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OPTIMIZATION OF TURNING PROCESS PARAMETERS FOR EN-24 STEEL USING TAGUCHI METHOD AND REGRESSION ANALYSIS

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ABSTRACT

This article investigates the effect of cutting parameters on surface roughness & material removal rate in turning process through Taguchi method and Regression analysis. The material EN 24 alloy steel and the cutting ceramic tool have been taken for the investigation. The L9 array has been chosen for conducting the experiments. Cutting speed, feed rate &depth of cut are considered as the factors which influence the surface roughness and material removal rate. The results showed that spindle speed which significantly influences the surface roughness & material removal rate while the other parameters did not affect the response too much. The confirmation experiment with optimal level of process parameter is conducted to confirm the effect of process parameters

Keywords:- ANOVA, Taguchi method, S/N ratio, Regression analysis.

1. INTRODUCTION

Taguchi method is a statistical method developed by Taguchi for improving the quality of goods manufactured later its application was expanded to many other fields in Engineering and technology. Taguchi method is extensively used by many researchers for the optimization of process parameters. V.N. Gaitonde, et al(2009) applied Taguchi method and the utility concept for optimizing the machining parameters in turning of free-machining steel using a cemented carbide tool. S. Ranganathan and T. Senthilvelan investigated (2011) the multi-response optimization of machining parameters in hot turning of stainless steel based on Taguchi technique. S. Rajesh et al(2013) presented the effects of cutting speed, feed rate, depth of cut, and nose radius in computer numerical control (CNC) turning operation performed on red mud-based aluminum metal matrix composites. This work deals the effects of turning process parameters on surface roughness and material removal rate for the material EN24Alloy steel which is the most commonly used material in manufacturing Automobile parts and aircraft components. It is very hard and ductile and is easily machineable. Due to its enhanced ductility it is widely used in many applications. It comes under the category of high carbon steel and has carbon content of about 0.35 to 0.45 wt%. Other alloying elements present are Si - 0.10 to 0.35 %, Mn - 0.45 to 0.70 % , Cr - 0.90-1.40%, Mo - 0.20 - 0.35%, W - 0.70 - 1.8%.. Experiments were conducted and data are analysed through MINITAB software.

2. STEPS INVOLVED IN TAGUCHI METHOD

2.1. Select the factors and their levels.

Factors and their levels are selected based on the literature's and research articles. The main cutting parameters are speed, feed and depth of cut. The factors and the levels are given the table1.

Table 1. Factors and levels

SERIAL NO	FACTORS	LEVEL1	LEVEL2	LEVEL3
1	Speed (rpm)-A	460	750	1250
2	Feed (F) (mm/rev)-B	0.052	0.065	0.081
3	Depth cut(mm)-C	0.04	0.08	0.12

2.2. Select the appropriate orthogonal array

Selecting an orthogonal array depends on the total degrees of freedom for the corresponding factors. For factor with level of 3,the degrees of freedom is 2.In this experiment, there are three factors with level number 3 consequently, the total degrees of freedom is 8. In the mean time, the interaction between the cutting parameters is neglected here. There by L9 orthogonal array is used. The experimental table is shown in table 2.

Table 2.Orthogonal array

Experiment No	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

2.3. Experimental Data

Turning operation was conducted using the ceramic tool whose composition is given below in the table 3. Experiments were conducted as per the orthogonal array and the results are tabulated in the table 4.

Table 3 Composition of the tool materials

Elements	**% of composition**
Carbon, C	0.0600 - 1.03 %
Chromium, Cr	0.200 %
Copper, Cu	0.300 %
Iron, Fe	97.0 - 100 %
Lead, Pb	0.150 - 0.360 %
Manganese, Mn	0.250 - 2.05 %
Nickel, Ni	0.200 %
Phosphorous, P	0.0300 - 0.120 %
Silicon, Si	0.100 - 0.400 %
Sulfur, S	0.0350 - 0.350 %

Table 4. Experimental results

Experiment /Trail No.	**Weight of chip removed (in gms)**	**Time taken (in sec)**	**Material removal rate (in gm/sec)**	**Readings Ra in mm**
1	5	460	0.00591	0.04
2	6	455	0.00675	0.12
3	4	448	0.00892	0.027
4	4	362	0.01104	0.036
5	4	364	0.01098	0.051

6	2	367	0.00544	0.04
7	7	116	0.089	0.079
8	6	124	0.0483	0.084
9	8	104	0.0769	0.087

The data collected by conducting the experiments are tabulated below:

3. DATA ANALYSIS BY USING TAGUCHI'S METHOD

3.1 Effect of Speed, Feed and depth of cut on Surface Roughness:

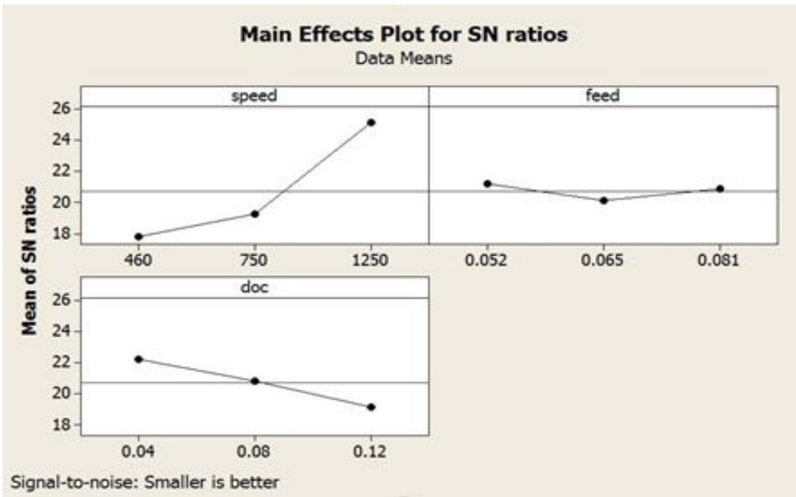

Fig.1. Effect of Speed, Feed and depth of cut on Surface Roughness

Effect of Speed, Feed and depth of cut on MRR:

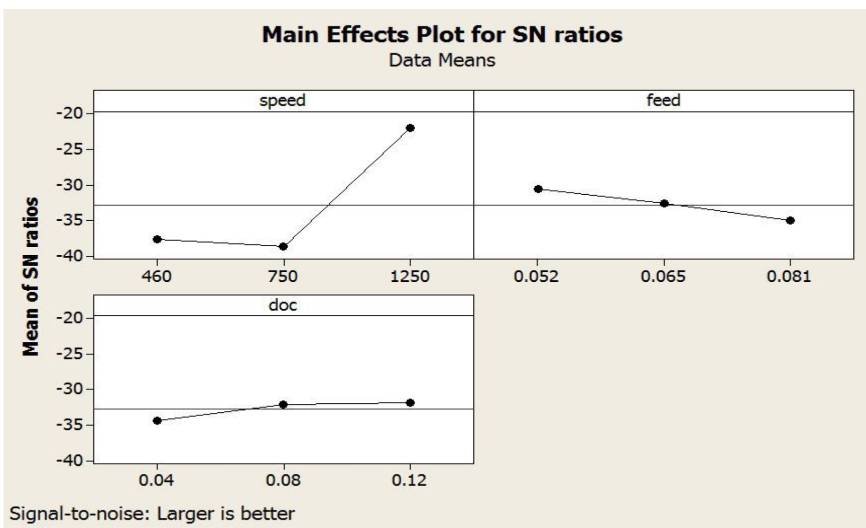

Fig.2. Effect of Speed, Feed and depth of cut on MRR

4. RESULTS & DISCUSION

4.1 Signal to noise ratio

4.1.1 Signal to noise ratio for surface roughness

Taguchi Analysis: Ra 1, Ra 2 versus speed, feed, doc

Response Table for Signal to Noise Ratios
Smaller is better

Level	speed	feed	doc
1	17.79	21.18	22.24
2	19.24	20.12	20.81
3	25.13	20.86	19.11
Delta	7.34	1.06	3.13
Rank	1	3	2

Response Table for Means

Level	speed	feed	doc
1	0.12957	0.08912	0.07872
2	0.11117	0.10648	0.09527
3	0.05220	0.09733	0.11895
Delta	0.07737	0.01737	0.04023
Rank	1	3	2

4.1.2 Signal to noise ratio for material removal rate

Taguchi Analysis: mrr1, mrr 2 versus speed, feed, doc

Response Table for Signal to Noise Ratios
Nominal is best (10*Log10(Ybar**2/s**2))

Level	speed	feed	doc
1	9.817	6.236	1.791
2	2.211	8.807	11.832
3	12.279	9.264	10.683
Delta	10.068	3.028	10.041
Rank	1	3	2

Response Table for Means

Level	speed	feed	doc
1	0.01627	0.05586	0.06475
2	0.04411	0.03680	0.03631
3	0.09037	0.05808	0.04968
Delta	0.07410	0.02129	0.02844
Rank	1	3	2

4.2 DATA ANALYSIS BY USING ANOVA METHOD

4.2.1 ANOVA Table for MRR

General Linear Model: mrr1 versus speed, feed, doc

Factor	Type	Levels	Values
speed	fixed	3	460, 750, 1250
feed	fixed	3	0.052, 0.065, 0.081
doc	fixed	3	0.04, 0.08, 0.12

Analysis of Variance for mrr1, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Percentage
speed	2	0.0080002	0.0080002	0.0040001	40.25	0.024	89.89
feed	2	0.0002719	0.0002719	0.0001360	1.37	0.422	3.055
doc	2	0.0004285	0.0004285	0.0002143	2.16	0.317	4.814
Error	2	0.0001988	0.0001988	0.0000994			2.233
Total	8	0.0088994					

S = 0.00996900 R-Sq = 97.77% R-Sq(adj) = 91.07%

4.2.2 ANOVA TABLE FOR SURFACE ROUGHNESS

General Linear Model: Ra 1, Ra 2 versus speed, feed, doc

Factor	Type	Levels	Value
speed	fixed	3	460, 750, 1250
feed	fixed	3	0.052, 0.065, 0.081
doc	fixed	3	0.04, 0.08, 0.12

Analysis of Variance for Ra 1, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P	percetage
speed	2	0.0128242	0.0128242	0.0064121	12.29	0.075	63.412
feed	2	0.0005640	0.0005640	0.0002820	0.54	0.649	2.78
doc	2	0.0057915	0.0057915	0.0028957	5.55	0.153	28.63
Error	2	0.0010437	0.0010437	0.0005219			5.16
Total	8	0.0202234					

S = 0.0228444 R-Sq = 94.84% R-Sq(adj) = 79.36%

From the ANOVA table shown it is clear that speed is the most influencing factor for both surface roughness & material removal rate. The percentages of the factors affecting the output are highlighted.

4.3 REGRESSION ANALYSIS

P value ≤ 0.05 is considered to be the most influencing output parameter.R-sq value greater than 80% is acceptable that the regression values 80% nearer to the actual values

4.3.1 Regression analysis for Surface roughness

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Regression Analysis: Ra 1 versus speed, feed, doc

The regression equation is
Ra 1 = 0.102 - 0.000115 speed + 0.545 feed + 0.761 doc


Predictor          Coef      SE Coef      T      P
Constant        0.10168      0.04056   2.51  0.054
speed       -0.00011473  0.00001868  -6.14  0.002
feed             0.5448       0.5139   1.06  0.338
doc              0.7613       0.1866   4.08  0.010


S = 0.0182864   R-Sq = 91.7%   R-Sq(adj) = 86.8%


Analysis of Variance

Source          DF         SS         MS      F      P
Regression       3  0.0185514  0.0061838  18.49  0.004
Residual Error   5  0.0016720  0.0003344
Total            8  0.0202234


Source  DF     Seq SS
speed    1  0.0126125
feed     1  0.0003757
doc      1  0.0055632
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4.3.2 Regression Analysis for MRR

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Regression Analysis: mrr1 versus speed, feed, doc

The regression equation is
mrr1 = - 0.0483 + 0.000086 speed - 0.143 feed + 0.205 doc

Predictor         Coef     SE Coef      T      P
Constant      -0.04829     0.03687  -1.31  0.247
speed       0.00008601  0.00001698   5.07  0.004
feed           -0.1425      0.4672  -0.31  0.773
doc             0.2052      0.1696   1.21  0.280

S = 0.0166217   R-Sq = 84.5%   R-Sq(adj) = 75.2%

Analysis of Variance

Source          DF         SS         MS     F      P
Regression       3  0.0075180  0.0025060  9.07  0.018
Residual Error   5  0.0013814  0.0002763
Total            8  0.0088994


Source  DF     Seq SS
speed    1  0.0070879
feed     1  0.0000257
doc      1  0.0004044
```

Equation from minitab for Regression value for surface roughness

Ra1 =0.102 - 0.000115speed + 0.545feed + 0.761doc

Table 5. Comparison experimental with regression value of Ra

Speed(rpm)	Feed(mm/rev)	Depth of cut(mm)	Ra (mm)	Regression value
460	0.052	0.04	0.1168	**0.10788**
460	0.065	0.08	0.1398	**0.145405**
460	0.081	0.12	0.1678	**0.184565**
750	0.052	0.08	0.088	**0.10497**
750	0.065	0.12	0.1726	**0.142495**
750	0.081	0.04	0.0972	**0.090335**
1250	0.052	0.12	0.075	**0.07791**
1250	0.065	0.04	0.0187	**0.024115**
1250	0.081	0.08	0.0642	**0.063275**

Fig.3. Graph showing the Comparison experimental with regression value of Ra

4.3.3Regression analysis table for MRR

Equation from minitab for Regression value for MRR :

MRR = -0.0483+0.000086 speed - 0.143 feed +0.205do

Table 6. Comparison experimental with regression value of MRR

Speed(rpm)	Feed(mm/rev)	Doc(mm)	MRR (gm/sec)	Regression value
460	0.052	0.04	0.00591	0.005665
460	0.065	0.08	0.00675	0.000745
460	0.081	0.12	0.008928	0.02194
750	0.052	0.08	0.01105	0.027475
750	0.065	0.12	0.01098	0.007795
750	0.081	0.04	0.00544	0.07314
1250	0.052	0.12	0.089	0.054075
1250	0.065	0.04	0.0483	0.058995
1250	0.081	0.08	0.0769	0.0483

Fig.4 Graph showing the Comparison experimental with regression value of MRR

4.3.5 Summary

Table 7. optimum value of parameters for Ra

Experiment no	Speed (rpm)	Feed(mm/rev)	Depth of cut (mm)	Ra (mm)
8	1250	0.065	0.04	0.0187

Table 8.Table optimum value of parameters for MRR

Experiment no	Speed (rpm)	Feed (mm/rev)	Depth of cut (mm)	MRR (gm/sec)
9	1250	0.081	0.08	0.0769

5. CONCLUSION

In this study the material removal rate and surface roughness prediction of turning on EN 24 steel has been considered. Turning tests were carried out on a Lathe using and Ceramic tool with single insert. A regression model was created for the material removal rate and surface roughness. These models have given the better agreement with the experimental results. From the experimental study it can be seen that cutting speed has the significant effect on material removal rate and roughness when compared to feed rate. As for as the surface finish it can be seen that, surface finish obtained is better at high speeds and low feed rate.

6. REFERENCES

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