International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 02 Issue: 09 | Dec-2015 www.irjet.net p-ISSN: 2395-0072

EVALUATION OF TiCN/TiN AND TiAlN COATED TOOLS FOR TURNING AISI1040 UNDER DRY CONDITION

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Abstract - ***AISI1040 are extensive applications in industries due to the demand of steel in upcoming days. The way to meet the consumer demand is to raise the rate of production and operation. The raises in rate of production causes creation of high heat zone at the tool and also spoil the quality of the product. But no compromise can be allowed with surface finish and dimensional accuracy of the product. In order to solve these problems during machining is to use coated cutting tools under optimum cutting conditions. So this research is concentrated on TiCN/TiN and TiAlN coated tools for turning AISI1040 under dry condition. Performance of the both the cutting tool are compared. The optimum parameter is obtained from Taguchi technique and significant parameter is obtained from Analysis of variance for coated cutting tools.***

Keywords: *AISI1040; Coated tool; Taguchi Techniques; ANOVA*

1.INTRODUCTION

AISI1040 steel parts that carry critical loads in everything from automotive drive trains and jet engines to industrial bearings and metal forming machinery are normally produced by a series of processes, including time consuming and costly grinding and polishing operations. An efficient and less costly method would be to precisely forge hot metal into near net shaped parts, then harden and machine, or cut, the parts using a process known as turning [1]. Manufacturing is the backbone of any modern industrialized economy. In manufacturing material removal or machining is one of the oldest and most indispensable processes for shaping components. Machining process with its intrinsic versatility and associated precision machine tools capable of being driven by computers has been responsible for recent industrial advancements. The main objective of machining is to produce a product of required shape and dimension with specific quality and surface finish. The growth of a manufacturing based economy largely depends on the development of various machining operations. The driving force behind this development is the ability to make parts of different shapes with high quality and precision both faster and at lower cost. In view of its economic importance, complexity of the process, and to develop new cutting equipments, techniques, or processes, researchers have continuously expressed their desire in understanding the principles of cutting mechanisms [2].

Many types of tool materials, ranging from high carbon steel to ceramics and diamonds, are used as cutting tools in today's metalworking industry. It is important to be aware that differences do exist among tool materials, what these differences are, and the correct application for each type of material. A cutting tool must have the hardness, toughness and wear resistance characteristics in order to produce good quality and economical parts [3]. Coating technology is one means of achieving a crucial enhancement in tool performance. However, there is such a huge variety of available coating materials, coating structures and coating processes that careful selection of a suitable coating system is essential. The ability of a coating to reduce wear sufficiently is the criterion for choosing it. There are two major ways in which a coating may influence tool wear. On the one hand, the wear mechanisms may firstly be classified into the three surface effects of adhesion, abrasion and tribo-oxidation [4]. Machine tool industry has made exponential growth in its manufacturing capabilities in last decade but still machine tools are not utilized at their full potential. This limitation is a result of the failure to run the machine tools at their optimum operating conditions. The problem of arriving at the optimum levels of the operating parameters has attracted the attention of the researchers and practicing engineers for a very long time [5].

1.1. Literature Review

The various methodologies and strategies that are adopted by researchers in turning optimization and different techniques used by the researchers in turning process are follows Singh et al [6] investigated the effects of cutting parameters like spindle speed, feed and depth of cut on surface finish and material removal rate of EN-8 on CNC Lathe by using CNMG120408 insert with Taguchi approach. The results found were, spindle speed contributed 63.90%, depth of cut contributed 11.32% and feed rate contribution was 8.33% for Ra. Adinarayana et al [7] studied optimization of power consumption in turning operations using CVD cutting tool on AISI 4340 alloy Steel with speed, feed and depth of cut as control parameters. Result obtained was, power consumption is increase with increase in cutting speed, feed rate and depth of cut.

Singh et al [8] investigated the effects of cutting parameters like spindle speed, feed and depth of cut on surface finish and material removal rate on EN-8 under turning conditions on CNC lathe by using carbide tool. Response Surface Methodology has applied to optimize cutting parameters. Result found was that speed and depth of cut are put negligible effect on the surface roughness and feed rate shown increasing trend. Suresh et al [9] studied that performance of multilayer hard coatings on cemented carbide substrate using CVD for machining of hardened AISI 4340 steel using Taguchi approach in turning process by cutting speed, feed and depth of cut as a controlled factor and power consumption as performance measure. Result found was cutting speed has the highest influence on the machining power required to perform machining operation (77.67%) followed by feed rate (17.39%) and depth of cut (2.82%).

Babu et al [10] studied optimization of power consumption using Taguchi‟s technique. Experiment was conducted with an extruded aluminium shaft on a CNC lathe with cutting speed, feed rate and depth of cut as process parameters. It was observed that the feed rate and the depth of cut are greatly influencing the power consumption. Kumar et al [11] investigated influence of cutting conditions in facing operation (surface finish) of EN-8 using cemented carbide insert. Experiment conducted by using three levels of cutting speed (100, 360, 560) rpm, three levels of feed (0.14, 0.15, 0.16) mm/rev and three levels of depth of cut (0.5, 1, 1.5) mm with L27 Orthogonal array. Result was found that the effect of feed rate is more considerable than cutting speed on surface roughness. Aggarwal et al [12] studied effect of cutting speed, feed rate, depth of cut, nose radius and cutting environment in CNC turning of AISI P-20 tool steel by using response surface methodology and Taguchi technique for power consumption. Result found was, cryogenic environment is the most significant factor in minimizing power consumption followed by cutting speed and depth of cut.

The literature survey has revealed that a little research has been conducted to obtain the optimal levels of machining parameters that yield the best machining quality in AISI1040. The primary objective of the present work is to investigate the effects of the various machining process parameters on the machining quality and to obtain the optimal sets of process parameters so that the quality of machined parts can be optimized.

1.2. Taguchi techniques

Taguchi started to develop new methods to optimize the process of engineering experimentation. He believed that the best way to improve quality was to design and build it into the product. He developed the techniques which are now known as Taguchi Methods. His main contribution lies not in the mathematical formulation of the design of experiments, but rather in the accompanying philosophy. His concepts produced a unique and powerful quality improvement technique that differs from traditional practices. He developed manufacturing systems that were "robust" or insensitive to daily and seasonal variations of environment, machine wear and other external factors. His philosophy had far reaching consequences, yet it is founded on three very simple concepts. His techniques arise entirely out of these three ideas [13].

1.3. Analysis of variance

Analysis of variance (ANOVA) is a technique for analyzing experimental data in which one or more response variables are measured under various conditions identified by one or more classification variables. The combinations of levels for the classification variables form the cells of the experimental design for the data. In an analysis of variance, the variation in the response is separated into variation attributable to differences between the classification variables and variation attributable to random error. An analysis of variance constructs tests to determine the significance of the classification effects. A typical goal in an analysis of variance is to compare means of the response variable for various combinations of the classification variables [14].

2. DESIGN OF EXPERIMENTS

The work piece materials selected for all the trials are AISI1040. The chemical composition of the work piece material is given in Table 1. Experiments were conducted on CNC Fanuc lathe using AISI1040 steel rods of 22.8 mm diameter and 30 mm of machined length. Three operating factors such as depth of cut, feed and cutting speed have been selected for parametric optimization and each parameter has three levels. These factors and three levels are given in Table 2. Hence, L_{27} orthogonal array having 26 degrees of freedom is selected for the controllable factors are given in Table 3. Experiments were conducted on CNC Fanuc lathe using AISI1040 steel rods of 22.8 mm diameter. The SR was measured using Mitutoyo Surf Tester 211 with a cut off length of 0.25 mm. In this investigation the multi-layered TNMG 120408 coated with TiCN/TiN and TiAlN coated tolls are used as the insert for turning operation.

Table -1: Chemical composition of the AISI1040

C	Si	Mn	S	P
0.36-0.44%	0.10-0.40%	0.60-1.00%	0.050(max)	0.050(max)

Table -2: Factor and levels

Factors / levels	1	2	3
Cutting Speed (m/min)	130.79	156.94	183.08
Feed (mm/rev)	0.25	0.5	0.75
Depth of Cut (mm)	0.5	1	1.5

3. RESULT AND DISCUSSION

3.1. Optimum factor for TiCN/TiN and TiAlN coated tools

Taguchi method is used to find the optimum parameter with objective of minimization of SR, and maximization of MRR. The experimental results and S/N ratio for turning AISI1040 using TiCN/TiN and TiAlN coated tools are shown in Table 3.

The Taguchi analysis for TiCN/TiN coated tools of SR is given Table 4, it clearly shows the delta value for feed is 5.753 and cutting speed is 1.784. It can be seen that the feed is strongest effect on SR followed by cutting speed. Optimal setting parameters for minimization of SR is cutting speed set as 183.08 m/min, feed set to as 0.25 mm/rev, depth of cut set as 0.5 mm. The Taguchi analysis for TiCN/TiN coated tools of MRR is given Table 4, it clearly shows the delta value for depth of cut is 11.35 and feed is 0.284. It can be seen that the depth of cut is strongest effect on MRR followed by feed. Optimal setting parameters for maximization of MRR is cutting speed set as 130.79 m/min, feed set to as 0.75 mm/rev, depth of cut set as 1.5 mm.

The Taguchi analysis for TiAlN coated tools of SR is given Table 4, it clearly shows the delta value for feed is 6.617 and cutting speed is 0.314. It can be seen that the feed is strongest effect on SR followed by cutting speed. Optimal setting parameters for minimization of SR is cutting speed set as 183.08 m/min, feed set to as 0.25 mm/rev, depth of cut set as 0.5 mm. The Taguchi analysis for TiCN/TiN coated tools of MRR is given Table 4, it clearly shows the delta value for depth of cut is 6.61 and feed is 1.92. It can be seen that the depth of cut is strongest effect on MRR followed by feed. Optimal setting parameters for maximization of MRR is cutting speed set as 130.79

m/min, feed set to as 0.75 mm/rev, depth of cut set as 1.5 mm.

Table -3: Experimental result and S/N ratio for TiCN/TiN AND TiALN TOOLS

SI.NO	V	F	D	TiCN/TiN				TiAlN			
				MRR	S/N	SR	S/N	MRR	S/N	SR	S/N
1	130.79	0.25	0.5	0.233	-12.653	1.813	-5.168	0.60	-4.437	1.676	-4.486
2	130.79	0.25	1	0.558	-5.067	1.83	-5.249	1.20	1.584	1.616	-4.169
3	130.79	0.25	1.5	0.845	-1.463	2.25	-7.044	1.60	4.082	1.656	-4.381
4	130.79	0.5	0.5	0.248	-12.111	2.786	-8.900	0.888	-1.032	2.680	-8.563
5	130.79	0.5	1	0.576	-4.792	2.703	-8.637	1.333	2.497	2.426	-7.698
6	130.79	0.5	1.5	0.885	-1.061	3.03	-9.629	1.333	2.497	2.586	-8.253
7	130.79	0.75	0.5	0.245	-12.217	3.62	-11.174	0.888	-1.023	3.470	-10.807
8	130.79	0.75	1	0.59	-4.583	3.576	-11.068	1.333	2.497	3.596	-11.116
9	130.79	0.75	1.5	0.983	-0.149	3.876	-11.768	1.777	4.994	3.726	-11.425
10	156.94	0.25	0.5	0.246	-12.181	1.736	-4.791	0.60	-4.437	1.720	-4.711
11	156.94	0.25	1	0.533	-5.466	1.876	-5.465	1.20	1.584	1.576	-3.951
12	156.94	0.25	1.5	0.893	-0.983	1.79	-5.057	1.40	2.923	1.583	-3.990
13	156.94	0.5	0.5	0.244	-12.252	2.446	-7.769	0.666	-3.531	2.186	-6.793
14	156.94	0.5	1	0.513	-5.798	2.2	-6.849	1.333	2.497	2.403	-7.615
15	156.94	0.5	1.5	0.898	-0.935	2.536	-8.083	1.555	3.835	2.410	-7.640
16	156.94	0.75	0.5	0.247	-12.146	3.273	-10.299	0.888	-1.032	3.513	-10.914
17	156.94	0.75	1	0.583	-4.687	3.37	-10.553	1.333	2.497	3.696	-11.355
18	156.94	0.75	1.5	0.894	-0.973	3.413	-10.663	1.777	4.994	3.660	-11.270
19	183.08	0.25	0.5	0.252	-11.972	1.393	-2.879	0.60	-4.437	1.613	-4.153
20	183.08	0.25	1	0.572	-4.852	1.806	-5.134	1	0.000	1.703	-4.624
21	183.08	0.25	1.5	0.909	-0.829	1.39	-2.860	1.60	4.082	1.710	-4.660
22	183.08	0.5	0.5	0.24	-12.396	2.29	-7.197	0.666	-3.531	2.306	-7.257
23	183.08	0.5	1	0.564	-4.974	2.123	-6.539	1.333	2.497	2.316	-7.295
24	183.08	0.5	1.5	0.897	-0.944	2.533	-8.073	1.555	3.835	2.596	-8.286
25	183.08	0.75	0.5	0.236	-12.542	3.276	-10.307	0.888	-1.032	3.273	-10.299
26	183.08	0.75	1	0.582	-4.702	3.043	-9.666	1.333	2.497	3.546	-10.995
27	183.08	0.75	1.5	0.901	-0.906	3.136	-9.928	1.555	3.835	3.350	-10.501

Table- 4; Taguchi analysis for for TiCN/TiN AND TiALN tools

TiCN/TiN coated tools						
Level	SR			MRR		
	A	B	C	A	B	C
1	-8.737	**-4.850**	**-7.609**	**-6.0106**	-6.1628	-12.2744
2	-7.725	-7.964	-7.68 4	-6.1578	-6.1403	-4.9911
3	**-6.954**	-10.603	-8.12 3	-6.0129	**-5.8781**	**-0.9158**
Delta	1.784	5.753	0.513	0.1472	0.2847	11.3586
Rank	2	1	3	3	2	1
TiAlN coated tools						
Level	A	B	C	A	B	C
1	-7.877	**-4.347**	**-7.553**	**1.2953**	0.1049	-2.7211
2	-7.582	-7.711	-7.646	1.0365	1.0625	2.0163
3	**-7.563**	-10.964	-7.823	0.8606	**2.0250**	**3.8973**
Delta	0.314	6.617	0.269	0.4347	1.9202	6.6184
Rank	2	1	3	3	2	1

3.2. Significant factor for TiCN/TiN and TiAlN coated tools

The experimental results were analyzed using ANOVA for identifying the significant parameters affecting the performance measurers on the total variance of the results. The Table ANOVA has the following components: Source of variation, degrees of freedom (DOF), sum of square (SS), mean square (MS), F-values (F), P-values. A table 5 shows the results of ANOVA of SR and MRR respectively. The analysis was carried out for a confidence level of 95% (significance level of $\alpha = 0.05$).

The ANOVA for TiCN/TiN coated tools of SR on AISI1040 is given in Table 5, it is clearly shows that the feed is most significantly affect the SR with F value of 258.11 followed by the cutting speed with F value of 24.64. The ANOVA for MRR on AISI1040 is given in Table 5, it is clearly shows that the depth of cut is most significantly affect the MRR with F value of 1663.64 followed by the feed with F value of 2.77. The ANOVA for TiAlN coated tools of SR on AISI1040 is given in Table 5, it is clearly shows that the feed is most significantly affect the SR with F value of 508.30 followed by the cutting speed with F value of 1.89. The ANOVA for MRR on AISI1040 is given in Table 5, it is clearly shows that the depth of cut is most significantly affect the MRR with F value of 151.02 followed by the feed with F value of 10.36.

3.3. Comparison of TiCN/TiN and TiAlN coated tools

Steels are used for many commercial and industrial applications owing to its mechanical property with economic. The coated cutting tool is mainly affect the quality of the product and different coated cutting tools such as TiCN/TiN and TiAlN coated tools are used to turning AISI1040 under dry conditions. Figure 1 shows comparison of different coated tools with SR at cutting speed of 183.08 m/min, feed of 0.25 mm/rev, depth of cut of 0.5 mm. Figure 1 shows the comparison of different coated tools with MRR at cutting speed of 130.79 m/min, feed of 0.75 mm/rev, depth of cut of 1.5 mm. It clearly showed the minimum SR and maximum MRR was obtained from the TiAlN coated tool than the TiCN/TiN coated tools coated tools.

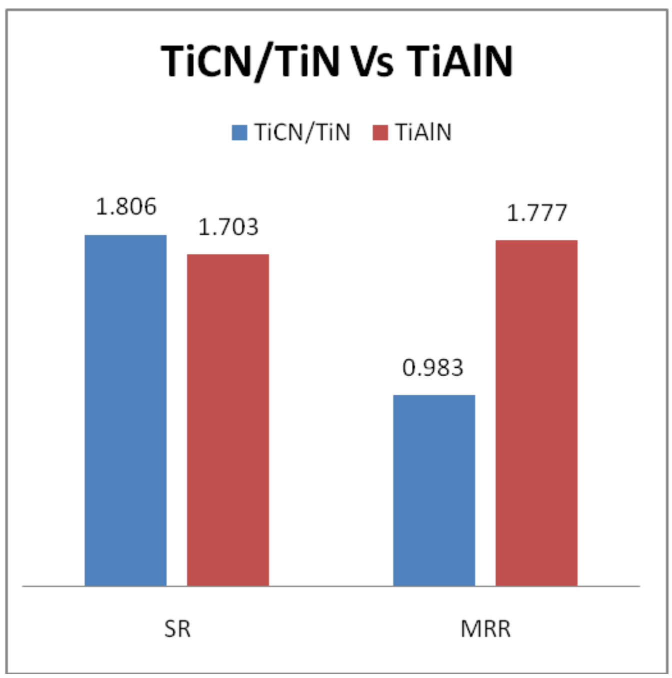

Figure 1 Comparison of TiCN/TiN and TiAlN coated tools

Table -5: Significant factor for for TiCN/TiN and TiALN tools

TiCN/TiN coated tools									
Source	DF	SR				MRR			
		SS	MS	F	P	SS	MS	F	P
A	2	1.1484	0.5742	24.64	0.000	0.00085	0.00043	0.73	0.494
B	2	12.0288	6.0144	258.11	0.000	0.00324	0.00162	2.77	0.087
C	2	0.1405	0.0702	3.01	0.072	1.94352	0.97176	1663.64	0.000
Error	20	0.4660	0.0233			0.01168	0.00058		
Total	26	13.7838				1.95929			
TiAlN coated tools									
Source	DF	SS	MS	F	P	SS	MS	F	P
A	2	0.0600	0.0300	1.89	0.178	0.00994	0.00497	0.47	0.629
B	2	16.1641	8.0821	508.30	0.000	0.21739	0.10869	10.36	0.001
C	2	0.0392	0.0196	1.23	0.312	3.16873	1.58436	151.02	0.000
Error	20	0.3180	0.0159			0.20982	0.01049		
Total	26	16.5814				3.60588			

4. CONCLUSION

The paper examines the single response process parameter optimization of turning AISI1040. The responses that are considered for optimization are surface roughness and material removal rate for the process. The significant process parameters were identified as well as the optimum levels of the process parameters were found out by the Taguchi single objective optimization techniques. From this study, the following findings were derived

- The TiAlN coated tool performs better performance than the TiCN/TiN coated tools for turning AISI1040.
- The optimum process parameter evolved with respect to minimization of surface roughness is cutting speed set as 183.08 m/min, feed set to as 0.25 mm/rev, depth of cut set as 0.5 mm using TiCN/TiN and TiAlN coated tools.
- The optimum process parameter evolved with respect to minimization of surface roughness is cutting speed set as 130.79 m/min, feed set to as 0.75 mm/rev, depth of cut set as 1.5 mm using TiCN/TiN and TiAlN coated tools.
- Feed is most significantly affecting the SR followed by the cutting speed and depth of cut is most significantly affecting the MRR followed by the feed for TiCN/TiN and TiAlN coated tools.

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