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Analyses of surface roughness by turning process using Taguchi method

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ABSTRACT

Purpose: The purpose of this research paper is focused on the analysis of optimum cutting conditions to get lowest surface roughness in turning SCM 440 alloy steel by Taguchi method.
Design/methodology/approach: Experiment was designed using Taguchi method and 18 experiments were designed by this process and experiments conducted. The results are analyzed using analysis of variance (ANOVA) method.
Findings: Taguchi method has shown that the depth of cut has significant role to play in producing lower surface roughness followed by feed. The Cutting speed has lesser role on surface roughness from the tests.
Research limitations/implications: The vibrations of the machine tool, tool chattering are the other factors which may contribute poor surface roughness to the results and such factors ignored for analyses.
Originality/value: The results obtained by this method will be useful to other researches for similar type of study and may be eye opening for further research on tool vibrations, cutting forces etc.
Keywords: Machining; Dry turning; Surface roughness; Taguchi metod

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 cutting 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 and tool wear [4]. The Taguchi design of experiments was used to optimize the cutting parameters and more detail on Taguchi is mentioned below.

2. 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 [8]. 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].

3. Experimental set up and cutting conditions

3.1. Experiments

The experiment was conducted using one work piece material namely soft SCM 440 steel with coated ceramic tool. The Cutting tool used was coated and having combination of Al2O3 + TiC with tin coating (Golden) manufactured by Kyocera and named as A66.The tests were carried for a length of 200 mm in a Harrison 400 lathe. This machine is having fixed revolution per minute and fixed feed. The cutting parameters are shown in the Table 1. Three levels of cutting speed, three levels of feed and two levels of depth of cut were used and are shown in the Table 1. The different alloying elements present in a work piece are shown in the table 2.

Table 1.
Cutting parameters

Symbol	Cutting Parameter	Level 1	Level 2	Level 3
A	Cutting speed	135	185	240
B	Feed	0.04	0.05	0.063
C	Depth of cut	1.00	1.50	--

Table 2.
Composition of SCM 440 alloy steel

Material	C %	Mn %	Cr.%	Mo. %
SCM 440	0.35 /0.43	0.75/1.00	0.80/0.75	0.15/0.25

The surface roughness was measured by using Mahr Pertho meter. The dependent variable is surface roughness. In total 18 experiments were designed by Taguchi method, conducted and responses are shown in the Table 3. The Table 3 gives the various cutting parameters for each experiment; the results are measured and shown in the last column of the same Table 3. The different units used here are: cutting speed – m / min, Feed-mm rev, depth of cut (DOC) – mm, surface roughness Ra - µm. Design – Expert software was used for Taguchi's method. Dry turning process was used.

3.2. Turing process

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 cutting speed, feed and depth of cut need to be determined in a turning operation. The turning operations are accomplished using a cutting tool; the high forces and temperature during machining create a harsh environment for the cutting tool. Therefore tool life is important to evaluate cutting performance. The purpose of turning operation is to produce low surface roughness of the parts. Surface roughness is another 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. In this study, only surface roughness was studied by Taguchi method.

Table 3.
Cutting conditions and response

Run	Cutting speed A	Feed B	DOC C	Surface Roughness Ra (µm)
1	135	0.05	1.50	0.60
2	185	0.04	1.50	0.41
3	185	0.04	1.50	0.63
4	135	0.063	1.50	0.84
5	240	0.063	1.00	0.82
6	240	0.04	1.50	0.46
7	240	0.05	1.50	0.80
8	135	0.04	1.00	0.76
9	185	0.063	1.00	0.65
10	240	0.063	1.50	0.41
11	185	0.05	1.50	0.98
12	135	0.04	1.50	0.50
13	240	0.04	1.00	0.53
14	240	0.05	1.00	0.59
15	185	0.04	1.00	0.43
16	185	0.063	1.50	0.77
17	135	0.05	1.00	0.90
18	135	0.063	1.00	0.44

3.3. Surface roughness

Surface properties such as roughness are critical to the function ability of machine components. Increased under standing of the surface generation mechanisms can be used to optimize machining process and to improve component functionability [11]. Numerous investigators have been conducted to determine the effect of parameters such as feed rate, tool nose radius, cutting speed and depth of cut on surface roughness in hard turning operation [12-13]. The surface roughness decreases with increasing nose radius. Large nose radius tools have produced better surface finish than small nose radius tools [14]. The research 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. The second was to demonstrate a systematic procedure using Taguchi design in process design of turning operations. In this experiment both were achieved.
The average surface roughness is given by [15]

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

Where Ra is the arithmetic average deviation from the mean line, L is the sampling length, y coordinate of the profile curve. The equation obtained by this method has agreement to the surface roughness by validation for set of cutting parameters. The obtained results are analyzed using Design –Expert soft ware and all the values are shown in the table 4. From the ANOVA table 4, it is evident that 14.467 % depth of cut C is contributing on surface roughness than other two cutting parameters. The feed is the next contributing factor having 9.764 % on surface roughness and Cutting speed has very little role to play. The results obtained by this method was formed as equation by the same soft ware and given as equation 2.

The equation obtained by the Taguchi method is:

= 0.64 + 0.0500*A- 0.22*B[1]+ 0.075*B[2]+ -0.828*C[1]+ 0.082*C[2]-0.075*AB[1]+ 0.11AB[2]- 0.032*AC[1]+0.052*AC[2]+3.333 E-003*B[1]C[1]- 0.013*B[2]C[1]-0.17B[1]C[2]+8.333 E -003*B[2]C[2] (2)

The formed equation was validated by tests and the error between the theoretical and actual value was very negligible.

Table 4.
ANOVA table for Surface roughness

	S.S.	DF	M.S.	F Value	Prob >F	C %
Model	0.55	13	0.043	9.49	-	-
A	0.045	1	0.045	10.04	0.0339	8.137
B	0.054	2	0.027	5.98	0.0628	9.764
C	0.080	2	0.040	8.93	0.0335	14.467
AB	0.110	2	0.055	12.36	0.0194	19.893
AC	0.024	2	0.012	2.72	0.1792	4.339
BC	0.24	4	0.060	13.32	0.013	43.400
Residual	0.018	4	4.483E-003			100.00
Cor Total	0.57					

SS-Sum of Squares, D.F. Degrees of freedom, M.S.- Mean Square, C- Contribution

4. Concluding remarks

The following are conclusions drawn based on the tests conducted on turning SCM 440 steel with Al2O3 + TiC golden coating coated cutting tool.

1. From the ANOVA, Table 4 and the P value, the depth of cut is the only significant factor which contributes to the surface roughness. i.e. 14.467 % contributed by the depth of cut on surface roughness.
2. The second factor which contributes to surface roughness is the feed having 9.764 %
3. The Validation experiment confirms that the error occurred was less than 1.0% between equation and actual value.
4. It is recommended from the above results that depth of cut of 1 to 1.5 mm can be used to get lowest surface roughness.
5. Taguchi gives systematic simple approach and efficient method for the optimum operating conditions.

This research gives how to use Taguchi's parameter design to obtain optimum condition with lowest cost, minimum number of experiments and industrial engineers can use this method. The research can be extended by using tool nose radius, lubricant, material hardness, etc as parameters.

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. Kampuŝ, B. Sustarsic, The use of the Taguchi approach ro 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. Königi, 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] Y. Kevin Chou, Hui Song, Tool nose radius effects on finish hard turning, Journal of Materials Processing Technology, 148 (2004) 259-268.
[15] I. Puertas Arbizu, C.J. Luis Pėrez, Surface roughness prediction by factorial design of experiments in turning processes, Journal of Materials Processing Technology, 143-144 (2003) 390-396.