Applied Mechanics and Materials *Online: 2014-06-18*
ISSN: 1662-7482, Vol. 573, pp 638-643
doi:10.4028/www.scientific.net/AMM.573.638

EXPERIMENTAL STUDY FOR TURNING AISI1040 STEEL USING TiCN/TiN COATED TOOL

P.Marimuthu [a] and N.E. Edwin paul [b]

[a] Professor, Department of Mechanical Engineering and Principal Syed Ammal Engineering College, Ramanathapuram, Tamilnadu, India,
Email: pmarimuthu69@gmail.com and Corresponding author

[b] Research scholar, Department of Mechanical Engineering, Bharath University, Chennai - 73, and Assistant Professor, Department of Mechanical Engineering, GRT Institute of Engineering & Technology, Tirutani – 631 209
Email: edwinpaul@gmail.com

Keywords: AISI1040; CNC Turning; Surface roughness; Tool wear; Taguchi method.

Abstract. AISI 1040 is a high quality, unalloyed medium carbon steel usually good ductility with resistance to wear. Tool wear (TW) and surface roughness (SR) are mostly considered as demanding phases, and thus causing poor results in machining operations. Optimization of cutting parameter is more crucial at this condition for improving the quality of the product. Taguchi method is the method to achieve a robust experimental design in the study of product quality is an important issue. The best factors/levels combination with lowest societal cost solution to achieve customers requirements look by Taguchi method. Various cutting speed, feed and depth of cut are taken as parameters. In this study single response optimization was performed in computer numerically controlled (CNC) turning AISI1040 with TiCN/TiN coated cutting tool under dry condition using Taguchi Techniques with the objective of minimization SR and TW. Analysis of variance (ANOVA) was used for identifying the significant parameters affecting the responses.

1. INTRODUCTION

Modern industries are trying to achieve the high quality products in a very short time with less operator input. For that purpose, the CNC machine tools with automated and flexible manufacturing systems have been implemented. In the manufacturing industries, various manufacturing processes are adopted to remove the material from the work piece. Out of these, turning is the first most common method for metal cutting because of its ability to remove materials faster with a reasonable good surface quality [1, 2]. Surface finish is one of the most important quality characteristics in manufacturing industries which influences the performance of mechanical parts as well as production cost. SR of a machined product could affect several of the product's functional attributes such as contact causing surface friction, wearing, light reflection, heat transmission, ability of distributing and holding a lubricant, coating and resisting fatigue. Therefore, SR is one of the important quality aspects in turning and facing operations [3, 4]. TW which results in tool substitution is one of the most important economical penalties, so it is very important to minimize TW, and optimizing all the cutting parameters [5, 6].

In actual practice, there are many factors which affect surface roughness and tool wear, such as cutting conditions, tool variables and work piece variables. Cutting conditions include cutting speed, feed and depth of cut where as tool variables include tool material, nose radius, rake angle, cutting edge geometry, tool vibration, tool overhang, tool point angle etc. and work piece variable include material hardness and other mechanical properties [7]. However, it is very difficult to control all the parameters at a time that affect the surface roughness and tool wear for a particular manufacturing process. In a turning operation, it is a vital task to select the cutting parameters properly to achieve the high quality performance [8]. Generally, the desired cutting parameters are selected based on experience or use by the hand book. But a better result may be achieved by modeling and optimization of cutting parameters. Several mathematical models based on statistical

regression or neural network techniques have been constructed to establish the relationship between the cutting performance and cutting parameters. Various compositions of cutting tools were used by past researchers for turning AISI1040. But single response optimization on AISI1040 with multi layered coated cutting tool were not carried out by them. So, in this investigation, single response optimization was performed in turning AISI1040 with TiCN/TiN coated cutting tool using Taguchi Techniques for minimization of SR and TW.

2. MATERIAL AND METHODS

The work piece materials selected for all the trials are AISI1040. The chemical composition of the work piece material is given in Table 1. Experiments were conducted on CNC Fanuc lathe using AISI1040 steel rods of 22.8mm diameter and 30mm of machined length.

Table 1 Chemical composition of the AISI1040

C	Si	Mn	S	P
0.36-0.44%	0.10-0.40%	0.60-1.00%	0.050	0.050

2.1. Taguchi Techniques

Taguchi method based robust design approach has produced a unique and powerful quality improvement discipline that differs from traditional practices. Taguchi approach can economically satisfy the need of problem solving and product/process design optimization projects in the manufacturing industries [9]. By applying this, it is possible to reduce the time for experimental investigations and improve the process quality. Robust design is a methodology for finding the optimum setting of the control factor to make the product or process insensitive to the noise factors. Robust design is based upon the technique of matrix experiments. Experimental matrices are special orthogonal arrays, which allow the simultaneous effect of several process parameters to be studied efficiently [10]. The purpose of conducting the orthogonal experiment is to determine the optimum level for each factor and to establish the relative significance of individual factors in terms of their main effects on the response. Taguchi suggests signal to noise ratio (S/N) as the objective function for matrix experiments. The S/N ratio is used to measure the quality characteristics and is also used to measure the significant machining parameters through the ANOVA [11]. Taguchi classifies objective function into three categories, such as smaller the better type, larger the better type, nominal the best type. The optimum level for the factor is the level that results in the highest value of signal to noise ratio in the experimental region [12, 13]. The main objective of this paper is to study the different process parameters during turning of AISI1040 steel using robust design methodology for minimization of SR and TW. This paper attempts to introduce how Taguchi parameter design could be used in identifying the significant processing parameters and optimizing the SR for turning operations. Since the quality characteristics are to be minimized, the-lower-the-better category is used to calculate the S/N ratio for SR and TW. Equation (1) shows the lower the better characteristic.

$$\text{S/N ratio } (\eta) = -10 \log_{10} \left(\frac{1}{n} \sum_{i=1}^{n} y_{ij}^{2} \right) \quad (1)$$

Where: η = Signal to noise ratio, n = Number of repetitions of experiment, y = Measured value of quality characteristic

3. EXPERIMENTAL DETAILS

Three operating factors such as depth of cut, feed and cutting speed have been selected for parametric optimization and each parameter has three levels. These factors and three levels are given in Table 2. Orthogonal array gives more reliable estimates of factor effects with less number of experiments, when compared to the traditional methods, such as one factor at a time experiments.

Hence, L_{27} orthogonal array having 26 degrees of freedom was selected for the controllable factors. L_{27} indicates 27 trials considered for experimentation, the array along with factor assignment to the columns is given in Table 3. Experiments were conducted on CNC Fanuc lathe using AISI1040 steel rods of 22.8mm diameter as dictated by L_{27} orthogonal array. The SR was measured using Surf Test 211 with a cut off length of 0.25mm. TW was measured by optical tool maker's microscope with image optic plus version 2.0 software designed to run under Microsoft window's 32 bit system which can be captured by the area of the TW. In this investigation the multi-layered TNMG 120408 coated with TiCN/TiN of 6 μm is used as the insert for turning operation. Tool holder of MTJNR 25 × 25 M16 was selected. Minitab14 statistical software has been used for the analysis of the experimental work. The software studies the experimental data and then provides the calculated results of S/N ratio. In this work, the software has given the S/N ratio for both the SR and TW. The effect of different process parameters on SR and TW are in table 4 and tale 5. The main effect plot for S/N ratio for SR and TW are shown in fig 1 and fig 2. From the figure, it reveals that process parameters changes from one level to another. The average value of S/N ratio has been calculated to find out the effects of different parameters and their levels. The experimental results were analyzed with ANOVA which is used for identifying the factors which significantly affecting the performance measures. The results of the ANOVA for SR and TW are shown in Table 6 and 7, respectively. This analysis was carried out for significance level of $\alpha = 0.05$, i.e. for a confidence level of 95%.

Table 2 Factor and Levels

Factors / levels	Design.	1	2	3
Cutting Speed m/min)	V	130.79	156.94	183.08
Feed (mm/rev)	F	0.25	0.5	0.75
Depth of Cut(mm)	a	0.5	1	1.5

Table 3 Experimental results and S/N ration for SR and TW

Si no	v	F	a	SR in microns	S/N	TW in microns	S/N
1	1	1	1	1.813	-5.168	54	-34.647
2	1	1	2	1.83	-5.249	76	-37.616
3	1	1	3	2.25	-7.043	116	-41.289
4	1	2	1	2.786	-8.899	72.03	-37.150
5	1	2	2	2.703	-8.636	90	-39.084
6	1	2	3	3.03	-9.628	130.4	-42.305
7	1	3	1	3.62	-11.174	94	-39.462
8	1	3	2	3.576	-11.068	96	-39.645
9	1	3	3	3.876	-11.767	144.22	-43.180
10	2	1	1	1.736	-4.791	74.03	-37.388
11	2	1	2	1.876	-5.464	102	-40.17
12	2	1	3	1.79	-5.057	178.01	-45.008
13	2	2	1	2.446	-7.769	94	-39.462
14	2	2	2	2.2	-6.848	112.07	-40.989
15	2	2	3	2.536	-8.083	186.01	-45.390
16	2	3	1	3.273	-10.298	122.02	-41.728
17	2	3	2	3.37	-10.552	168.76	-44.545
18	2	3	3	3.413	-10.662	214.01	-46.608
19	3	1	1	1.393	-2.879	104.31	-40.366
20	3	1	2	1.806	-5.134	176.05	-44.912

21	3	1	3	1.39	-2.860	208	-46.361
22	3	2	1	2.29	-7.196	132.02	-42.412
23	3	2	2	2.123	-6.539	186.01	-45.390
24	3	2	3	2.533	-8.072	222.01	-46.927
25	3	3	1	3.276	-10.306	126	-42.007
26	3	3	2	3.043	-9.666	188.04	-45.48
27	3	3	3	3.136	-9.927	250.97	-47.992

Table 4 Taguchi Analysis: SR versus v, f, a

Level	v	f	a
1	-8.737	**-4.850**	**-7.609**
2	-7.725	-7.964	-7.684
3	**-6.954**	-10.603	-8.123
Delta	1.784	5.753	0.513
Rank	2	1	3

Table 5 Taguchi Analysis: TW versus v, f, a

Level	v	f	a
1	**-39.38**	**-40.86**	**-39.40**
2	-42.37	-42.12	-41.98
3	-44.65	-43.41	-45.01
Delta	5.27	2.54	5.60
Rank	2	3	1

Table 6 Analysis of Variance for SR

Source	DF	SS	MS	F	P
v	2	1.1484	0.5742	24.64	0.000
f	2	12.0288	6.0144	258.11	0.000
a	2	0.1405	0.0702	3.01	0.072
Error	20	0.4660	0.0233		
Total	26	13.7838			

S = 0.152649 R-Sq = 96.62% R-Sq (adj) = 95.60%

Table 7 Analysis of Variance for TW

Source	DF	SS	MS	F	P
v	2	28885	14442	61.85	0.000
f	2	5569	2784	11.93	0.000
a	2	33883	16942	72.56	0.000
Error	20	4670	233		
Total	26	73006			

S = 15.2803 R-Sq = 93.60% R-Sq(adj) = 91.68%

4. RESULT AND DISCUSSIONS

4.1. Single response optimization for SR with TiCN/TiN coated cutting tool

From Table 3, the S/N ratio for SR at each level of the machining parameters is clear and also it shows when the setting of each machining parameter is changed from one level to another. The Taguchi analysis of the S/N ratio for SR of TiCN/TiN by Taguchi analysis has been given in Table 4. It shows the rank value for machining parameters and it is stated that feed has the strongest

influence on SR, followed by cutting speed, and depth of cut. The main effect plot for SR of TiCN/TiN is shown in Fig.1. In the plots, the x-axis indicates the value of each machining parameter at the three levels and the y-axis indicates the response value. The horizontal line indicates the mean value of the response. The main effect plots are used to determine the optimal design conditions, to obtain the optimum SR. The graph shows that for reducing the level of SR, the feed must be set to its lowest level (0.25 mm/rev), depth of cut to its low level (0.5 mm), and cutting speed to its high level (183.08 m/min). Table 6 shows the results of ANOVA for SR of TiCN/TiN coated cutting tool. It is observed that the feed (*P* value=0.000) is the most significant parameter, followed by the cutting speed (*P* value=0.000), while the effect of depth of cut has not been found to be statistically significant (*P* value=0.072). A larger F-value shows the greater impact on the machining performance characteristics. Larger F-values are observed for feed and depth of cut.

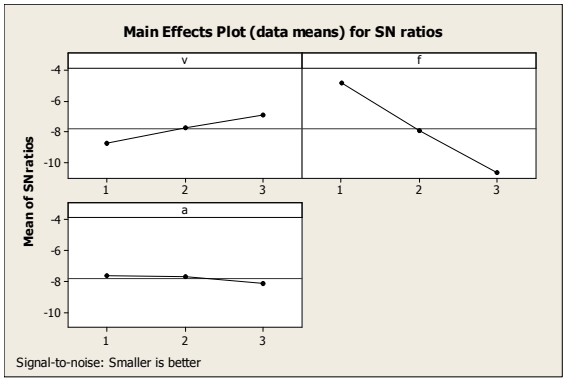

Figure 1 Main Effects Plot for SN ratio of SR

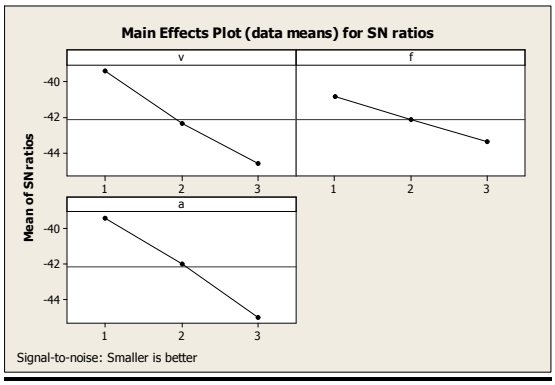

Figure 2 Main Effects Plot for SN ratio of TW

4.2. Single response optimization for TW with TiCN/TiN coated cutting tool

From Table 3, the S/N ratio for TW at each level of the machining parameters is clear and also it shows when the setting of each machining parameter is changed from one level to another can be seen. The Taguchi analysis of the S/N ratio for TW of TiCN/TiN by Taguchi analysis has been given in Table 5. It shows the rank value for machining parameters and it is stated that depth of cut has the strongest influence on TW, followed by cutting speed. The main effect plot for TW of TiCN/TiN is shown in Fig.2. The main effect plots are used to determine the optimal design conditions, to obtain the optimum TW. The graph shows that for reducing the level of TW, the feed must be set to its lowest level (0.25 mm/rev), depth of cut to its low level (0.5 mm), and cutting speed to its low level (130.79 m/min). Table 7 shows the results of ANOVA for TW of TiCN/TiN coated cutting tool. It is observed that the depth of cut (*P* value=0.000) is the most significant parameter, followed by the cutting speed (*P* value=0.000).

5. CONCLUSION

The objective of study is single response optimization of CNC turning on AISI1040 using TiCN/TiN coated cutting tool for minimization of SR and TW. The following conclusions can be arrived from the analysis.

1. Optimum parameter setting for minimization of SR is obtained at a cutting speed of 183.08 m/min, feed rate 0.25 mm/rev and depth of cut 0.5 mm, ie, v_3 f_1 a_1.
2. Optimum parameter setting for minimization of TW is obtained at a cutting speed of 130.79 m/min, feed rate 0.25 mm/rev and depth of cut 0.5 mm, ie, v_1 f_1 a_1.
3. The results of ANOVA, the feed and cutting speed are the significant cutting parameters for affecting the SR. Similarly the depth of cut and cutting speed were the significant cutting parameters for affect TW.
4. Taguchi technique is most effective tool for solving single response problems.

REFERENCES

[1] A.E. Diniz, R. Micaroni, Cutting conditions for finish turning process aiming: the use of dry cutting, Int.J.Mac.Tool.Manuf. 42 (2002) 899- 904.

[2] G. Boothroyd, W.A. Knight, Fundamentals of machining and machine tools, 03 (2006) 573.

[3] Z.W. Zhong, L.P. Khoo, S.T. Han, Prediction of surface roughness of turned surfaces using neural networks, J.Adv.Manuf.Technol. 28 (2006) 688–693.

[4] J.A. Baley, S. Jeelani, S.E. Becker, Surface integrity in machining AISI 4340 steel, J.Engg.Ind., 98 (2007) 999- 1007.

[5] E.O. Ezugwu, C.I. Okeke, Tool life and wear mechanisms of TiN coated tools in an intermittent cutting operation, J.Mat.Proc.Tech. 01 (2001) 116:10–15.

[6] M. Nouari, G. List, F. Girot, D. Coupard, Experimental analysis and optimization of tool wear in dry machining of aluminum alloys, Wear, 255 (2003) 1359–1368.

[7] R. Jeyapaul, P. Shahabudeen, K. Krishnaiah, Simultaneous optimization of multi-response problems in the Taguchi method using genetic algorithm, Int.J.Adv.Manuf.Tech. 30 (2006) 870:878.

[8] M. Kaladhar, K. Venkata Subbaiah, C. Srinivasa Rao, Performance evaluation of coating materials and process parameters optimization for surface quality during turning of AISI 304 austenitic stainless steel, Int.J.Engg.Sci.Tech. 3 (2011) 89-102.

[9] S. Bharathi Raja, N. Baskar, Optimization techniques for machining operations: a retrospective research based on various mathematical models, Int.J.Adv.Manuf.Tech. 48 (2009) 1075–1090.

[10] P.J. Ross, Taguchi Techniques for Quality Engineers, McGraw-Hill Company, Singapore, 1988.

[11] E. Aslan, N. Camuscu, B, Birgoren, Design optimization of cutting parameters when turning hardened AISI 4140 steel with Al_2O_3/TiCN mixed ceramic tool, Materials and Design, 28 (2007) 1618–1622.

[12] N.H.M. Nor, N. Muhamad, M.H.I. Ibrahim, M. Ruzia, K.R. Jamaludin, Optimization of injection molding parameter of Ti-6Al-4V powder mix with palm stearin and polyehylene for the highest green strength by using Taguchi method, Int.J.Mech.Mat.Engg., 06 (2011) 126-132.

[13] A.M. Zaharudin, R.J. Talib, M.N. Berhac, S. Budin, M.S. Aziurah, 'Taguchi method for optimizing the manufacturing parameters of friction materials, Int.J.Mech.Mat.Engg., 07 (2012) 83–88.