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Machining Performance of the MSS using Baln/Sic Coated Tool

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Abstract: Martensitic Stainless Steels (MSS) are similar to iron-carbon alloys. They are austenitized, hardened by quenching, and then tempered for increased ductility and toughness. They are magnetic, and their heat-treated structure is body centered tetragonal. MSSs are used in cutlery, valves, gears, shafts, rollers, cams, ball bearings, scissors, springs, blades and similar components used in food processing, fasteners, shafts, valves and tools. In general, stainless steels are considered more difficult to machine than other metals such as aluminum and low-carbon steels. Stainless steels have been characterized as gummy during cutting, showing a tendency to produce long, stringy chips that seize or form a BUE on the tool. This may result in reduced tool life and degraded surface finish. The modern industries are expecting the better condition for making the quality product. So in order to get the quality product by machining, it is necessary to work with better optimum machining parameter condition by optimization methodology. Hence, in this paper, Taguchi method is used for identifying best machining parameter for turning MSS under dry condition. More Significant parameters are also identified from the analysis of variance.
Keyword : *CNC Turning; AISI410; Taguchi Methodology; ANOVA.*

1. Introduction

During the last few decades, the usage of stainless steel materials have been increased due to its excellent corrosion resistance, wide range of strength levels, good formability, and an aesthetically pleasing appearance. Even though many new materials have developed in recent decades, stainless steel still remains as one of the most important and potential materials that are used in Industries for making the products. The martensitic stainless steel offer two important advantages over austenitic stainless steel, namely improved chloride stress corrosion cracking resistance and higher mechanical properties [1]. MSS are extensively used in many industrial sectors like chemical and petrochemical, off-shore, desalination, oil and gas industry, pollution control equipment, chemical tankers, pressure vessels, storage tanks, machinery in the pulp and paper industry, marine industry and also in civil engineering applications [2]. Stainless steels are difficult to machine material due to its high toughness, low thermal conductivity, high degree of work hardening rate and tendency to the built up edge formation. Difficulties are faced while machining MSS and high strength stainless steels [3]. Machinability is influenced by a number of variables such as characteristics of the work materials, cutting tool materials, tool geometry, cutting conditions, type of cutting, cutting fluid, machine tool rigidity, its capacity etc.

These variables are the machining process input variables and they are independent of the machining process. On the other hand, dependent process variables are the machining process output variables such as tool life, surface finish, dimensional accuracy, temperature developed, cutting forces, noise, vibration, chip characteristics etc [4]. Many of the researchers worked in this area in different directions and their research findings are listed below

Senthilkumar et al [5] studied the effect of tool wear on tool life of alumina-based ceramic cutting tools while machining hardened MSS. It has been reported that the flank wear affects the tool life at lower cutting speed, whereas, crater wear or notch wear affects the tool life at higher cutting speed. The ceramic cutting tools are the suitable choice for the industry to machine hard materials at lower cost than cubic boron nitride and poly crystalline diamond cutting tools. Noordin et al [6] investigated the usability of coated TiCN based cermet and coated carbide cutting tools to turn tempered MSS with hardness in the 43 45 HRC range under dry cutting conditions. The use of greater insert radius, low feed rate and low depth of cut were recommended to obtain better surface roughness. Thamizhmanii & Hasan [7] conducted machining studies on hard AISI 440 C material by using CBN and polycrystalline cubic boron nitride cutting tools. The CBN tool produced better surface roughness than PCBN tool at high cutting speed with low feed rate. The formation of flank wear on CBN tool was more than PCBN tool at high speeds. Thamizhmanii et al [8] analyzed the tool flank wear of SS 440 C MSS during dry hard turning using CBN cutting tool. The flank wear was occurred at low cutting speed with high feed rate and more depth of cut. The flank wear was due to abrasive action between tool tip and cutting tool, hard carbides in the work piece material. At low cutting speed, formation of BUE was inevitable due to more contact time. Researchers were concentrated on the cermet and CBN tool to machine AISI410 under different condition. But BAlN/SiC coated tool received less attention. So the main objectives of the present research work is to find out the influence of cutting parameters such as cutting speed, feed and depth of cut on output parameters like surface roughness and tool wear in turning operations and to optimize the cutting parameter for minimize the surface roughness and tool wear.

1.1. Taguchi Techniques

Taguchi method is developed by Taguchi. It is widely used for optimizing industrial/production processes. This method offers an efficient, simple and systematic approach to optimize design for performance, quality and cost. Conventional experimental design methods are too complex and expensive. A large number of experiments have to be carried out to study the process. Taguchi method uses an OA to study the entire process with only a small number of experiments. By using the Taguchi technique one can reduce the experimental time, thereby reduce the costs and increasing the profit. The Taguchi design optimization method can be divided into three stages: (a) System design, (b) parameter design and (c) tolerance design. In system design, scientific and engineering knowledge are applied by engineer to make a basic functional prototype design. System design consists of two stages namely the product design and the process design. The second stage is parameter design. The aim of the parameter design is to optimize the process parameters for optimizing responses. Finally, tolerance design is used to find and analyze tolerances around the optimal settings recommended by the parameter design. Among the three stages, the parameter design stage is considered to be the most important stage. Taguchi method is used for optimizing process parameters and identifying the optimal combination of factors for the desired responses [9, 10]

2. Experimental Details

The aim of the work 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 is C: 0.095%, Si: 0.341, Mn: 0.680%, P: 0.040%, S: 0.0063, Cr: 12.170. Insert coated with BAlN/SiC, tool geometry of CNMG120408 and tool holder of PCLNR25 × 25 M12.1 was selected for the experimentation. 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 and TW are the important turning characteristics in turning operation and hence minimization of SR and TW were taken as objective of this work. SR was measured for all the case by the SURF TEST 211 and 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 and Minitab14 statistical software has been used for the analysis of the experimental work.

Table 1 Experimental reading and S/N ratio (SNRA**) for BAlN/SiC**

Trials	V	F	D	SR	SNRA1	TW	SNRA2
1	90	0.15	0.5	1.455	-3.2573	0.249	12.076
2	90	0.15	1.25	1.555	-3.8346	0.283	10.9643
3	90	0.15	2	0.92	0.7242	0.319	9.9242
4	90	0.25	0.5	1.645	-4.3233	0.289	10.782
5	90	0.25	1.25	1.635	-4.2704	0.245	12.2167
6	90	0.25	2	1.645	-4.3233	0.319	9.9242
7	90	0.35	0.5	3.823	-11.6481	0.269	11.405
8	90	0.35	1.25	4.295	-12.6593	0.267	11.4698
9	90	0.35	2	3.792	-11.5774	0.339	9.396
10	140	0.15	0.5	1.635	-4.2704	0.289	10.782
11	140	0.15	1.25	1.485	-3.4345	0.271	11.3406
12	140	0.15	2	2.71	-8.6594	0.359	8.8981
13	140	0.25	0.5	1.555	-3.8346	0.257	11.8013
14	140	0.25	1.25	2.275	-7.1396	0.273	11.2767
15	140	0.25	2	1.573	-3.9346	0.349	9.1435
16	140	0.35	0.5	3.313	-10.4044	0.258	11.7676
17	140	0.35	1.25	2.345	-7.4029	0.255	11.8692
18	140	0.35	2	2.724	-8.7041	0.319	9.9242
19	180	0.15	0.5	1.463	-3.3049	0.28	11.0568
20	180	0.15	1.25	0.675	3.4139	0.277	11.1504
21	180	0.15	2	0.825	1.6709	0.329	9.6561
22	180	0.25	0.5	1.636	-4.2757	0.26	11.7005
23	180	0.25	1.25	1.815	-5.1775	0.273	11.2767
24	180	0.25	2	1.669	-4.4491	0.309	10.2008
25	180	0.35	0.5	2.005	-6.0423	0.259	11.734
26	180	0.35	1.25	3.325	-10.4358	0.262	11.634
27	180	0.35	2	2.713	-8.669	0.369	8.6595

3. Result and Discussion

Signal to noise ratio: Analysis of the influence of each control factor (A, B and C) on the roughness SR and TW has been performed with a so-called signal to noise ratio of response table. Response tables of S/N ratio for SR and TW are shown in Table 2, it shows the S/N ratio at each level of control factor and how it has been changed when settings of each control factor are changed from one level to another. The influence of each control factor can be more clearly represented with response graphs Fig.1 and Fig.2.

Table 2 Taguchi Analysis: SR & TW versus A, B, C

Level	Surface roughness			Tool wear		
	A	B	C	A	B	C
1	-6.130	**-2.328**	-5.707	**10.906**	10.650	11.456
2	-6.421	-4.636	-5.660	10.756	**10.925**	**11.466**
3	**-4.141**	-9.727	**-5.325**	10.785	10.873	9.525
Delta	2.279	7.399	0.382	0.151	0.275	1.941
Rank	2	1	3	3	2	1

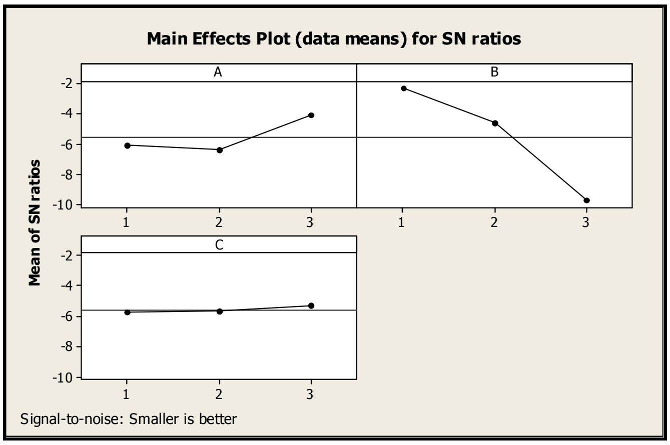

Figure 1 Main effect plots for SR of BAlN/SiC

The slope of the line which connects between the levels and it clearly shows the power of the influence of each control factor. Taguchi analysis shows the better condition for the minimization of SR and TW using BAlN/SiC coated tool turning of AISI410. The optimum cutting condition for SR is A3B1C3 with an evident of S/N ratio value A:-4.141, B:-2.328, C: 5.325 and optimum cutting condition for TW is A1B2C2 with the evident of S/N ratio value A: 10.906 B: 10.925 C: 11.466. The better condition for minimization of SR is cutting speed: 180m/min; feed: 0.15mm/rev and depth of cut: 2mm. The better condition for minimization of TW is cutting speed: 90m/min; feed: 0.25mm/rev and depth of cut: 1.25mm.

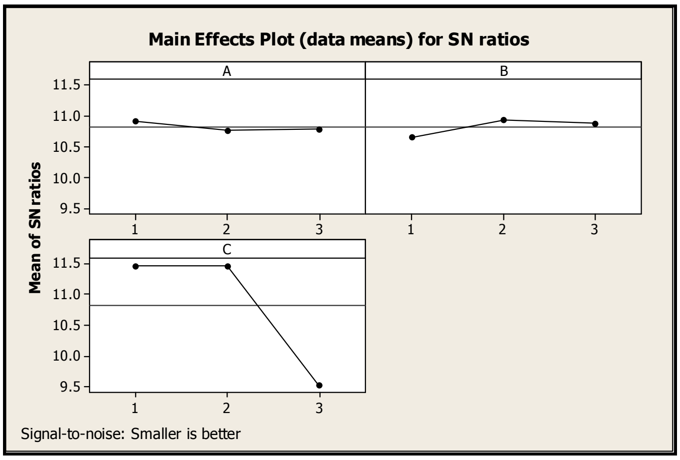

Figure 2 Main effect plots for SR of BAlN/SiC

Table 3 ANOVA: SR versus A, B, C

Source	DF	Surface roughness				Tool wear			
		SS	MS	F	P	SS	MS	F	P
A	2	1.2969	0.6484	1.99	0.162	0.0001580	0.0000790	0.28	0.761
B	2	15.4531	7.7266	23.77	0.000	0.0003976	0.0001988	0.70	0.510
C	2	0.0542	0.0271	0.08	0.920	0.0269349	0.0134674	47.12	0.000
Error	20	6.5022	0.3251			0.0057162	0.0002858		
Total	26	23.3064				0.0332067			

In addition, a statistical ANOVA was performed to see those process parameters that significantly affect the responses. The experimental results were analyzed with ANOVA which is used for identifying the factors which significantly affecting the performance measures. This analysis was carried out for the significance level of $\alpha = 0.05$, i.e. for the confidence level of 95% and it presented in Table 3. The significant factor affecting the surface roughness is feed with evident of F: P value of 23.77:0.000 followed by cutting speed with F: P value of 1.99:0.162. The significant factor affecting the tool wear is depth of cut with evident of F: P value of 47.12:0.000 followed by feed with F: P value of 0.70:0.510.

Conclusion

The conclusions are drawn based on the results obtained from the experimental and parametric studies. The major conclusions of this research study and contributions of the present work are presented.

- The selection of machining parameters for desired surface roughness and minimum tool wear for machining of AISI410 done by optimization and ANOVA. The statistical significance and the F: P for the machining parameters has been evaluated.
- Optimum machining condition for turning AISI410 using BAlN/SiC is cutting speed set as 180m/min, feed set as 0.15mm/rev and depth of cut set as 2mm for minimization of surface roughness.
- Optimum machining condition for turning AISI410 using BAlN/SiC is cutting speed set as 90m/min, feed set as 0.25mm/rev and depth of cut set as 1.25 mm for the minimization of tool wear.
- The significant factor affecting the surface roughness is feed with the evident of F: P value of 23.77:0.000 and The significant factor affecting the tool wear is depth of cut with evident of F: P value of 47.12:0.000 followed by feed with F: P value of 0.70:0.510.

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