66	2.55
3.	2.36	2.9	2.47
Delta	0.441	0.50	0.47
Rank	3	1	2

Table 4: Response table for noise ratios (Smaller is better)

Level	Cutting speed	Feed rate	Depth of cut
1.	-8.90	-7.56	-9.36
2.	-8.94	-8.44	-8.10
3.	-7.41	-9.25	-7.80
Delta	1.52	1.68	1.55
Rank	3	1	2

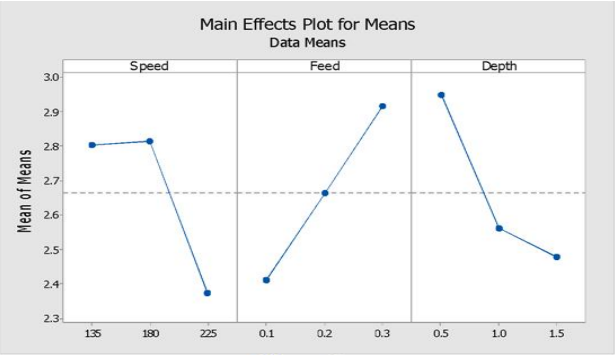

Figure-3
Main effects plot for means(Ra)

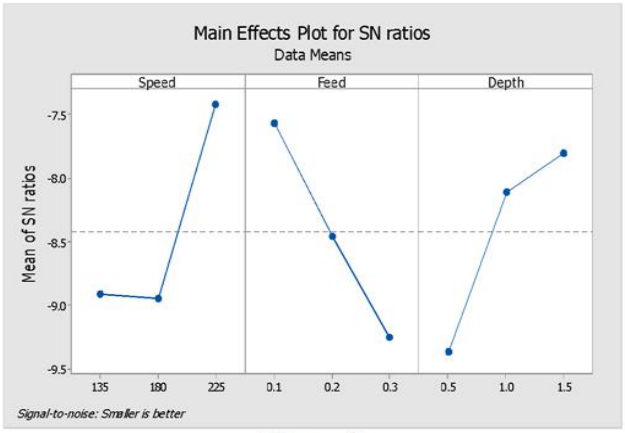

Figure-4
Main effects plot for SN ratio(Ra)

Graphs are drawn from the data obtained from the experiments. When Speed increases surface roughness also increases. But when feed increases surface roughness decreases. But in the case of depth of cut, it increases with increase in surface roughness values. In the case of SN ratios, surface roughness increases with increase in cutting speed. But when Feed rate decreases, the surface roughness value also decreases. Whereas in the case of depth of cut the surface roughness value increases with increase in depth of cut. Plots for means and SN ratios are shown in Fig. respectively. From the Taguchi analysis it was found that the feed rate is the most important significant factor which affects the surface roughness Ra followed by cutting speed and depth of cut respectively.

6. CONCLUSION

- The experimental results showed that the Taguchi parameter design is an effective way of determining the optimal cutting parameters for achieving low surface roughness.
- The Surface Roughness (Ra) mainly depends on feed rate as concluded from the delta values of S/N ratios with CNMG tool.
- Machining Parameters namely cutting speed (A), Feed rate (B), depth of cut (C) is optimized to meet the objectives. The results reveal that the primary factor affecting the surface roughness is feed rate, subsequently followed by speed and depth of cut.
- The optimized factor for minimizing the Surface roughness Ra is Feed rate f1=0.1mm/rev, Cutting speed, V3=225m/min, Depth of Cut d3=1.5mm.

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