EFFECTIVENESS OF MULTILAYER COATED TOOL IN TURNING OF AISI 430F STEEL

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Abstract

This paper presents minimization of surface roughness in dry turning of AISI 430F steel using TiN-TiCN-Al_2O_3-ZrCN multilayer coated cemented carbide & cryo-treated inserts. Effect of cutting velocity, feed rate, depth of cut & machining duration is studied on the surface roughness. Taguchi's design of experiment is used to find the optimum factor levels. It is found that the feed rate has much effect in producing lower surface roughness followed by speed. The depth of cut has lesser role on surface roughness. The result of Taguchi method shows that cutting velocity of 250m/min, feed rate of 0.25 mm/rev and depth of cut of 0.3mm should be maintained as optimal parameter settings for both coated and cryo-treated tools. Cryo-treated tools perform better.

Keywords: *Cryo-treatment, Dry Turning, Surface roughness, Taguchi Method*

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1. INTRODUCTION

Now-a-days, determination of optimum values of process parameters in manufacturing are the areas of great interest for researchers and manufacturing engineers. For modern machining, it is necessary to focus on the achievement of high quality in terms of product dimensional accuracy, surface quality, high production rate, less tool wear and economy of machining. Surface roughness is among the inevitable customer requirements as it is caused by the influence of the cutting tool during the machining process. Roughness is the dominant magnitude related to the machinability of the processed material, the tool form, the machining conditions, and the tolerance requirements. Therefore, attempt should be made to minimize surface roughness because higher unevenness leads to functional discrepancies.

1.1 Surface Roughness

R_a value, the arithmetic average roughness (center line average), determined from deviations about the center line within the evaluation length is the most popular parameter for a machining process and product quality control. This parameter is easy to define, easy to measure even in the least suitable profile-meters and gives a general description of surface amplitude. Though it lacks physical significance, it is established in almost every national standard for measuring roughness. The average surface roughness is given by

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

Here, Ra is the arithmetic average deviation from the mean line; l is the sampling length, y coordinate of the profile curve.

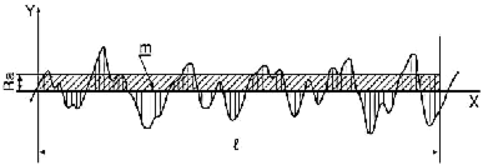

Fig-1: Evaluation of surface roughness

1.2 Taguchi DOE

Taguchi's design of experiment methodology is a convenient tool to optimize the cutting parameters with less experimental runs [2]. Taguchi primarily recommends experimental design as a tool to make products more robust – to make them less sensitive to noise factors. The experimental design procedure is suitable tool for reducing the effect of variation on product and process quality characteristics [3]. Analysis of Variance (ANOVA) can be employed to identify the most significant

Variables and interaction effects [4] In turning, many researchers have modeled surface roughness. Davim [5] has presented a study of the influence of cutting parameters on the surface roughness obtained in turning of free machining steel using Taguchi design and shown that the cutting velocity has a greater influence on the roughness followed by the feed rate. Lin et al. [6] have shown that feed rate is the critical parameter in turning to affect the surface roughness as increase of feed rate increases the surface roughness. Suresh et al. [7] have shown that surface roughness decreases with an increase in cutting speed in turning of mild steel. Arbizu and Perez [8] have developed models to determine surface quality of parts obtained through turning processes and shown that surface roughness increases with increase in depth of cut and feed rate. Sahin and Motorcu [9] have developed a surface roughness model for turning of mild steel with coated carbide tools and shown that feed rate is the main influencing factor on surface roughness. Surface roughness increases with increase in feed rate but decreases with increase in cutting speed and depth of cut. The literature survey shows that mainly three cutting parameters viz. cuttings peed, feed rate and depth of cut are the common parameters considered for most of the studies. The present research has two purposes. The first is to demonstrate the use of Taguchi's parameter design in order to identify the optimum parametric combination to minimize surface roughness. The second is to propose a predictive methodology for estimating surface roughness using data obtained during experimentation conducted as per Taguchi design.

2. EXPERIMENTAL DETAILS

2.1 Work Piece Material

The work piece material used was AISI 430F steel in the form of cylindrical bar of diameter 50mm and length 250mm. The composition of AISI 430F is listed in weight percentage as Cr 16%, C 0.12%,Mn 1.25%, Si 1%,P 0.06%, S .15% min. and Fe remaining.

2.2 Cutting Tool Material

The cutting tool is P30 cemented carbide inserts (Make: Widia) having Insert designation as CNMG 12 04 08 and tool geometry -60, -60, 60, 60, 150, 750, 0.8 mm. P 30 grade of cemented carbide has excellent hardness, wear resistance and toughness [10]. The composition of P30 carbide inserts WC74.25%, TiC 8.25%, Ta +NbC 8.80%, and Co 8.70%.

2.3 Machine Tool

The turning operations were carried out in a rigid CNC turning machine AMS India, Bangalore. The tool holder used for machining is MCLNR 2525 M12.

2.4 Surface Roughness Measurement

Surface roughness was measured using a portable stylus-type profilometer, Talysurf (Taylor Hobson, Surtronic 3+, UK)

2.5 Experimentation

Three cutting parameters with their levels are shown in Table1. A L_{27} orthogonal array was chosen for conducting experiments [11, 12]. The complete experimental plan along with response (surface roughness) for coated and cryotreated tools is shown in Table 2. The responses are converted into signal-to-noise ratio (S/N ratio) for lower-the-better quality characteristic. Analysis of responses is carried out by MINITAB 14 software. S/N ratio for 'lower the better' type response is given by

$$S/N \text{ ratio} = -10\log\left[(1/n\,(y_1^2+y_2^2+\ldots\ldots+y_n^2)\right] \quad (2)$$

Where y_1, y_n are the responses of values of quality characteristic for the trial condition repeated 'n' times.

2.6 Cro-Treatment

In the present investigation, PVD coated carbide inserts were subjected to deep cryogenic treatment (-190°C). Cryo-treatment (CT) is a secondary process to conventional heat treatment that involves deep freezing of materials at cryogenic temperatures to enhance the mechanical and physical properties [13].

Table 1: The cutting parameters with their levels

Input Parameters	Levels		
Cutting Speed, V_C (m/min)	150	200	250
Feed rate, f (mm/rev)	0.3	0.5	0.7
Depth of cut, d (mm)	.25	.5	.75
Machining Duration, s (sec)	60		

3. RESULTS AND DISCUSSION

Analysis of variance (ANOVA) conducted on responses obtained using coated and cryotreated tools are shown in Table 2 and 3 respectively. It is to be noted that feed rate has significant effect on the surface roughness than other parameters in both cases. However, percentage contribution of feed rate in case of uncoated tool is marginally higher. The R^2 value (coefficient of determination) is obtained as 80.65% and 85.1% for coated and cryotreated inserts respectively.

The residual plots are shown in Figure 3 and 5 for cryotreaded and coated inserts respectively. It is evident from these figures that the residuals follow approximately in a normal distribution. It indicates that ANOVA has proceeded in a correct manner.

The main effect plots are shown in Figures 2 and 4 respectively for cryotraeted and coated inserts. The best parameter setting for minimizing surface roughness is found as cutting velocity of 250 m/min, feed rate of 0.25 mm/rev and depth of cut of 0.3 mm for both types of inserts.

CONCLUSIONS

Taguchi approach is very simple and efficient way to find out the optimality conditions. In this work, the optimal cutting parameters are found to be velocity of 250 m/min, feed rate of 0.25 mm/rev and depth of cut of 0.3 mm for minimizing surface roughness while turning mild steel with coated carbide and cryotreated tool. With this particular combination of input parameters, the roughness value is 0.2 and 0.019 of coated and cryotreated respectively.

Analysis of variance indicates that feed rate and velocity are the most influencing parameter for minimizing surface roughness in both the tool conditions and the performance of cryotreated is better.

Table 2: Parameters and their levels

V_c(m/min)	S/N Ratio		d(mm)		f(mm/rev)	Ra(µm)
	Coated			Coated	Cryotreated	Cryotreated
150	6.7448	0.25	0.3	0.46	0.288	10.8122
0	-4.1849	0.25	0.5	1.619	1.427	-3.08848
150	-7.3843	0.25	0.7	2.34	2.153	-6.66088
150	6.3752	0.5	0.3	0.48	0.287	10.8424
150	-6.7292	0.5	0.5	2.17	1.968	-5.8805
150	-10.955	0.5	0.7	3.53	3.334	-10.4593
150	-5.7111	0.75	0.3	1.93	1.731	-4.76594
150	-8.0624	0.75	0.5	2.53	2.325	-7.32846
150	-11.174	0.75	0.7	3.62	3.427	-10.6983
200	5.3521	0.25	0.3	0.54	0.341	9.34491
200	-8.1648	0.25	0.5	2.56	2.352	-7.42875
200	-9.7625	0.25	0.7	3.077	2.885	-9.20292
200	-5.3903	0.5	0.3	1.86	1.67	-4.45433
200	-9.6001	0.5	0.5	3.02	2.818	-8.99882
200	-10.98	0.5	0.7	3.54	3.347	-10.4931
200	-8.3991	0.75	0.3	2.63	2.419	-7.67272
200	-12.063	0.75	0.5	4.01	3.826	-11.6549
200	-14.353	0.75	0.7	5.22	5.024	-14.021
250	13.979	0.25	0.3	0.2	0.019	34.4249
250	-2.8603	0.25	0.5	1.39	1.182	-1.45235
250	-8.755	0.25	0.7	2.74	2.529	-8.05898
250	6.7448	0.5	0.3	0.46	0.255	11.8692
250	-7.3471	0.5	0.5	2.33	2.122	-6.53491
250	-11.457	0.5	0.7	3.74	3.55	-11.0046
250	-4.0279	0.75	0.3	1.59	1.391	-2.86654
250	-10.955	0.75	0.5	3.53	3.337	-10.4671
250	-12.948	0.75	0.7	4.44	4.226	-12.5186

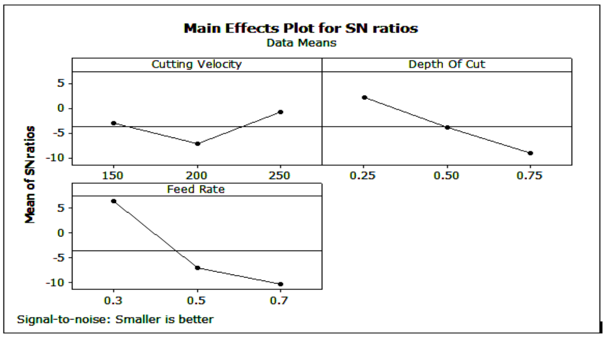

Fig- 2: Main effect plot (cryotreated)

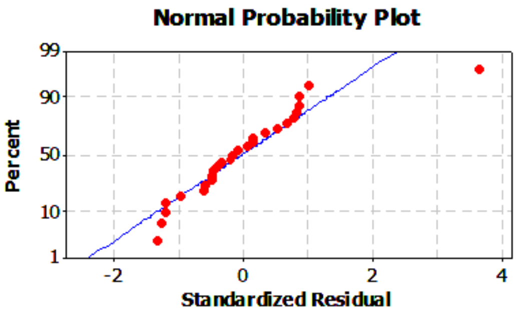

Fig- 3: Normal probability plot (cryotreated)

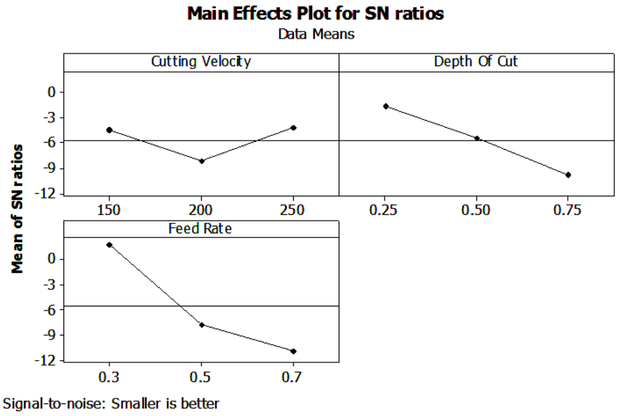

Fig-4: Main effect plot (coated)

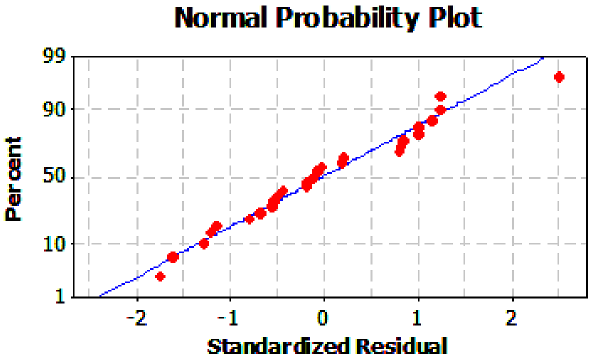

Fig- 5: Normal probability plot (cryotreated)

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