T. Sreenivasa Murthy, R.K.Suresh, G. Krishnaiah, V. Diwakar Reddy / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 3, Issue 2, March -April 2013, pp.1144-1148

Optimization of process parameters in dry turning operation of EN 41B alloy steels with cermet tool based on the Taguchi method

T. Sreenivasa Murthy[1], R.K.Suresh[2], G. Krishnaiah[3], V. Diwakar Reddy[4]
[1] PG Scholar , [2] Asst. Professor (Sr.) - Department of Mechanical Engineering ,
Srikalahasteeswara Institute of Technology, Srikalahasti.
[3]Professor ,[4]Asso. Professor - Department of Mechanical Engineering,
SVU College of Engineering, S. V. University. Tirupathi.

ABSTARCT

This paper envisages the optimal setting of process parameters which influences the surface roughness during the machining operation of En 41B alloy steel with cermet tool. Experiments have been carried out by using Taguchi design. The surface roughness is considered as quality characteristic while the process parameters considered are speed, feed and depth of cut. The results of the machining experiments for En 41B were used to characterize the main factors affecting surface roughness by the Analysis of Variance (ANOVA). The feed and speed are identified as the most influential process parameters on work piece surface roughness.

Keywords : Machining, Surface Roughness, Taguchi Method, En 41B,ANOVA.

1. INTRODUCTION :

The challenge of modern machining industries is mainly focused on the achievement of high quality, in terms of work piece dimensional accuracy, surface finish, high production rate, less wear on the cutting tools, economy of machining in terms of cost saving and increase the performance of the product with reduced environmental impact [1]. Surface roughness plays an important role in many areas and is a factor of great importance in the evaluation of machining accuracy [2].The Taguchi method is statistical tool, adopted experimentally to investigate influence of surface roughness by cutting parameters such as speed, feed and depth of cut [3]. The Taguchi process helps to select or to determine the optimum cutting conditions for turning process. Many researchers developed many mathematical models to optimize the cutting parameters to get lowest surface roughness by turning process. The variation in the material hardness, alloying elements present in the work piece material and other factors affecting surface finish [4]. The Taguchi design of experiments was used to optimize the cutting parameters and more detail on Taguchi is mentioned below.

Taguchi method

Taguchi method is a powerful tool for the design of high quality systems. It provides simple, efficient and systematic approach to optimize designs for performance, quality and cost [5]. Taguchi method is efficient method for designing process that operates consistently and optimally over a variety of conditions. To determine the best design it requires the use of a strategically designed experiment [6]. Taguchi approach to design of experiments in easy to adopt and apply for users with limited knowledge of statistics, hence gained wide popularity in the engineering and scientific community [7-8]. The desired cutting parameters are determined based on experience or by hand book. Cutting parameters are reflected on surface roughness, surface texture and dimensional deviation turned product [15-16]. In a manufacturing process it is very important to achieve a consistence tolerance and surface finish [9]. Taguchi method is especially suitable for industrial use, but can also be used for scientific research [10].

Analysis of variance (ANOVA)

Since there are a large number of variables controlling the process, some mathematical models are required to represent the process. However, these models are to be developed using only the significant parameters influencing the process rather than including all the parameters. In order to achieve this, statistical analysis of the experimental results will have to be processed using the analysis of variance (ANOVA) [17] . ANOVA is a computational technique that enables the estimation of the relative contributions of each of the control factors to the overall measured response.

2. EXPERIMENTAL ANALYSIS

Turning is very important machining process in which a single point cutting tool removes unwanted material from the surface of a rotating cylindrical work piece. The cutting tool is fed linearly in a direction parallel to the axis of rotation. Turning is carried on a lathe that provides the power to turn the work piece at a given rotational speed and to feed to the cutting tool at specified rate and depth of cut. Therefore three cutting parameters namely speed, feed and depth of cut need to be determined in a turning operation. The turning operations are accomplished using a cutting tool. The purpose of turning operation is to produce low surface roughness of the parts. Surface roughness is an important factor to evaluate cutting performance. Proper selection of cutting parameters and tool can produce longer tool life and lower surface roughness. Hence, design of experiments by Taguchi method on cutting parameters was adopted to study the surface roughness [5]. The cutting parameters chosen are shown in the Table 3.

Fig. 1 View of cutting zone

The experiment was conducted for dry turning operation of EN 41-B alloy steel with cermet tool. The tests were carried for a length of 200 mm in a PSG A141 lathe. The control factors and their levels are illustrated in Table 1. The cutting parameters ranges were selected based on machining guidelines provided by manufacturer of cutting tools manufacturers Kayocera. The different alloying elements present in a work piece are shown in the Table 2.

Table 1 Control factors and levels

Code	Control factors	Levels		
		1	2	3
A	speed, s (rpm)	360	450	580
B	feed, f (mm/rev)	0.05	0.07	0.09
C	Depth of cut, d (mm)	0.05	0.1	0.15

Table 2 Chemical composition of En 41B Alloy Steel

C	Mn	Si	S	P	Cr	Ni	Mo
0.35 - 0.45	0.60 MAX	0.10 - 0.45	0.04	0.04	1.50 - 1.80	0.40 MAX	0.10 -0.25

The surface roughness of machined surface has been measured by a stylus (surftest SJ210-P) instrument. The dependent variable is surface roughness. Table 3 shows standard L_{27} (3^3) orthogonal array designed by Taguchi with experimental results. The left side of the Table 3 includes coding values of control factors and real values of cutting parameters. The right side of the Table 3 includes the results of the measured values of the surface roughness and calculated S/N ratio. The different units used here are: speed – rpm, feed mm/ rev, depth of cut – mm and surface roughness Ra - µm. Design – MINTAB version 16 software was used for Taguchi's method and for analysis of variance (ANOVA).

Table 3. Plan of experiments with Results

Experiment No.	Control Factors			Parameters			Surface Roughness Ra - µm	S/N Ratio
	A s	B f	C d	Speed s -rpm	Feed(f) mm/rev	DOC d -mm		
1	1	1	1	360	0.05	0.05	2.09	-6.402
2	1	1	2	360	0.05	0.1	2.34	-7.384
3	1	1	3	360	0.05	0.15	2.68	-8.562
4	1	2	1	360	0.07	0.05	2.83	-9.035
5	1	2	2	360	0.07	0.1	1.861	-5.394
6	1	2	3	360	0.07	0.15	1.9	-5.575
7	1	3	1	360	0.09	0.05	3.94	-11.909
8	1	3	2	360	0.09	0.1	3.74	-11.457
9	1	3	3	360	0.09	0.15	3.69	-11.340
10	2	1	1	450	0.05	0.05	1.562	-3.873
11	2	1	2	450	0.05	0.1	1.8	-5.105
12	2	1	3	450	0.05	0.15	1.71	-4.659

13	2	2	1	450	0.07	0.05	1.31	-2.345
14	2	2	2	450	0.07	0.1	1.27	-2.076
15	2	2	3	450	0.07	0.15	3.67	-11.293
16	2	3	1	450	0.09	0.05	2.71	-8.659
17	2	3	2	450	0.09	0.1	3.59	-11.101
18	2	3	3	450	0.09	0.15	2.5	-7.958
19	3	1	1	580	0.05	0.05	2.37	-7.494
20	3	1	2	580	0.05	0.1	2.103	-6.456
21	3	1	3	580	0.05	0.15	1.94	-5.756
22	3	2	1	580	0.07	0.05	1.89	-5.529
23	3	2	2	580	0.07	0.1	2.94	-9.366
24	3	2	3	580	0.07	0.15	2.72	-8.691
25	3	3	1	580	0.09	0.05	4.27	-12.608
26	3	3	2	580	0.09	0.1	4.07	-12.191
27	3	3	3	580	0.09	0.15	3.39	-10.604

Surface roughness

Surface properties such as roughness are critical to the function ability of machine components. Increased understanding of the surface generation mechanisms can be used to optimize machining process and to improve component function ability [11]. Numerous investigators have been conducted to determine the effect of parameters such as feed rate, speed and depth of cut on surface roughness in hard turning operation [12-13]. The present study has shown two purposes. The first was to demonstrate the use of Taguchi parameter design in order to identify the optimum surface roughness with particular combination of cutting parameters and a systematic procedure using Taguchi design in process design of turning operations. The second was to determine the optimum combination of process parameters more accurately by investigating the relative importance of process parameters using ANOVA. The average surface roughness is given by [14]

$$Ra = \frac{1}{L}\int_0^L |\,y(x)\,|\ dx$$

Where Ra is the arithmetic average deviation from the mean line, L is the sampling length, y coordinate of the profile curve. The obtained results are analyzed using Minitab software and all the values are shown in the Table 4.

Table 4. ANOVA table for Surface roughness

Source	DOF	S.S	M.S	F Value	C%
Speed(s)	2	2.07	1.04	1.54	9.99
Feed (f)	2	11.58	5.79	8.61	55.89
Depth of cut (s)	2	0.23	0.12	0.17	1.12
s X f	4	0.03	0.01	0.01	0.13
s X d	4	1.02	0.26	0.38	4.93
f X d	4	0.41	0.10	0.15	1.98

DOF - Degrees of freedom , S.S - Sum of Squares , M.S - Mean of Squares and C - Contribution

From the ANOVA Table 4, it is evident that the maximum contribution factor is feed having percentage contribution up to 55.89 . After that second main contribution is speed having percentage contribution up to 9.99 and depth of cut has very little role to play on surface roughness. Hence the individual ranking of cutting parameters on the average value of mean on surface roughness are shown in Table 5:

Table 5 : Ranking of cutting parameters

Level	**Speed**	**Feed**	**Depth of cut**
1	2.786	**2.066**	**2.552**
2	**2.236**	2.266	2.635
3	2.855	3.544	2.689
Rank	**2**	**1**	**3**

Mathematical modeling

A regression model was developed for surface roughness using Minitab-16 software. The predictions are speed, feed and depth of cut. Regression equation for surface roughness is $Ra = e^{3.02}\, S^{0.068}\, f^{0.874}\, d^{0.074}$

Main effect plots analysis

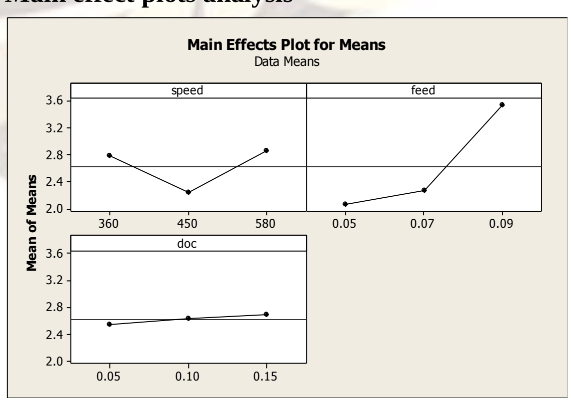

Fig 2: Effect of turning parameters on Surface Roughness

The analysis is made with the help of software package MINITAB-16. The main effect of plot is shown in Fig. 2. It shows the variation of individual response with three parameters i.e. speed, feed and depth of cut separately. In the plot x-axis represents the value of each process parameter and y-axis is response value. Horizontal line indicates the mean of the response. The main effect plots are used to determine the optimal design conditions to obtain the optimal surface finish.

According to this main effect plot, the optimal conditions for minimum surface roughness are speed at level 2 (450 RPM) , feed rate at level 1 (0.05 mm/rev) and depth of cut at level 1 (0.05mm).

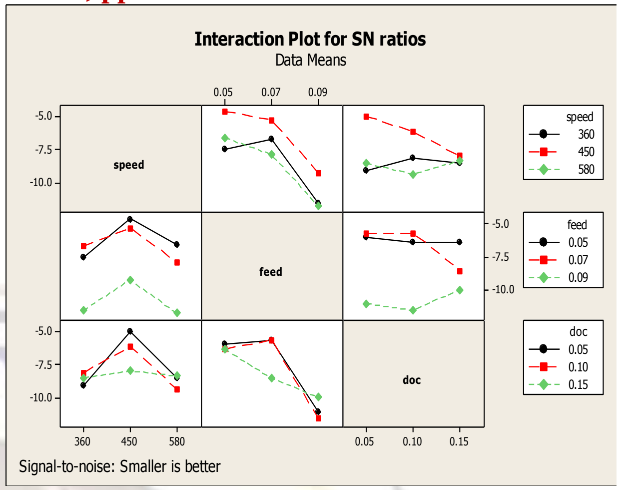

Fig 3. Interaction plot for S/N Ratios of the Surface Roughness

Interaction plot for S/N ratios of the Surface roughness for data means is shown in Fig .3 Signal-to-Noise ratio of common interest for optimization for surface roughness is smaller the better.

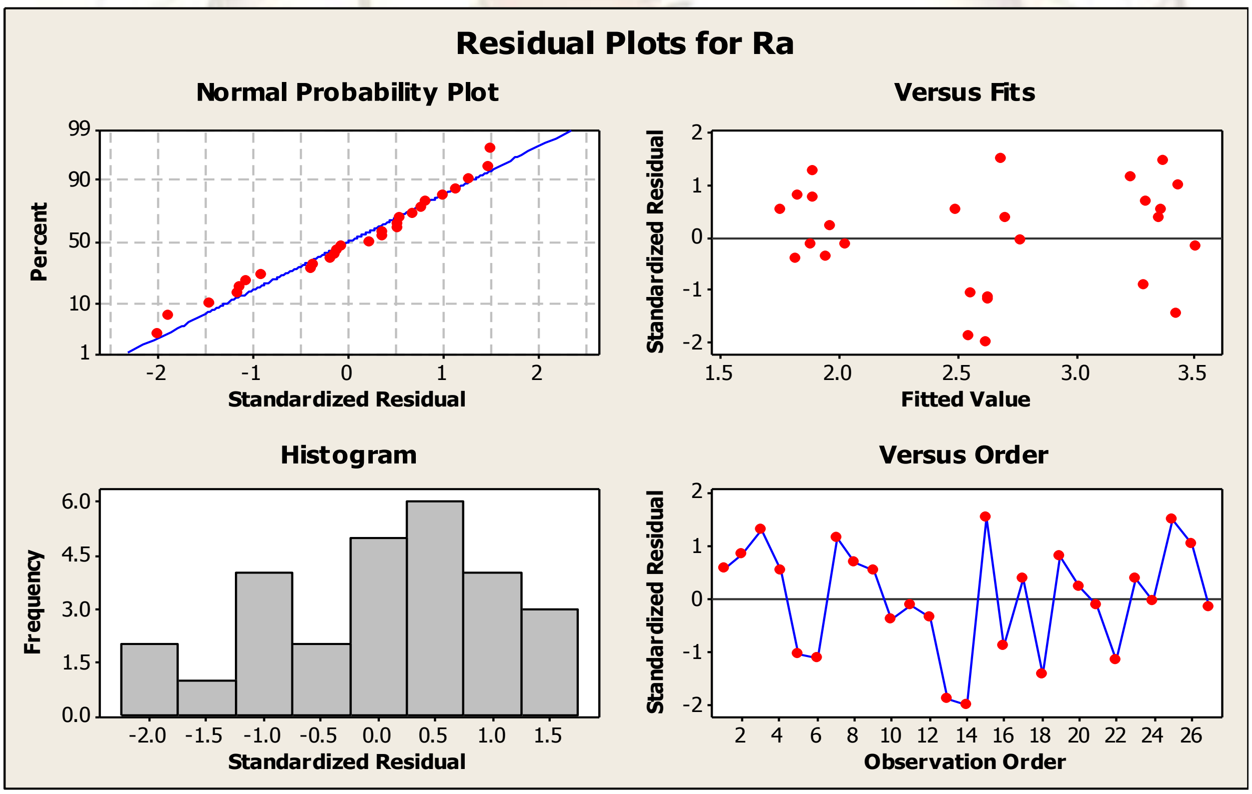

Fig 4. Residual analysis of Surface roughness

The diagnostic checking has been performed through residual analysis for the developed model. The residual plots for surface roughness are shown in Fig. 4. These are generally fall on a straight line implying that errors are distributed normally. From Fig .4, it can be concluded that all the values are within the control range, indicating that there is no obvious pattern and unusual structure and also the residual analysis does not indicate any model inadequacy. Hence these values yield better results in future predictions.

3. CONCLUDING REMARKS

The following are conclusions drawn based on the experimental investigation conducted on turning EN 41-B alloy steel with cermet cutting tool at three levels by employing Taguchi technique to determine the optimal level of process parameters.

1. The ANOVA and F-test revealed that the feed is dominant parameter followed by speed for surface roughness.
2. The optimal combination process parameters for minimum surface roughness is obtained at 450 rpm, 0.05 mm/rev and 0.05mm.
3. A regression model is developed for surface roughness. The developed model is reasonably accurate and can be used of prediction within limits.
4. Taguchi gives systematic simple approach and efficient method for the optimum operating conditions.

References

[1] S. Thamizhmanii, S. Hasan, Analyses of roughness, forces and wear in turning gray cast iron, Journal of achievement in Materials and Manufacturing Engineering, 17, 2006.

[2] Palanikumar, L. Karunamoorthy, R. Krathikeyan, Assessment of factors influencing surface roughness on the machining of glass– reinforced polymer composites, Journal of Materials and Design, 27 (2006) 862-871.

[3] Xue Ping, C. Richard Liu, Zhenqiang Yao, Experimental study and evaluation methodology on hard surface integrity, International Journal Advanced Manufacturing Technology, ODI 10.1007/s00170-006-0576-6.

[4] T. Tamizharasan, T. Selvaraj, A. Noorul Hag, Analysis of tool wear and surface finish in hard turning, International Journal of Advanced Manufacturing Technology (2005), DOI 10/1007 /s 00170-004-2411-1.

[5] W.H. Yang, Y.S. Tang, Design optimization of cutting parameters for turning operations based on Taguchi method, Journal of Materials Processing Technology, 84 (1998) 122-129.

[6] Ersan Aslan, Necip Camuscu Burak Bingoren, Design of optimization of cutting parameters when turning hardened AISI 4140 steel (63 HRC) with Al 2 O3 + TiCN mixed ceramic tool, Materials and Design, date received 21.07.2005 and date accepted 06.01.2006.

[7] D.C. Montgometry, Design and analysis of experiments, 4th edition, New York: Wiley; 1997.

[8] N. Nalbant, H. Gokkaya, G. Sur, Application of Taguchi method in the optimization of cutting parameters for surface roughness in turning, Materials and Design, date received 21.07.2006 and date accepted 06.01.2006.

[9] I.A. Choudhury, M.A. El-Baradie, Surface roughness prediction in the turning of high strength steel by factorial design of experiments, Journal of Materials Processing technology, 67 (1997) 55-67.

[10] B. Erginc, Z. Kampus, B. Sustarsic, The use of the Taguchi approach to determine the influence of injection –molding parameters on the properties of green parts, Journal of achievement in Materials and Manufacturing Engineering, 15, 2006.

[11] X.L. Liu, D.H. Wen, Z.J. Li, . Xiao, .G. Yan, Experimental study on hard turning of hardened GCr15 steel with PCBN tool, Journal of Materials Processing Technology, 129 (2002) 217-221.

[12] W. Konigi, M. Klinger, R. Link, Ann.CIRP 39 (1990) 61-64.

[13] M.A. Davis, Y. Chou, C.J. Evans, Ann.CIRP 45(1996) 77-82.

[14] I. Puertas Arbizu, C.J. Luis Perez, Surface roughness prediction by factorial design of experiments in turning processes, Journal of Materials Processing Technology, 143- 144 (2003) 390-396.

[15] Naveen, A. Sait, S, Aravindan, and Noorul Haq., A., (2009), Influence of machining parameters on surface roughness of GFRP pipes. Journal of Advances on Production Engineering and Management, 4 (1-2), p. 47-58.

[16] Yusuf, K., Nukman, Y., Yusof, T. M., Dawal, S. Z., Qin Yang, H., Mahlia., T. M. I., and Tamrin., K. F., (2010), Effect of cutting parameters on the surface roughness of titanium alloys using end milling process. Journal of Scientific Research and Essays 5(11), p. 1284-1293.

[17] Rahul Davis, Jitendra Singh Madhukar, Vikash Singh Rana, and Prince Singh ., Optimization of Cutting Parameters in Dry Turning Operation of EN24 Steel . International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, Volume 2, Issue 10, October 2012)

[18] Onkar N. Panday " Total Quality Management "