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PERFORMANCE OF TOOL COATED WITH B-TIC DURING TURNING STAINLESS STEEL

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ABSTRACT

This paper presents the results of experimental work in dry turning of martensitic stainless steels (AISI410) using physical vapor deposition (PVD) coated carbide tools. The turning tests were conducted at different cutting speeds (110, 160 and 210 m/min); feed (0.1, 0.2 and 0.3 mm/rev) and depth of cut (0.7, 1.4 and 2.1 mm) respectively. The cutting tool used was B-TiC coated carbides. The influences of cutting speed, cutting tool coating and work piece material were investigated on the machined surface roughness (SR) and the Tool wear (TW). The results showed that feed significantly affected the machined surface roughness and depth of cut significantly affected the tool wear. The machining parameters which are affecting the quality of turning operation, it is necessary to optimize the machining parameters to obtain better productivity. Multi response optimization of machining parameters was performed with coated tool using grey relational analysis.

Key words: AISI410; CNC Turning; Grey relational analysis; Surface roughness; Tool wear.

1. INTRODUCTION

In industry, the goal is to manufacture low cost and high quality products in a short time. Automated and flexible manufacturing systems are employed for that purpose along with computerized numerical control (CNC) machine tools that have become very common in factories and are capable of achieving high accuracy and very low processing time. Turning is the first and most common method for cutting, especially for the finished machined parts (Nalbant et al. 2005; Abburi et al. 2006). In machining of parts, surface quality is one of the most specified customer requirements where major indication of surface quality on machined parts is surface roughness. Surface roughness is one of the main results of process parameters such as tool geometry (i.e.nose radius, edge geometry and rake angle) and cutting conditions (feed, cutting speed, depth of cut) (Oezel and Karpat 2005). The AISI 400 series of martensitic stainless steels represent the largest group of steels in use of total (Sullivan and M. Cotterell 2002). However these steels have very high corrosion resistance, it is more difficult to machine these materials because of their low heat conductivity, built up edge tendency and high work hardening properties than carbon and low alloy steels. Poor surface finish and high tool wear are the common problems (Paro et al. 2001; Kopac and Sali, 2001). Little work has been carried on the determination of optimum machining parameters when machining martensitic stainless steels. In this study, parameters such as cutting speed, feed and depth of cut were changed to explore their effects on the surface roughness and tool flank wear. Optimization of cutting parameter is necessary for the achievement of minimal TW and SR. The Taguchi method of experimental design is one of the widely accepted techniques for off line quality assurance of products and processes. Most of the applications of Taguchi method concentrate on the optimization of single response problems (Suresh et al. 2002). The grey relational analysis based on grey system theory can be used for solving the complicated interrelationships among the multi responses (Deng 1989).

2. MATERIALS AND METHODS

AISI410 was taken as the work piece materials for all trials of diameter 32 mm and machined length of 60 mm. The chemical compositions of the materials are given in Table1.

Table 1 Chemical composition of AISI410

C	Si	Mn	P	S	Cr
0.09	0.34	0.68	0.04	0.01	12.17

2.1. GREY RELATIONAL ANALYSIS

Grey relational analysis is a measurement technique which focuses on the quantitative explanation and comparison of variation. It quantifies all effect of various factors on response and their relation which is called the whitening of factor relation. In grey theory, the black box is used to point out a system lacking internal information. The black is indicating as lack of information but the white is full of information. Thus, the information which is either incomplete or undetermined is called Grey. A system having incomplete information is called grey system. The Grey number in Grey system represents a number with less complete information. The Grey element represents an element with incomplete information. The Grey relation is the relation with incomplete information. Grey relational analysis is a measurement technique in grey system theory that analysis the degree of relation in a discrete sequence (Jeyapaul et al. 2006; Rafie et al. 2010).

Step 1: Calculate S/N Ratio for the corresponding responses using the equation 1 and equation 2. This is applied for problem where maximization of the quality characteristic of interest is sought. This is referred as the smaller-the-better type problem where minimization of the characteristic is intended in Equation 1.

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

Where n= number of replications y_{ij}= Observed Response value.

Step 2: y_{ij} is normalized as Z_{ij} ($0 \le Z_{ij} \le 1$) by the following formula to avoid the effect of adopting different units and to reduce the variability. It is necessary to normalize the original data before analyzing them with the grey relation theory or any other methodologies. Thus, we recommend that the S/N ratio value be adopted when normalizing data in grey relation analysis. Equation 2 shows the smaller the better characteristic.

$$Zij = \frac{\max(y_{ij}, i=1,2,.....n) - y_{ij}}{\max(y_{ij}, i=1,2,......n) - \min(y_{ij}, i=1,2,.....n)} \qquad (2)$$

Step 3: Calculate Grey relational Co-efficient for the normalized S/N ratio values are Equation 3.

$$\gamma(y_o(k), y_i(k)) = \frac{\Delta\min + \xi\Delta\max}{\Delta_{oj}(k) + \xi\Delta\max} \qquad (3)$$

Where $\Delta_{\max} = \max_{\forall j \in i} \max_{\forall k} \left\| y_o(k) - y_j(k) \right\|$ is the largest value of $y_j(k)$, ζ is the distinguishing coefficient which is defined in the range $0 \le \zeta \le 1$ (the value may adjusted based on the practical needs of the system).

Step 4: Generation of Grey relational grade by Equation 4.

$$\overline{\gamma}_j = \frac{1}{k} \sum_{i=1}^{m} \gamma_{ij} \qquad (4)$$

Where $\overline{\gamma}_j$ is the grey relational grade for the j^{th} experiment and k is the number of performance characteristics.

3. EXPERIMENTAL DETAILS

The experiments were conducted on the Fanuc CNC lathe. Single layered CNMG 120408 coated with B-TiC is used as the insert for all machining operations. The range of cutting parameters was selected based on past experience, data book and available resources. Surface roughness is measured by the Mitutoyo surface roughness tester. TW was measured by an optical tool maker's microscope with image optic plus version 2.0 software designed to run under Microsoft widow's 32 bit system, which can be captured by the area of the tool wear. The three cutting parameters selected for the present investigation is cutting speed, feed and depth of cut. Since the considered factors are multi-level variables and their outcome effects are not linearly related, it has been decided to use three-level tests for each factor. The machining parameters used and their levels chosen are given in Table 2. In addition, a statistical ANOVA is performed to see those process parameters that significantly affect the responses. Analyzed with ANOVA which is used for identifying the factors which significantly affecting the performance measures. This analysis is carried out for significance level of $\alpha = 0.05$, i.e., for a confidence level of 95%.

Table 2 Machining parameters and levels.

Parameter	L 1	L 2	L 3
Cutting speed (m/min)	110	160	210
Feed (mm/rev)	0.1	0.2	0.3
Depth of cut (mm)	0.7	1.4	2.1

Table 3 Grey relational analyses for AISI410

Trial No.	Experimental		S/N Ratios		Normalized values of S/N Ratios		Grey relational coefficient		Grey grade
	SR (μm)	TW(μm)	SR	TW	SR	TW	SR	TW	
1	0.54	140.89	5.352	-42.978	0.000	0.733	1.000	0.405	0.703
2	1.16	149.84	-1.289	-43.513	0.449	0.810	0.527	0.382	0.454
3	0.70	147.60	3.098	-43.382	0.152	0.791	0.767	0.387	0.577
4	1.24	107.37	-1.868	-40.618	0.488	0.394	0.506	0.559	0.533
5	1.51	91.61	-3.580	-39.239	0.603	0.196	0.453	0.718	0.586
6	1.77	158.80	-4.959	-44.017	0.696	0.882	0.418	0.362	0.390
7	1.97	125.24	-5.889	-41.955	0.759	0.586	0.397	0.460	0.429
8	2.39	118.60	-7.568	-41.482	0.873	0.518	0.364	0.491	0.428
9	2.68	143.10	-8.563	-43.113	0.940	0.753	0.347	0.399	0.373
10	0.92	118.10	0.724	-41.445	0.313	0.513	0.615	0.494	0.554
11	1.36	149.80	-2.671	-43.510	0.542	0.810	0.480	0.382	0.431
12	1.46	165.10	-3.287	-44.355	0.583	0.931	0.461	0.349	0.405
13	1.53	107.35	-3.694	-40.616	0.611	0.394	0.450	0.559	0.505
14	1.69	87.22	-4.558	-38.812	0.669	0.135	0.428	0.787	0.607
15	1.27	165.50	-2.076	-44.376	0.502	0.934	0.499	0.349	0.424
16	2.68	140.90	-8.563	-42.978	0.940	0.733	0.347	0.405	0.376
17	2.42	132.00	-7.676	-42.412	0.880	0.652	0.362	0.434	0.398
18	2.34	167.70	-7.384	-44.491	0.860	0.950	0.368	0.345	0.356
19	0.81	100.64	1.830	-40.055	0.238	0.314	0.678	0.615	0.646
20	1.22	127.50	-1.727	-42.110	0.478	0.609	0.511	0.451	0.481
21	1.40	158.80	-2.923	-44.017	0.559	0.882	0.472	0.362	0.417
22	1.51	78.27	-3.580	-37.872	0.603	0.000	0.453	1.000	0.727
23	1.60	91.69	-4.082	-39.246	0.637	0.197	0.440	0.717	0.578
24	1.45	109.58	-3.227	-40.795	0.579	0.420	0.463	0.544	0.503
25	2.97	120.80	-9.455	-41.641	1.000	0.541	0.333	0.480	0.407
26	2.71	125.80	-8.659	-41.994	0.946	0.592	0.346	0.458	0.402
27	2.33	174.50	-7.347	-44.836	0.858	1.000	0.368	0.333	0.351

4. RESULT AND DISCUSSIONS

The signal to noise ratio for SR and MRR is computed by using equation 1 and Equation 2. Normalize the S/N ratio values for SR and MRR is computed by using Equations 3 and Equation 4. Calculate Grey Relational Co-efficient for the normalized S/N ratio values by using Equation 5. The grey relational grade can be computed by Equation 6. Finally, the grades are considered for optimizing the multi response parameter design problem. The results are given in the Table 3. The higher grey relational grade implies the better product quality; therefore, on the basis of grey relational grade, the factor effect can be estimated and the optimal level for each controllable factor can also be determined. The main effects are tabulated in Table 4 and considering maximization of grade values in Table 4 is the optimal parameter conditions obtained are V_3 F_2 D_1. The cutting speed set as high level (210 m/min), the feed set as middle level (0.2 mm/rev) and depth of cut set as low level (0.7 mm). The ANOVA for SR on AISI410 is given in Table 5, it is clearly shows that the feed rate is most significantly affect the SR with p value of 0.000 followed by the cutting speed with p value of 0.163. The ANOVA for TW on AISI410 is given in Table 6, it is clearly shows that the depth of cut is most significantly affect the TW with p value of 0.00 followed by feed with p value of 0.001.

Table 4 Grey grade for AISI410

Level	1	2	3
V	0.497	0.461	**0.601**
F	0.619	**0.639**	0.391
a	**0.642**	0.486	0.422

Table 5 ANOVA for SR on AISI410

Source	DF	SS	MS	F	P
v	2	0.266	0.133	1.9	0.16
f	2	9.722	4.861	72	0.00
a	2	0.204	0.102	1.5	0.24
Error	20	1.338	0.06		
Total	26	11.53			

Table 6 ANOVA for TW on AISI410

Source	DF	SS	MS	F	P
v	2	1222.9	611.5	2.5	0.10
f	2	4862.1	2431.1	10	0.00
a	2	8323.1	4161.6	17	0.00
Error	20	4806.2	240.3		
Total	26	19214.4			

5. CONCLUSIONS

In this experimental study, the effect of turning parameters such as cutting speed, feed and depth of cut on machining characteristics of AISI410 was investigated. Summarizing the main features of the results, the following conclusions may be drawn.

1. From grey relational analysis optimum setting for minimization of SR and TW on AISI410 is the cutting speed set as 210 m/min, feed set as 0.2 mm/rev and depth of cut set as 0.7 mm; $V_3 F_2 D_1$.
2. From ANOVA for AISI410, it is clearly shows that the feed is most significantly affect the SR with p value of 0.000 and depth of cut is most significantly affect the TW with p value of 0.000.

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