Journal Of Harmonized Research (JOHR)

Journal Of Harmonized Research in Engineering
2(2), 2014, 259-265

ISSN 2347 – 7393

Original Research Article

MULTI-OBJECTIVE OPTIMIZATION OF TURNING PROCESS BY USING QUALITY LOSS FUNCTION

Jatin Koranne, Manish Verma, Ashish Kumar Khandelwal

Choukey Engineering College, Bilaspur

Abstract
The present work studies the performance of multi-layer coated tool in machining of hardened steel (AISI 4340 steel) under high speed turning. The influence of cutting parameters (speed, feed, and depth of cut) on cutting forces and surface finish has been analyzed.L_{27} OA based Taguchi design was used to study cutting force (Fx, Fy and Fz) and surface finish (SR) of turning on AISI 4340 hardened steel work-piece. Cutting force and SR are mostly affected by speed and feed. Taguchi quality loss function was adopted to optimize the turning process with multiple performance characteristics.

Key Words: AISI 4340 steel; Taguchi quality loss function; surface finish; Cutting force.

1. Introduction

Metal cutting is the removal of metal from work piece in the form of chips in order to obtain a finished product with desired size, shape and surface finish is depend on coating materials tool are deposited on sharp tool edges in order to enhance machining productivity. The cost of machining amounts to more than 15% value of the all manufactured products in all industrial countries. Of all the processes used to shape metals, in material cutting the conditions of operation can be varied to improve the quality and productivity with a reduced cost.

For Correspondence:
j.koranne85ATgmail.com
Received on: March 2014
Accepted after revision: April 2014

Finish hard turning is a new machining process that enables manufacturers to machine improves materials to their finish part quality for avoiding grinding. This process enables manufacturers to increase product quality and efficiency, while decreasing the cost and processing time. Hard turning is also very attractive to manufacturers because this process is avoiding the use of cutting fluid or other lubricants. The increasing need to boost productivity, to machine more difficult materials and to enhance quality in high volume by the manufacturing industry has been the driving force behind the modified of cutting tool materials. Coated cutting tools have been developed continuously since the first cutting tool material suitable for use in metal cutting, carbon steel was developed a century ago.

Due to their significantly higher hardness, carbide-cutting tools are widely used in the manufacturing industries today as compare to high-speed steels. Coated and uncoated carbides are used in the metal working industry and provide the best alternative for most turning operations [2]. Due to their heat resistance, cemented carbides can be used in very hot applications and all types of PVD and CVD processes can be used to deposit coatings [3]. The important properties such as wear, abrasion resistance and adhesion strength of a coating can't perform well unless complimented by a hard and tough substrate. Thus, a hard coating deposited on a soft substrate leads to poor properties [4]. Physically and chemically vapor deposited coatings offer today a powerful alternative to improve further the cutting performance of the cutting materials.

Tugrul O zel et al [7] presented the effects of cutting edge preparation geometry, work-piece surface hardness and cutting conditions on the surface roughness and cutting forces in the finish hard turning of AISI H13 steel. The cutting forces are influenced not only by cutting conditions but also the cutting edge geometry and work-piece surface hardness which is found in his research. J. Rech [12] found out that coatings exhibit to the best tribological improvements compared to uncoated tools.

Motivation of the research work

From the available literature, it can be observe that some work has been reported on influence of turning parameters on surface roughness and cutting forces measurement of the machined surface, no attempt has so far been made to systematically to optimize the input variables with a view to obtain favorable responses. Moreover, cutting forces cannot be characterized as a single response since it typically includes cutting force on turning process.

- The influence of cutting parameters (speed, feed, and depth of cut) on cutting forces and surface finish has been analyzed. Under the different cutting conditions.
- L_{27} OA based Taguchi design was used to study cutting force (Fx, Fy and Fz) and surface finish (SR) of turning on AISI 4340 hardened steel work-piece.
- Taguchi quality loss function was adopted to optimize the turning process with multiple performance characteristics. The optimal machining parameter was found by using quality loss function for maximum cutting force and minimum surface roughness.

2. Methodology

The cutting tool is one of the important elements in realizing the full potential out of any metal cutting operation. Metal cutting process forms the ideal for the engineering industry and is involved either directly or indirectly in the manufacture of every product of our present human need. Over the years the demands of economic competition have identify a lot of research in the field of metal cutting leading to the evolution of new tool materials for an impressive increase in productivity.

The Taguchi quality loss function is to calculate the deviance between the experimental value and desired value [Gaitonde et al. (7)]. The calculation of Taguchi quality loss function is following steps,

- All experimental value converted to loss function (L_{ij}).
- Normalized loss function (N_{ij}).
- Calculated the total loss function (TL_{ij}).
- Finally calculated the Taguchi quality loss function (η_j).

In the first steps for all experimental observed value of cutting forces and surface roughness are converted into loss function (L_{ij}) that is shown in Table 5.2. MRR is Higher-The-Better (HTB) quality characteristics and OC is the Lower-The-Better (LTB) quality characteristics. The loss function of HTB and LTB quality characteristics are show in equation 1 and 2 respectively.

LTB response variable

$$L_{ij} = y_{ij}^2 \quad (1)$$

HTB response variable

$$L_{ij} = \frac{1}{y_{ij}^2} \quad (2)$$

Where, L_{ij} and y_{ij} is the loss function and experimental value, respectively, for i^{th} experiment using j_{th} response. The second step for normalized the loss function of cutting force and surface roughness, with the help of equation 3. That values of presented in Table 5.2.

$$N_{ij} = \frac{L_{ij}}{\overline{L}_i} \quad (3)$$

Where, $\overline{L}_i = \frac{1}{n}\sum_{j=1}^{n} L_{ij}$ is the average loss function of i^{th} experimental value and n is the trial number. Then calculate the total loss function by using equation 4.

$$TL_j = \sum_{i=1}^{p} W_i N_{ij} \quad (4)$$

Where, the W_i is the weighted function and the $\sum W_i = 1$. p is the performance characteristics. Then the final steps to calculate the Taguchi loss function with the help of equation 5.

$$\eta_j = -10\log(TL_j) \quad (5)$$

Where, the η_j is the Taguchi loss function and the Taguchi loss function. Forces were measured and recorded for the different cutting conditions both for coated and uncoated tools. The three force components are, the main cutting force (Fz), thrust force (Fx) and radial force (Fy).The measuring signal output was recorded by the N.I. (National Instrument) LAB VIEW data acquisition system (NI 9234) with RS-232C interface between amplifier and the PC allowing all settings and queries to be made in the instrument. Since the analogue signals received from the dynamometer were low, the amplifiers were needed. Three amplifiers were used to amplify analogue signals received from three channels; and supply voltage, input/output signals and deviation values for the desired measurement range were adjusted. Turning experiment was carried in a capstan lathe. The following cutting conditions were employed for measuring surface roughness: cutting speeds (v) of 80,105,130 and 160 m/min, feed rates (f) of 0.06,0.08,0.12 and 0.18 mm/rev and depths of cut (d) of 0.2,0.3,0.4 and 0.5mm.The surface roughness was measured by Surtronic surface roughness tester as shown in Figure 1

Figure 1. Surface roughness tester

Experimental procedure

It is an important engineering material employed in manufacturing of components in auto and aerospace industries. The present work deals with the turning of hard material such as AISI 4340 steel. Since the present trend in the manufacturing industry applied to evaluate the performance of coated tools in typical manufacturing processes.

The machining of AISI 4340 steel was carried out with uncoated and TiN coated tools and in the second phase, machining of same workpiece with the TiN coated carbide tool was carried out and the surface roughness and tool wear were measured. In this case, continuous dry turning tests were performed. Solid bars of AISI 4340 steel with 37mm diameter, 160mm long and of 45 HRC were used as workpiece that are shown in Figure 2.

Figure 2. AISI 4340 steel bar

Commercially available uncoated and TiN coated carbide inserts were employed with geometry of DCMT 11T304-THM and DCMT 11T304-TN 2000 respectively. Cutting tests were carried out on a coated tool insert with capstan lathe machine under dry conditions this is shown in Figure 3.

Figure 3 Coated tool insert

Table 1 Experimental results

S. N.	S	F	DOC	SR	Fx	Fy	Fz
1	80	0.06	0.2	1.93	34.80	50.20	78.68
2	80	0.06	0.3	2.02	91.80	116.20	119.78
3	80	0.06	0.4	2.07	171.55	144.91	185.105
4	80	0.08	0.2	2.49	89.99	195.33	152.13
5	80	0.08	0.3	2.59	95.60	253.09	217.81
6	80	0.08	0.4	2.63	50.92	60.32	252.75
7	80	0.12	0.2	3.25	76.56	132.93	162.60
8	80	0.12	0.3	3.34	115.63	104.82	210.00
9	80	0.12	0.4	2.65	65.32	59.66	182.56
10	105	0.06	0.2	1.65	30.89	47.66	64.43
11	105	0.06	0.3	1.88	41.64	105.12	89.38
12	105	0.06	0.4	1.93	50.67	66.96	103.56
13	105	0.08	0.2	2.16	54.09	94.80	106.01
14	105	0.08	0.3	2.3	125.40	74.63	159.20
15	105	0.08	0.4	2.4	105.23	72.84	187.29
16	105	0.12	0.2	2.63	37.24	95.76	122.02
17	105	0.12	0.3	2.77	102.69	165.99	207.48
18	105	0.12	0.4	2.91	83.88	59.07	211.72
19	130	0.06	0.2	1.42	41.64	132.05	85.53
20	130	0.06	0.3	1.55	105.86	71.13	158.54
21	130	0.06	0.4	1.59	108.79	133.85	139.31
22	130	0.08	0.2	2.02	58.00	44.74	120.92
23	130	0.08	0.3	2.16	39.68	42.41	123.37
24	130	0.08	0.4	2.21	58.24	52.105	138.83
25	130	0.12	0.2	2.54	47.01	44.14	153.52
26	130	0.12	0.3	2.63	50.18	58.18	150.37
27	130	0.12	0.4	2.73	74.12	56.20	198.03

3. Result and Discussions

Results of cutting tests are presented in terms of Experimental results which shown inTable 1. The variation of different forces with different cutting speed, feed and depth of cut for the TiN coated tool. The results present the variation of cutting forces under feed rates of 0.06, 0.08 and 0.12 mm/rev and various cutting speeds such as 80,105 and 130 m/min with different depth of cut(0.2, 0.3 and 0.4 mm). Table 5.1 representation of the experimental observed data of cutting forces and surface roughness. The forces decrease with the increase in cutting speed and their values are in the range 85-60 N for Fx (thrust component of force), range 120-20 N for Fy (radial component of force) and range 170- 135 N for Fz (cutting component of force).This indicates the favourable effect of coatings on cutting forces. At higher feed rate the cutting force values are maximum then decreases cutting forces with increasing of feed rate. The shape of the cutting force curves depends on the cutting tool. Depth of cut is not giving the significant effect of the cutting force (axial component of the force).

It has been seen that, as cutting speed is increased, the three components of the machining forces (Fx, Fy, Fz) are reduced. This reduction in the forces may be attributed to the variation of friction due to the temperature increase in the secondary- shear zone area, which resulted in a reduction in the restricted force. For all the tested tools, the cutting forces for the coated tools present a lower value. In fact, it is usually expected that the main cutting force Fz should be the highest and the radial force Fy and thrust (axial) force (Fx) should be the lowest in magnitude. The cutting force usually decreases with increasing cutting speed because of the high temperatures generation at the cutting zone.The value of ηjis the higher the better quality characteristics so higher value of η_j represented the best settings machining parameters with higher cutting speed and good surface Finish as shown in table 2.

Table 2 Taguchi quality loss function steps data.

N_{ij} SR	N_{ij} Fx	N_{ij} Fy	N_{ij} Fz	T_{ij}	η_i	Ranking
0.0247	0.0962	0.0687	0.0958	0.0713	11.4665	26
0.0271	0.0138	0.0128	0.0413	0.0238	16.2401	7
0.0284	0.0040	0.0082	0.0172	0.0144	**18.4030**	**1**
0.0411	0.0144	0.0045	0.0256	0.0214	16.6928	6
0.0445	0.0127	0.0027	0.0125	0.0181	17.4215	3
0.0459	0.0449	0.0476	0.0093	0.0369	14.3287	16
0.0700	0.0199	0.0098	0.0224	0.0305	15.1520	11
0.0740	0.0087	0.0158	0.0135	0.0280	15.5328	10
0.0466	0.0273	0.0486	0.0178	0.0351	14.5505	13
0.0181	0.1220	0.0762	0.1429	0.0898	10.4672	27
0.0234	0.0672	0.0157	0.0743	0.0451	13.4553	21
0.0247	0.0454	0.0386	0.0553	0.0410	13.8728	18
0.0309	0.0398	0.0193	0.0528	0.0357	14.4737	15
0.0351	0.0074	0.0311	0.0234	0.0242	16.1545	8
0.0382	0.0143	0.0326	0.0169	0.0255	15.9333	9
0.0459	0.0840	0.0189	0.0398	0.0471	13.2662	22
0.0509	0.0110	0.0063	0.0138	0.0205	16.8833	4

0.0562	0.0166	0.0496	0.0132	0.0339	14.6999	12
0.0134	0.0672	0.0099	0.0811	0.0429	13.6766	20
0.0159	0.0104	0.0342	0.0236	0.0210	16.7710	5
0.0168	0.0098	0.0097	0.0306	0.0167	17.7708	2
0.0271	0.0346	0.0865	0.0406	0.0472	13.2626	23
0.0309	0.0740	0.0962	0.0390	0.0600	12.2166	25
0.0324	0.0343	0.0618	0.0308	0.0398	13.9972	17
0.0428	0.0527	0.0888	0.0252	0.0524	12.8092	24
0.0459	0.0462	0.0511	0.0262	0.0424	13.7294	19
0.0494	0.0212	0.0548	0.0151	0.0351	14.5425	14

The Figure 4 is shown the main effect plot for Taguchi loss function, according to this graph for optimal setting cutting speed 80 m/min, feed 0.06 rev/min. and dept. of cut 0.4 mm for maximum cutting force and minimum surface finish.

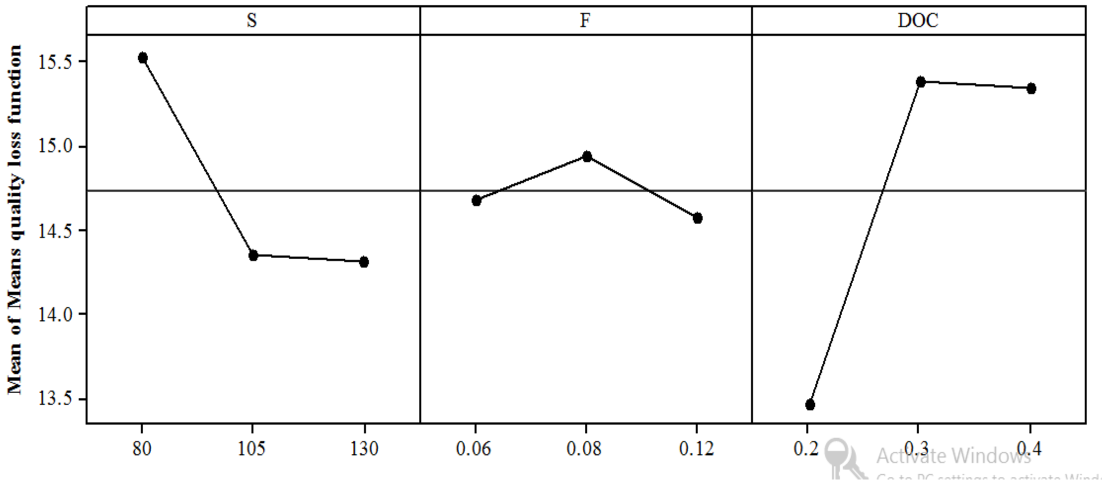

Figure 4 Main effect plots for Taguchi quality loss function

4. Conclusions

The mechanisms involved in the wear of cutting tools, especially in hard machining include different interacting effects linked together in a complex manner, the three components of forces, i.e., the main cutting force (*Fz*), feed force (*Fx*) and radial force (*Fy*) generated by TiN coated carbide tools for all cutting speeds indicating that turning with former tools is more economical than the latter in terms of energy and power requirements. Taguchi quality loss function was adopted to optimize the Turning process with multiple performance characteristics i.e cutting force and surface roughness. The optimal turning parameter setting were found to be setting cutting speed 80 m/min, feed 0.06 rev/min. and dept. of cut 0.4 mm for maximum cutting force and minimum surface roughness.

5. References

[1]. Soderberg, S., Sjostrand, M., Ljungberg, B., Advances in coating technology for metal cutting tools, Metal Powder Report 56 (2001) 24-30.

[2]. Haron, C. H., Ginting, A., Goh, J. H., Wear of coated and uncoated carbides in turning tool steel, Journal of materials processing technology 116 (2001) 49-54.

[3]. Armarego, E. J. A., Verezub, S., Samaranayake, P., The effect of coatings on

the cutting process, friction, forces and predictive cutting models in machining operations, Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture 216 (2002) 347-356.

[4]. Smith, G. T., Advanced Machining: The Handbook of Cutting Technology, IFS Publications, 1989.

[5]. Cho, S. S., Komvopoulos, K., Wear Mechanisms of Multi-Layer Coated Cemented Carbide Cutting Tools, Journal of Tribology 119 (1997) 8-17.

[6]. J.A. Ghani , I.A. Choudhury, H.H. Masjuki. Wear mechanism of TiN coated carbide and uncoated cermets tools at high cutting speed applications, Journal of Materials Processing Technology 153–154 (2004) 1067–1073.

[7]. V.N. Gaitonde, S. R. Karnik, B.T. Achyutha and B. Siddeswarappa, "Multi-response optimization in drilling using Taguchi's quality loss function", Indian Journal of Engineering & Materials Sciences, vol. 13, pp. 484-488, 2006.

[8]. Jeong Suk Kim, Gyeng Joong Kim, Myung Chang Kang, Jung Wook Kimb, Kwang Ho Kim, Cutting performance of Ti–Al–Si–N-coated tool by a hybrid-coating system for high-hardened materials, Surface & Coatings Technology 193 (2005) 249– 254.