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Performance of Uncoated and Baln/Tin Coated Tool on Aisi410 in CNC Turning

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Abstract : Stainless steels are classified according to their crystalline structure with the addition of nickel content and Martensitic stainless steel (AISI410) is one of the categorized metals with a high resistance to pitting corrosion with variety of applications but making of product is difficult. CNMG uncoated carbide tool and BAlN/TiN coated cutting tool is selected for CNC turning on AISI410 under dry conditions. This turning process is conduct in three different cutting conditions of cutting speed, feed and depth of cut varied to determine the output response characteristics like surface roughness, material removal rate and tool wear. The present research work approaches to optimization of turning process parameters using grey relational analysis and the experiments were conducted according to within the intervals recommended by the tool manufacturer.
Keywords: AISI410; CNC Turning; Grey relational analysis; coated cutting tool.

Introduction

Stainless steels are corrosion resistant; it maintains its strength at high temperatures. It is widely used in items such as food processing products, automotive as well as medical and health equipment [1]. The most widely used martensitic stainless steel is plain chromium stainless class with exceptional strength, enabling a high level of strength advised by the martensitic stainless steel. It is a heat treatable grade of low cost which is suitable for non-severe corrosion applications [2]. Turning is the most widely used among all the cutting processes. The increasing demands for turning operations is attaining new dimensions at present, in which the growing competition needs all the efforts to be directed towards the economical manufacture of machined parts. This can be made possible by the use of CNC lathe machines. Surface roughness, Tool wear and Material Removal Rate can be very helpful to predict the importance of different set up variables. Hence by optimizing these desired results are considered to be important in the present industrial applications [3]. The proper selection of machining process parameters is crucial before the process takes place in order to get a better surface finish. It has long been recognized that conditions during machining, optimized values of cutting speed, feed rate and depth of cut, should be selected to maintain the economics of machining operations. This can be assessed by the total productivity, total manufacturing cost per component or some other suitable criterion [4]. The purpose of this research is to analyze the surface finish and tool life produced by turning process on martensitic stainless steel by different tool. Many of the researchers worked in this area in different directions and their research findings are listed below

Jukko Paro [5] discussed the machinability studies of high strength stainless steels with modern machine tools using variant cutting tools which were investigated over a wide range of machining parameters in various operations like grinding, turning and drilling operations. He found that the formation of built up edges gets increased when machining stainless steel in dry conditions. Rajesekaran et al [6] analyzed the turning parameters influencing the surface roughness and their contribution towards the surface roughness. The machining parameters considered are cutting speed, feed rate and the depth of cut. The results revealed that the feed rate plays a primary role in producing the surface roughness followed by the cutting speed. The depth of cut does not make any significant effect on surface roughness. Mahmoud & Abdelkarim [7] discussed the turning operation using high speed steel as cutting tool with 45^0 approach angle. The tool showed that it could perform cutting operation at higher cutting speed and longer tool life than traditional tool with 90^0 approach angle. The study finally determined optimal cutting speed for operation costs, minimum cost, high production rate, and production time and tool life.

Liew et al [8] conducted study on turning martensitic stainless steel by using PCBN cutting tool. The tool wear was due to abrasion and cutting temperature. The porosity, ductility, and the bonding strength of the grains in the tool, apart from its thermal conductivity have great influence on the fracture resistance of the tool. Attanasion et al [9] made attempts on the machinability of martensitic stainless steel with respect to chip thickness ratio, shear angle and flank wear using CBN and PCBN cutting tools under wet condition. These tools were considered for cutting due to increased demand on surface quality and less tool wear. The poor machinability of the stainless steel was usually accounted for reasons having very low heat conductivity, high ductility, high tensile strength, high fracture toughness and work hardening rate.

Thamizhmnaii et al [10] studied the tool flank wear analyses on martensitic stainless steel by CBN tool in turning. The flank wear occurred at low cutting speed with high feed and more depth of cut. The influence of tool flank wear was due to abrasive action between tool tip and cutting tool, hard carbides in the work piece material. Formation of built up edge was inevitable due to more contact time. The flank wear was also due to heat generated at low cutting speed. Further research could be extended on temperature measurements. Ashvin et al [11] studied the application of RSM on the AISI410 in carrying out the turning operation. A quadratic model was developed for surface roughness to investigate the influence of machining parameters. The feed was the main influencing factor on the roughness, followed by the tool nose radius and cutting speed. Depths of cut had no significant effect on the surface roughness.

Most of the researchers investigated the performance of the CBN and PCBN cutting tool on turning stainless steel. But coated tools were essential for achieving a crucial enhancement in tool performance. So in this work uncoated and BAlN/TiN coated cutting tools were used for turning martensitic stainless steel (AISI410) under dry condition. The optimum machining parameters are required for minimization of responses such as surface roughness (SR); tools wear (TW) and maximization of material removal rate (MRR). Optimization of machining parameters is cannot be easily understood by engineers and it is required to find some methodologies to handle the existing complexity in solving multi response problem. Therefore this research work mainly focuses on optimization of machining parameters such as cutting speed, feed and depth of cut of turning using grey relational analysis.

Experimental Details

The aim of the paper is to investigate the influence of coated cutting tools on AISI410 in CNC turning under dry conditions. AISI410 were taken as the work piece materials for all trials of diameter 24 mm and machined length of 80 mm. The chemical composition of given sample as C: 0.095%, Si: 0.341, Mn: 0.680%, P: 0.040%, S: 0.0063, Cr: 12.170. Uncoated and coated with BAlN/TiN insert with tool geometry of CNMG 120408 and tool holder of PCLNR 25 × 25 M12.1 was selected. The experiments were conducted on Fanuc CNC lathe. Three factors, at three levels were taken for this work. Cutting speed (90, 140 and 180m/min), feed (0.15, 0.25 and 0.35 mm/rev) and depth of cut (0.5, 1.25, 2mm) were considered as parameters. The SR, MRR and TW are the important turning characteristics in turning operation and hence minimization of SR, TW and maximization of MRR were taken as objective of this work. SR was measured for all the case by the SURF TEST 211 and it TW was measured by a tool maker's microscope. Hence, an experimental plan based on Taguchi's L_{27} orthogonal array has been selected and 27 trials were carried out under dry condition with different combinations of parameters levels. The values of machining parameters and S/N ratio for responses are presented in Table 1.

Grey Relational Analysis

Grey relational analysis is a kind of measure method focusing on the quantitative description and comparison of variation. It quantifies all influences of various factors and their relation, which is called the whitening of factor relation. In grey theory, the black box is used to indicate a system lacking interior information. In the present study, experimental details using the Taguchi method of parameter design were employed for optimizing multi performance characteristics for turning of stainless steel. GRA was considered for optimization of multiple response characteristics [12].

Step 1: Calculate S/N Ratio for the smaller the better using the Equation 1 and S/N Ratio for the larger the better using the Equation 2.

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

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

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

Table 1 Experimental response for uncoated and BAlN/TiN tool

Factors			Uncoated tool			BAlN/TiN		
A	B	C	SR	MRR	TW	SR	MRR	TW
1	1	1	1.625	0.657	0.28	1.285	0.561	0.233
1	1	2	1.725	0.88	0.32	1.385	0.79	0.264
1	1	3	1.095	1.159	0.35	0.43	1.66	0.31
1	2	1	1.815	0.654	0.32	1.475	0.564	0.27
1	2	2	1.805	0.875	0.28	1.465	0.785	0.21
1	2	3	1.815	1.208	0.35	1.475	1.11	0.3
1	3	1	3.995	0.547	0.3	3.93	0.457	0.25
1	3	2	4.465	0.799	0.3	4.125	0.732	0.243
1	3	3	3.965	1.05	0.37	3.622	0.96	0.32
2	1	1	1.805	0.935	0.32	1.465	0.855	0.27
2	1	2	1.655	1.232	0.31	1.4	1.133	0.252
2	1	3	2.885	1.604	0.39	2.54	1.514	0.34
2	2	1	1.725	0.858	0.29	1.385	0.754	0.22
2	2	2	2.445	1.228	0.31	2.4	1.138	0.254
2	2	3	1.745	1.524	0.38	1.403	1.534	0.31
2	3	1	3.485	0.929	0.29	3.143	0.849	0.239
2	3	2	2.515	1.15	0.29	1.98	1.661	0.236
2	3	3	2.895	1.445	0.35	2.554	1.355	0.312
3	1	1	1.635	1.124	0.31	1.293	1.034	0.261
3	1	2	0.845	1.394	0.31	0.9	1.23	0.243
3	1	3	0.995	1.934	0.36	0.655	1.821	0.31
3	2	1	1.805	1.122	0.3	1.466	1.032	0.243
3	2	2	1.985	1.661	0.3	1.3	1.571	0.254
3	2	3	1.835	1.841	0.34	1.499	1.654	0.29
3	3	1	2.175	1.489	0.29	1.835	1.399	0.222
3	3	2	3.495	1.489	0.29	3.02	1.421	0.243
3	3	3	2.885	1.94	0.4	2.543	1.83	0.35

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. Equation 3 and Equation 4 shows the smaller and larger the better characteristic.

$$Zij = \frac{\max\left(y_{ij}, i = 1,2,.....n\right) - y_{ij}}{\max\left(y_{ij}, i = 1,2,......n\right) - \min\left(y_{ij}, i = 1,2,.....n\right)} \quad (3)$$

$$Z_{ij} = \frac{y_{ij} - \min\left(y_{ij}, i = 1,2,.....n\right)}{\max\left(y_{ij}, i = 1,2,.....n\right) - \min\left(y_{ij}, i = 1,2,......n\right)} \quad (4)$$

Table 2 S/N ratio and normalized S/N ratio for uncoated and BAlN/TiN coated tool

Uncoated tool			BAlN/TiN			Uncoated tool			BAlN/TiN		
S/N SR	S/N MRR	S/N TW	S/N SR	S/N MRR	S/N TW	Zij SR	Zij MRR	Zij TW	Zij SR	Zij MRR	Zij TW
-4.22	-3.65	11.06	-2.18	-5.02	12.65	0.46	0.15	0.00	0.48	0.17	0.22
-4.74	-1.11	9.90	-2.83	-2.05	11.57	0.50	0.38	0.37	0.52	0.46	0.48
-0.79	1.28	9.12	7.33	4.40	10.17	0.18	0.59	0.63	0.00	1.09	0.81
-5.18	-3.69	9.90	-3.38	-4.97	11.37	0.54	0.14	0.37	0.55	0.18	0.52
-5.13	-1.16	11.06	-3.32	-2.10	13.56	0.54	0.37	0.00	0.54	0.46	0.00
-5.18	1.64	9.12	-3.38	0.91	10.46	0.54	0.63	0.63	0.55	0.75	0.74
-12.03	-5.24	10.46	-11.89	-6.80	12.04	1.09	0.00	0.19	0.98	0.00	0.36
-13.00	-1.95	10.46	-12.31	-2.71	12.29	1.17	0.30	0.19	1.00	0.40	0.30
-11.96	0.42	8.64	-11.18	-0.35	9.90	1.09	0.52	0.78	0.94	0.63	0.87
-5.13	-0.58	9.90	-3.32	-1.36	11.37	0.54	0.42	0.37	0.54	0.53	0.52
-4.38	1.81	10.17	-2.92	1.08	11.97	0.47	0.64	0.29	0.52	0.77	0.38
-9.20	4.10	8.18	-8.10	3.60	9.37	0.87	0.85	0.93	0.79	1.01	1.00
-4.74	-1.33	10.75	-2.83	-2.45	13.15	0.50	0.36	0.10	0.52	0.42	0.10
-7.77	1.78	10.17	-7.60	1.12	11.90	0.75	0.64	0.29	0.76	0.77	0.40
-4.84	3.66	8.40	-2.94	3.72	10.17	0.51	0.81	0.86	0.52	1.02	0.81
-10.84	-0.64	10.75	-9.95	-1.42	12.43	1.00	0.42	0.10	0.88	0.52	0.27
-8.01	1.21	10.75	-5.93	4.41	12.54	0.77	0.59	0.10	0.68	1.09	0.24
-9.23	3.20	9.12	-8.14	2.64	10.12	0.87	0.77	0.63	0.79	0.92	0.82
-4.27	1.02	10.17	-2.23	0.29	11.67	0.47	0.57	0.29	0.49	0.69	0.45
1.46	2.89	10.17	0.92	1.80	12.29	0.00	0.74	0.29	0.33	0.84	0.30
0.04	5.73	8.87	3.68	5.21	10.17	0.12	1.00	0.71	0.19	1.17	0.81
-5.13	1.00	10.46	-3.32	0.27	12.29	0.54	0.57	0.19	0.54	0.69	0.30
-5.96	4.41	10.46	-2.28	3.92	11.90	0.60	0.88	0.19	0.49	1.04	0.40
-5.27	5.30	9.37	-3.52	4.37	10.75	0.55	0.96	0.54	0.55	1.09	0.67
-6.75	3.46	10.75	-5.27	2.92	13.07	0.67	0.79	0.10	0.64	0.95	0.12
-10.87	3.46	10.75	-9.60	3.05	12.29	1.00	0.79	0.10	0.86	0.96	0.30
-9.20	5.76	7.96	-8.11	5.25	9.12	0.87	1.00	1.00	0.79	1.17	1.06

Step 3: Calculate Grey relational Co-efficient for the normalized S/N ratio values are Equation 5.

$$\gamma(y_o(k), y_i(k)) = \frac{\Delta\min + \xi\Delta\max}{\Delta_{oj}(k) + \xi\Delta\max} \quad (5)$$

Step 4: Generation of Grey relational grade by Equation 6.

$$\overline{\gamma_j} = \frac{1}{k}\sum_{i=1}^{m}\gamma_{ij} \quad (6)$$

Table 3 Grey relational grades for uncoated and BAlN/TiN coated tool

Uncoated tool			BAlN/TiN			Uncoated tool	BAlN/TiN
GR SR	GR MRR	GR TW	GR SR	GR MRR	GR TW	CG	CG
0.521	0.776	1.000	0.508	0.742	0.699	0.765	0.650
0.499	0.571	0.572	0.491	0.519	0.513	0.547	0.508
0.733	0.457	0.444	1.000	0.314	0.382	0.545	0.565
0.481	0.780	0.572	0.478	0.738	0.489	0.611	0.568
0.483	0.574	1.000	0.480	0.522	1.000	0.686	0.667
0.481	0.444	0.444	0.478	0.400	0.403	0.457	0.427
0.314	1.000	0.721	0.338	1.000	0.580	0.678	0.639
0.299	0.626	0.721	0.333	0.557	0.623	0.549	0.504
0.315	0.493	0.390	0.347	0.443	0.364	0.399	0.385
0.483	0.541	0.572	0.480	0.486	0.489	0.532	0.485
0.514	0.438	0.637	0.489	0.394	0.569	0.529	0.484
0.366	0.370	0.350	0.389	0.330	0.333	0.362	0.351
0.499	0.584	0.836	0.491	0.541	0.838	0.640	0.624
0.401	0.439	0.637	0.397	0.393	0.559	0.492	0.450
0.495	0.382	0.369	0.489	0.328	0.382	0.415	0.400
0.334	0.544	0.836	0.362	0.488	0.651	0.571	0.500
0.394	0.460	0.836	0.425	0.314	0.674	0.563	0.471
0.366	0.395	0.444	0.388	0.352	0.378	0.401	0.373
0.518	0.468	0.637	0.507	0.420	0.526	0.541	0.484
1.000	0.404	0.637	0.605	0.374	0.623	0.680	0.534
0.813	0.334	0.415	0.729	0.300	0.382	0.521	0.470
0.483	0.468	0.721	0.480	0.421	0.623	0.558	0.508
0.454	0.363	0.721	0.505	0.324	0.559	0.513	0.463
0.478	0.343	0.479	0.475	0.315	0.427	0.433	0.406
0.429	0.387	0.836	0.438	0.346	0.813	0.551	0.532
0.333	0.387	0.836	0.367	0.343	0.623	0.519	0.444
0.366	0.333	0.333	0.389	0.299	0.320	0.344	0.336

Result and Discussion

The signal to noise ratio for SR, TW and MRR is computed by using Equation 1 and Equations 2. Normalize the S/N ratio values for SR, TW and MRR is computed by using Equations 3 and Equations 4. The signal to noise ratio and normalize the S/N ratio values for uncoated and BAlTiN coated cutting tool is given in Table 2. Calculate Grey Relational Co-efficient for the normalized S/N ratio values by using Equation 3. The grey relational grade can be computed by Equation 4. The Grey Relational Co-efficient and grey relational grade values for uncoated and BAlTiN coated cutting tool is given in Table 3. Finally, the grades are considered for optimizing the multi response parameter design problem and results are given in the Table 4. 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_1 F_1 A_1 for uncoated cutting tool. The cutting speed set as minimum level (90 m/min), the feed set as minimum level (0.15 mm/rev) and depth of cut set as maximum level (0.5mm). The optimum parameter for BAlN/TiN coated tool is V_1 F_2 A_1 ; The cutting speed set as minimum level (90 m/min), the feed set as minimum level (0.25 mm/rev) and depth of cut set as maximum level (0.5mm).

Table 4 Multi response optimum value for uncoated and BAlN/TiN coated tool

Factor/ level	Uncoated tool			BAlN/TiN		
	1	**2**	**3**	**1**	**2**	**3**
V	**0.582**	0.501	0.518	**0.546**	0.460	0.464
F	**0.558**	0.534	0.508	0.503	**0.506**	0.465
a	**0.605**	0.564	0.431	**0.554**	0.503	0.413

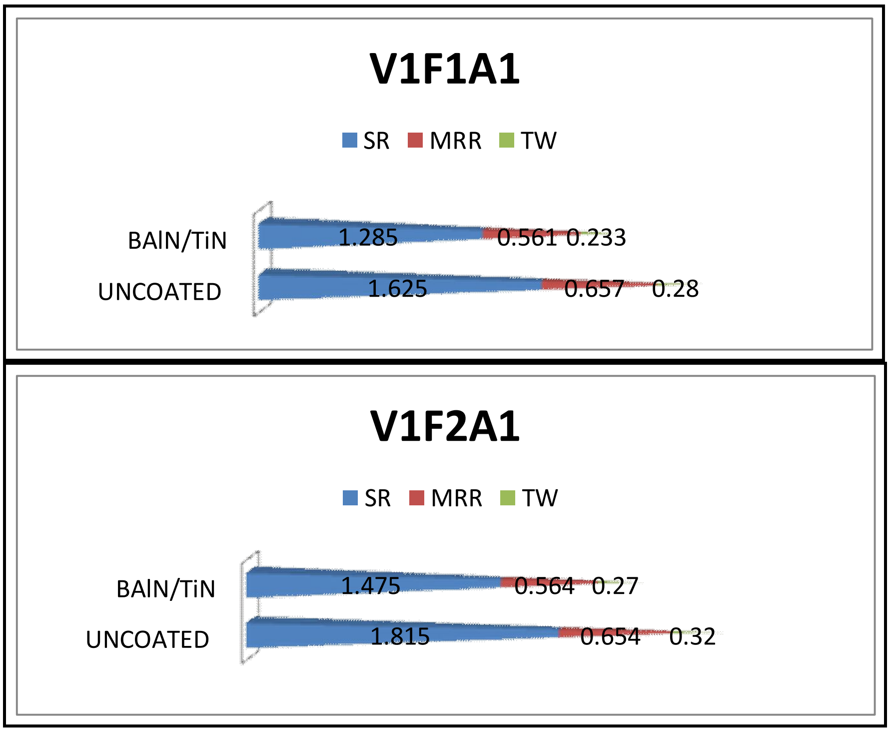

Figure 1 comparison of uncoated and BAlN/TiN coated tool

The performance of the both uncoated and BAlN/TiN coated cutting tool is shown in Figure 1 and it is clearly shows the performance of the BAlN/TiN coated tool is perform better then the uncoated cutting tool. The surface roughness, tool wear is minimum and material removal rate is maximum when compared to the uncoated cutting tool.

Conclusion

The main objective of this study is to investigate the effects of uncoated and BAlN/TiN coated tools AISI410 in CNC turning under dry conditions. The following are the outcomes of this study work conducted with the object of minimization of SR, TW and maximization of MRR.

1. Muti response optimization was performed for turning using the grey relational analysis. Optimum setting for minimization of SR, TW and MRR for turning AISI410 was cutting speed 90 m/min, feed rate 0.15 mm/rev, depth of cut 0.5 mm [$V_1F_1A_1$] using uncoated cutting tool.
2. Optimum setting for minimization of SR, TW and MRR for turning AISI410 was cutting speed 90 m/min, feed rate 0.25 mm/rev, depth of cut 0.5 mm [$V_1F_2A_1$] using BAlN/TiN coated cutting tool.

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