Performance Study of Ticn/Tin and Tialn Coated Cutting Tool on Inconel625 in CNC Turning

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***Abstract*— INCONEL 625 alloys are used many industrial applications such as petrochemical and power generation, due to their high performance in aggressive environments. However, INCONEL 625 material is difficult make a product because at the time of machining produce poor surface finish, high tool wear and reduce the production rate. The coating on tungsten carbide cutting tool is effective way to improve the quality of the product. So in this investigation TiCN/TiN and TiAlN Coated cutting tool is taken for machining on INCONEL 625 in CNC turning under dry condition. The current work focuses on determining the optimal cutting condition for turning INCONEL625 to achieve minimum surface roughness (SR), tool wear (TW) and maximum material removal rate (MRR).**

***Index Terms*— CNC Turning- Inconel 625- Taguchi Techniques- Box Bhenken Design**

I. INTRODUCTION

The challenges which are made by the modern machining industries is mainly focused on the achievement of high quality, dimensional accuracy, surface roughness, high material removal rate, less tool wear on the cutting tools, economy of machining in terms of cost saving and increase the performance of the product with reduced environmental impact (Kwok et al 2003). Turning operation is a typical machining method and extensively used in the manufacturing industry. In the turning process of bars, a bigger diameter error is usually caused due to the lower work piece stiffness. In order to improve machining quality, conservative cutting parameters are usually selected during machining and thus limit the increase of productivity (Stephenson, 2006).

Inconel 625 materials are widely used in chemical, aircraft and shipbuilding industries because thermal resistant retaining mechanical properties up to 700°C. On the other hand, they are very difficult to machine, due to their high shear strength, work hardening tendency, highly abrasive carbide particles, tendency to weld and form build-up edge and low thermal conductivity. For all these alloys high temperature characteristics translate directly to machining challenges. Usually during machining there is poor surface finish and lack of material removal rate. This often leads to edge breakdown of the tool through chipping or deformation. In addition, work piece surface hardens very quickly. A hardened surface can result in depth of cut line notching of the tool and may also compromise the fatigue strength and geometric accuracy of the part (Ezugwu and Wang 1998).

Coated carbides are basically a cemented carbide insert coated with one or more thinly layers of wear resistant materials, such as titanium nitride, titanium carbide and aluminum oxide. It is well known that coating can reduce tool wear and improve the surface roughness (Sarwar et al 1997). Therefore, most of the carbide tools used in the metal cutting industries is coated while coating brings about an extra cost (DeGarmo 1997). In almost all of this research the machining has been examined from the manufacturing technology point of view for the improvement of tool materials, geometries and machining parameters. The main reasons for the machining difficulties are due to its high strength and ductility at high temperatures, the austenitic matrix and its low thermal conductivity. The material can also adhere and weld onto the tool, the influence of the stress and temperature along tool-chip and tool- work interfaces. All these effects finally lead to poor surface integrity if the working conditions are not properly selected. Therefore, it is important to know the machining parameters (Addona, 2011; Devillez, 2011). The most of the researchers were concentrated the effect of the performance of the different cutting fluids, performance of the cubic boron nitride tool and polycrystalline cubic boron nitride cutting tool on turning inconel 625. Moreover the researchers had conducted turning experiments with high cost tools like cubic boron nitride tool and polycrystalline cubic boron nitride cutting tool (Biermann et al 2013).

Physical depositions have received wide application for the deposition of wear resistance coatings on the working surface of hard alloy and ceramic cutting tools. The deposition allows one to form coatings with high adhesion strength to substrate, density, and compositional uniformity. One characteristic structure of such coatings is grains, which adapt better to operation in continuous cutting conditions. The deposition technologies allow us to more effectively and purposefully control the structure and properties of coatings (Stephenson, 2014). However tools coated with TiCN/TiN and TiAlN in CNC turning on inconel 625 has received less attention. Limited researches were reported for turning inconel 625 using different coated cutting tool. Moreover, it is necessary to optimize the machining parameters to achieve the high quality. So in this research TiCN/TiN and TiAlN coated cutting tool was used to CNC turning on Inconel625 under dry condition and best cutting conditions were obtained using Taguchi Techniques.

Manuscript received Dec 16, 2015

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II. EXPERIMENTAL DETAILS

The experiments were conducted in Fanuc CNC lathe. TNMG 120408 coated with TiCN/TiN and TiAlN coated cutting tool is used as the insert for all machining operation. The range of cutting parameters were selected based on past experience, data book and available resources. Surface roughness is measured by the Mitutoyo surface roughness tester. Tool wear 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. A round rod of Inconel625 material was used in the present study. The nominal chemical composition of the Inconel 625 given sample as Ni: 58.0-63.0, Cr: 20.0-23.0, Mo: 8.0-10.0, Nb: 3.0-5.0, Fe: ≤5.0.

Table 1 Experimental analysis: SR, MRR, TW versus V, F, A for TiCN/TiN coated tool

Si.no	V	F	D	SR	S/N.SR	MRR	S/N.MRR	TW	S/N.TW
1	75	0.1	0.25	0.493	6.143	0.500	-6.021	74.480	-37.441
2	75	0.1	0.5	0.507	5.900	0.522	-5.647	205.390	-46.252
3	75	0.1	0.75	4.373	-12.816	0.583	-4.687	322.750	-50.177
4	75	0.2	0.25	0.607	4.336	0.800	-1.938	43.260	-32.722
5	75	0.2	0.5	0.427	7.391	0.800	-1.938	94.790	-39.535
6	75	0.2	0.75	0.767	2.304	0.933	-0.602	126.400	-42.035
7	75	0.3	0.25	3.337	-10.467	0.923	-0.696	67.710	-36.613
8	75	0.3	0.5	2.140	-6.608	0.769	-2.281	169.270	-44.572
9	75	0.3	0.75	4.117	-12.292	1.000	0.000	206.870	-46.314
10	100	0.1	0.25	0.560	5.036	0.400	-7.959	67.710	-36.613
11	100	0.1	0.5	0.390	8.179	0.526	-5.580	72.750	-37.237
12	100	0.1	0.75	0.810	1.830	1.158	1.274	129.160	-42.223
13	100	0.2	0.25	1.903	-5.589	0.923	-0.696	60.940	-35.698
14	100	0.2	0.5	1.773	-4.974	0.923	-0.696	195.230	-45.811
15	100	0.2	0.75	1.570	-3.918	0.923	-0.696	200.950	-46.062
16	100	0.3	0.25	3.430	-10.706	0.545	-5.272	135.420	-42.634
17	100	0.3	0.5	3.457	-10.774	1.091	0.757	277.630	-48.869
18	100	0.3	0.75	5.613	-14.984	0.667	-3.517	362.570	-51.188
19	125	0.1	0.25	0.837	1.546	0.588	-4.612	135.420	-42.634
20	125	0.1	0.5	0.660	3.609	0.556	-5.099	147.010	-43.347
21	125	0.1	0.75	1.107	-0.883	0.667	-3.517	753.860	-57.546
22	125	0.2	0.25	1.913	-5.634	0.500	-6.021	79.020	-37.955
23	125	0.2	0.5	4.470	-13.006	0.500	-6.021	406.610	-52.184
24	125	0.2	0.75	1.490	-3.464	1.500	3.522	458.160	-53.220
25	125	0.3	0.25	3.653	-11.253	0.545	-5.272	56.460	-35.035
26	125	0.3	0.5	4.270	-12.609	0.400	-7.959	338.410	-50.589
27	125	0.3	0.75	6.063	-15.654	0.545	-5.272	790.980	-57.963

The dimension of the material is 24 mm diameter and machined length is 30 mm for all trials. The three cutting parameters selected for the present investigation is cutting speed (75, 100, 125 m/min), feed (0.1, 0.2, 0.3 mm/rev) and depth of cut (0.25, 0.5 and 0.75). Taguchi's orthogonal array of L_{27} is most suitable for this experiment. This needs 27 runs and has 26 degrees of freedoms. Desirability function analysis was one of the most widely used methods in industry for the optimization of multi responses problems. In addition response surface regression was used for modeling and prediction to provide sufficient information about the main and interaction effects with a limited attempt of experiments. The experimental results for TiCN/TiN and TiAlN coated tool is given in Tavle 1 and Table 2.

Table 2 Experimental analysis: SR, MRR, TW versus V, F, A for TiAlN coated tool

Si.no	V	F	D	SR	S/N.SR	TW	S/N.TW	MRR	S/N.MRR
1	75	0.1	0.25	0.68	3.35	42.88	-32.65	0.50	-6.02
2	75	0.1	0.5	0.65	3.70	61.06	-35.72	0.52	-5.65
3	75	0.1	0.75	0.59	4.63	63.19	-36.01	0.61	-4.31
4	75	0.2	0.25	1.65	-4.35	51.91	-34.31	0.59	-4.54
5	75	0.2	0.5	1.59	-4.01	51.94	-34.31	0.43	-7.36
6	75	0.2	0.75	1.63	-4.23	138.01	-42.80	0.61	-4.31
7	75	0.3	0.25	3.41	-10.66	92.61	-39.33	1.00	0.00
8	75	0.3	0.5	3.56	-11.04	112.85	-41.05	0.92	-0.70
9	75	0.3	0.75	3.36	-10.53	449.03	-53.05	1.33	2.50
10	100	0.1	0.25	0.49	6.14	36.11	-31.15	0.53	-5.58
11	100	0.1	0.5	0.83	1.65	54.17	-34.68	0.63	-3.99
12	100	0.1	0.75	0.50	6.02	97.12	-39.75	1.05	0.45
13	100	0.2	0.25	1.65	-4.37	24.83	-27.90	0.92	-0.70
14	100	0.2	0.5	1.67	-4.45	29.40	-29.37	0.62	-4.22
15	100	0.2	0.75	1.54	-3.73	415.44	-52.37	1.08	0.64
16	100	0.3	0.25	4.19	-12.44	148.96	-43.46	0.73	-2.77
17	100	0.3	0.5	3.85	-11.72	189.59	-45.56	1.09	0.76
18	100	0.3	0.75	3.66	-11.28	203.57	-46.17	0.91	-0.83
19	125	0.1	0.25	0.35	9.04	31.83	-30.06	0.35	-9.05
20	125	0.1	0.5	0.36	8.87	60.94	-35.70	0.47	-6.55
21	125	0.1	0.75	0.77	2.27	444.68	-52.96	0.94	-0.53
22	125	0.2	0.25	1.62	-4.19	54.20	-34.68	0.67	-3.52
23	125	0.2	0.5	1.48	-3.41	63.19	-36.01	1.00	0.00
24	125	0.2	0.75	1.76	-4.89	489.89	-53.80	1.50	3.52
25	125	0.3	0.25	3.66	-11.28	112.85	-41.05	1.00	0.00
26	125	0.3	0.5	3.56	-11.02	162.51	-44.22	1.00	0.00
27	125	0.3	0.75	2.91	-9.27	581.05	-55.28	0.80	-1.94

Table 3 Taguchi Analysis: SR, MRR, TW versus V, F, A for TiCN/TiN coated tool

Level	SR			MRR			TW		
	V	F	D	V	F	D	V	F	D
1	**-1.79**	**2.06**	-2.95	-2.65	-4.65	-4.28	**-41.74**	-43.72	**-37.48**
2	-3.99	-2.51	**-2.54**	**-2.49**	**-1.68**	-3.83	-42.93	**-42.80**	-45.38
3	-6.37	-11.71	-6.65	-4.47	-3.28	**-1.50**	-47.83	-45.98	-49.64

Table 4 Taguchi Analysis: SR, MRR, TW versus V, F, A for TAlN coated tool

Level	SR			MRR			TW		
	V	F	D	V	F	D	V	F	D
1	-3.68	**5.075**	**-3.19**	-3.37	-4.58	-3.57	**-38.80**	**-36.52**	**-34.95**

2	-3.79	-4.181	-3.49	**-1.80**	-2.27	-3.07	-38.93	-38.39	-37.40
3	**-2.65**	-11.02	-3.4	-2.00	**-0.33**	**-0.53**	-42.64	-45.46	-48.02

3. RESULT AND DISCUSSION

3.1 Taguchi analysis for SR, MRR, TW versus V, F, A for TiCN/TiN coated tool

Taguchi planned that the engineering optimization of a process should be carried out in a three-step approach, that is, system design, parameter design, and tolerance design. In the system design, the engineer applies scientific and engineering knowledge to produce a basic functional prototype design. In the product design stage, the selections of materials, components, tentative product parameter values, etc., are involved. As to the process design stage, the analysis of processing sequences, the selections of production equipment, tentative process parameter values, etc., are involved. Since the system design is an initial functional design, it may be far from optimum in terms of quality and cost. Following the system design is the parameter design. The objective of the parameter design is to optimize the settings of the process parameter values to improve quality characteristics and to identify the product parameter values under the optimal process parameter values (Naveen Sait, 2009). There are three categories of quality characteristic in the analysis of the S/N ratio, (1) the-lower-the-better, (2) the-higher-the-better and (3) the-nominal-the-better. The Taguchi analyses for all the responses are given in Table 3. It shows the S/N ratio at each level of control factor and how it is changed when settings of each control factor are changed from one level to another. According to the rank value for each control factor that the feed has the strongest influence on SR followed by cutting speed. Thus in order to minimum level of SR, Feed should be set to 0.1mm/rev, depth of cut set to 0.5 mm and cutting speed set to 75 m/min. In order to minimum level of TW, cutting speed set to 75 m/min, feed set to 0.2 mm/rev and depth of cut set to 0.25 mm. Similarly maximum level of MRR is cutting speed set as 100 m/min, feed set as 0.2 m/rev and depth of cut set as 0.75 mm.

3.2 Taguchi analysis for SR, MRR, TW versus V, F, A for TiCN/TiN coated tool

The Taguchi analyses for all the responses are given in Table 4. It shows the S/N ratio at each level of control factor and how it is changed when settings of each control factor are changed from one level to another. According to the rank value for each control factor that the feed has the strongest influence on SR followed by cutting speed. Thus in order to minimum level of SR, Feed should be set to 0.1 mm/rev, depth of cut set to 0.25 mm and cutting speed set to 125 m/min. In order to minimum level of TW, cutting speed set to 75 m/min, feed set to 0.3 mm/rev and depth of cut set to 0.55 mm. Similarly maximum level of MRR is cutting speed set as 100 m/min, feed set as 0.3 m/rev and depth of cut set as 0.75 mm.

CONCLUSION

The present work is focused on the behavior of TiCN/TiN and TiAlN coated tool turning Inconel625 and resulted in the following major conclusions.

Optimization of the single response problem using Taguchi method provided an effectual tactic for the optimization of turning parameters. Optimum setting for minimization of SR for turning Inconel 625 was cutting speed 75 m/min, feed 0.1 mm/rev, and depth of cut of 0.5 mm [$V_1F_1D_2$]. Optimum setting for minimization of TW for turning Inconel 625 was cutting speed 75 m/min, feed 0.2 mm/rev, and depth of cut of 0.25 mm [$V_1F_2D_1$]. Optimum setting for maximization of MRR for turning Inconel 625 was cutting speed 125 m/min, feed 0.2 mm/rev, and depth of cut of 0.75 mm [$V_2F_2D_3$] using TiCN/TiN coated tool.

Optimum setting for minimization of SR for turning Inconel 625 was cutting speed 125 m/min, feed 0.1 mm/rev, and depth of cut of 0.25 mm [$V_3F_1D_1$]. Optimum setting for maximization of MRR for turning Inconel 625 was cutting speed 100 m/min, feed 0.3 mm/rev, and depth of cut of 0.75 mm [$V_2F_3D_3$]. Optimum setting for minimization of TW for turning Inconel 625 was cutting speed 75 m/min, feed 0.1 mm/rev, and depth of cut of 0.25 mm [$V_1F_1D_1$] using TiAlN coated tool.

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