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Optimization of Cutting Parameters for MRR in Turning Process of EN-31 Steel Using Taguchi Approach

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Abstract - *The turning operation on the EN-31 hardened steel using tool CNMG 120408 manufactured by Sandvik Company. Analysis of the MRR (material removal rate) is done experimentally with specific input values of speed, feed, and depth of cut and gradually the optimal condition is found out. A relation between the inputs and the output is determined and thereafter, the analysis is done. First using the full factorial composite design a layout of the experiment is made after which it is conducted. Here the L9 Taguchi method is used for the determination of the change in material removal rate with respect to the speed depth of cut, speed and feed. This can be analyzed with help of MINTAB 17 software which helps in to produce different graphs. By using ANOVA (Analysis of Variance) technique, the most effective or the optimal parameters for the output is determined. The regression equations are also obtained. All the parameters are found to be significant in determination of the material removal rate and possible conclusions are made at the end. From the analysis, it was found that, the CVD inserts have performed well and provide us with an optimal operating condition when at a combination of speed of 900 RPM, Feed Rate of 0.3 mm/rev and Depth of Cut 0.9 mm.*

KEYWORDS: Material Removal Rate (MRR), Taguchi Method, ANOVA, S/N Ratio.

1. INTRODUCTION

Turning is a machining operation perform on lathe machine, a material removal process, which is used to remove unwanted material from the work piece. Turning operation used single point cutting tool for material removal operation. The cutting tool feeds into the rotating work piece and removes unwanted material in the form of chips to create the required shape and size of work piece. Turning can done on both surfaces to produce and axially-symmetrical contoured part. The aim of turning process is to reduce diameter of work piece at required size to obtain material removal rate. Various optimizing methods are used to obtain optimum values for turning process parameters to get high quality of the machining component when operation is done. S. S. Acharya et al. [1] investigated the turning operation in MQL system and WET system on EN-31 alloy steel. From the analysis of various response variables like MRR, surface roughness etc. it is found that optimum results obtain from MQL system. MQL system enables improvement in MRR by allowing higher feed rate and higher cutting speed. MQL requires less coolant due to which cutting tool and work piece will remain clean which also save the recycling cost of lubricant oil. G. harinath Gowd et al. [2] have studied machining parameters for machining in turning operation on EN-31. Method used is ANN methodology. It is found that the speed, feed depth of cut have great significance on the force and temperature, whereas the feed has less significance on both the outputs.

1.1 Design of Experiment

The design of experiments for this study was based on Taguchi's design of experiments (DOE) and orthogonal array helps to investigate the effects of input variables or impact factor on an output variable or response variable at the same time. These experiments consist of a number of tests in which different output obtain by changing the input variable. Results are collected from each test run during experimentation. Experimentation use design of experiment to identify the various factors and input parameters that affect quality, and then determine the factor settings that optimize results. After identifying the process conditions and product components that affect product quality, it is easy to calculate efforts to enhance a product's manufacturing ability, reliability, quality, and on machine performance. Here factors are depth of cut, speed, feed and work piece material which affect the output variable.

1.2 Selection of Orthogonal Array

The experiment design is done based on the Taguchi Methodology. Orthogonal array consists number of experiments in which master matrices used to obtain desired optimum result. This technique almost used in different fields of engineering to optimize the process parameters. The control factors considered for the study are speed, feed and depth of cut. Three levels for each control factor are be used. On the basis of different number of process parameters and their levels, L9 orthogonal array (OA) is selected.Table-1 represents Factors and Levels of Process Parameters and Table-2 represents orthogonal design matrix.

Table 1 Factors And Levels of Process Parameters

LEVEL	Cutting Speed (RPM)	Feed Rate (mm/rev)	Depth of Cut (mm)
1	600	0.1	0.5
2	900	0.2	0.7
3	1200	0.3	0.9

Table 2 L9 Orthogonal Design Matrix

Sr. No.	Speed	Feed	DOC
1	Level 1	0.1	0.5
2	Level 1	0.2	0.7
3	Level 1	0.3	0.9
4	Level 2	0.1	0.7
5	Level 2	0.2	0.9
6	Level 2	0.3	0.5
7	Level 3	0.1	0.9
8	Level 3	0.2	0.5
9	Level 3	0.3	0.7

1.3 Selection of Material

The material of work piece is EN-31 hardened steel which is in the form of cylindrical round bars of 50 mm diameter and l 50 mm length. EN-31 is used as the work material because by its character it has very high resistance nature against wear can be used for components subjected to severe abrasion, wear and widely used in bearings, crankshaft, punches and dies.

Table 3 Chemical properties of En31 Material

Elements	Standard Value	Observed Value
C- Carbon	0.90-1.20	1.05
Si- Silicon	0.30-0.75	0.55
Mn- Manganese	0.10-0.35	0.25
Cr- Cromium	1.00-1.60	1.35
S- Sulphur	0.040	0.040
P- Phosphorus	0.040	0.040

2. EXPERIMENTAL WORK

The experiments were performed on CNC lathe FANUC series oi mate-TD CNC. The basic CNC machines consist of parts like vise, guard, chuck, motor, lathe bed, cutting tool etc. the maximum speed of this CNC machine is 4500 rpm and minimum speed of the CNC machine is 4t rpm. Max feed system cross travel along x axis is 105 mm, longitudinal travel along z axis is 320 mm, rapid traverse along x and z axis is 20,000 mm/min. there are total 8 number of workstations. Input power to the machine is ranging from 5.5 kW to 7.5 kW.

3. RESULT AND ANALYSIS

The purpose of the work is to obtain optimize value of material removal rate. Taguchi technique uses S/N ratio as a performance measure to choose control levels. The S/N ratio considers both the mean and the variability. In the present work, Taguchi technique and Utility concept is used for optimizing the material removal rate (MRR). Taguchi proposed many different possible S/N ratios to obtain the optimum parameters setting. Three process parameters with each of three levels were selected turning operation on selected material. Speed, depth of cut and feed rate are considered as turning process parameters.

$$MRR = \frac{Initial\ Weight(grams) - Final\ Weight(grams)}{Density(gram/mm^3) * Machining\ Time(Min)} \quad \ldots\ldots (1)$$

3.1 Regression Analysis

The regression equation that shows how the set of predictor variables are used to obtain desired result. The regression analysis equation defined by the formula,

$$y = c + bx \quad \ldots\ldots (2)$$

Where,

y = estimated dependent score,
c = constant,
b = regression coefficients,
x = independent variable.

Regression Equation obtained by MINITAB 17 Software is given below,

$$MRR = -5181 + 2.76\ speed + 55425\ feed + 648\ DOC \quad \ldots\ldots (3)$$

Table 4 Experimental Values with Calculations

Speed	Feed	DOC	MRR	SNRA1	MEAN1	Predicted MRR (mm3/min)	Actual MRR (mm3/min)
Level 1	0.1	0.5	2598.7261	68.29521016	2598.7261	2341.5	2598.7261
Level 1	0.2	0.7	5485.5463	74.7843977	5485.5463	8013.6	5485.5463
Level 1	0.3	0.9	14566.8789	83.2673302	14566.8789	13685.7	14566.8789
Level 2	0.1	0.7	3622.9299	71.18119862	3622.9299	3169.5	3622.9299
Level 2	0.2	0.9	10522.2929	80.44220773	10522.2929	8841.6	10522.2929
Level 2	0.3	0.5	15164.3312	83.61646522	15164.3312	14513.7	15164.3312
Level 3	0.1	0.9	3775.7961	71.54017067	3775.7961	3997.5	3775.7961
Level 3	0.2	0.5	10324.8407	80.27766719	10324.8407	9669.6	10324.8407
Level 3	0.3	0.7	13521.0191	82.62018853	13521.0191	15341.7	13521.0191

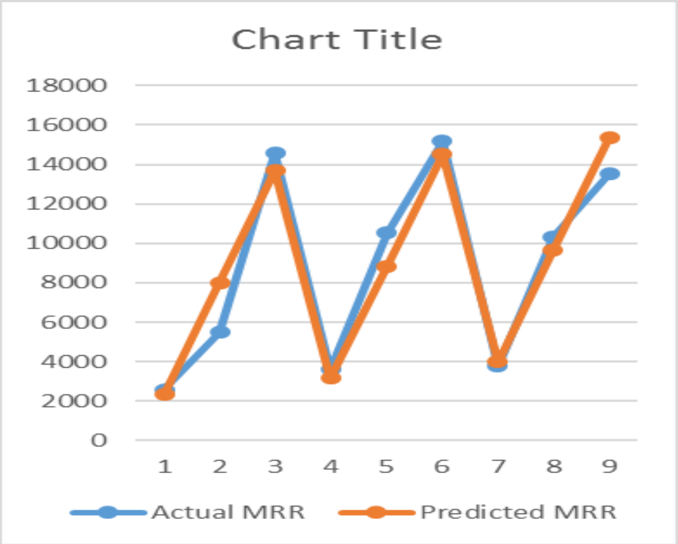

Figure 1 Actual MRR Vs Predicted MRR

$\frac{S}{N}$ *Ratio* $= 10 * log10\,[[\sum (1/y2)/n]$.......... (4)

From above table the optimum value of cutting parameters are second level of cutting speed (A), third level of feed rate (B) and third level of depth of cut (C) i.e. A= 900RPM, B=0.3mm/rev and C=0.9mm.

Table 5 Response Table for Signal to Noise Ratios (Larger is Better)

Level	Speed (A)	Feed (B)	DOC (C)
1	75.45	70.34	77.40
2	**78.41**	78.50	76.20
3	78.15	**83.17**	**78.42**
DELTA	2.96	12.83	2.22
RANK	2	1	3

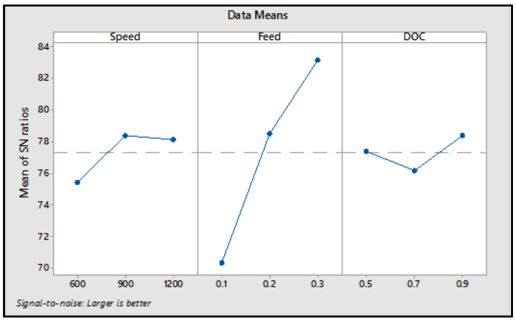

Figure 2 S/N Ratio

Table 6 Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Speed	2	7987694	3993847	2.86	0.259
Feed	2	184332335	92166168	65.99	0.015
DOC	2	7697680	3848840	2.76	0.266
Error	2	2793185	1396593		
Total	8	202810894			

4. CONCLUSION

Present work is concerned with determining the optimum value of process parameters for response variable like material removal rate on the basis of taguchi method. The L9 Orthogonal Array was used for experimental planning. The research finding along with the various mathematical analysis will provide the effective guideline to select favorable parameters for optimum value of MRR. The results obtained from ANOVA shows that the mathematical models allow prediction MRR with 95% of confident interval. From the analysis, it was found that, the CVD inserts have performed well and provide us with an optimal operating condition when at a combination of speed of 900 RPM, Feed Rate of 0.3 mm/rev and Depth of Cut 0.9 mm. The actual and predicted values are nearly same and percentage error between actual MRR and predicted MRR is 1.82 %.

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