Performance Parameters of AISI 52100 Bearing Steel with Ceramics and CBN/TIC Cutting Tools

N. Vijay Kumar[1] Mr. K. Pavan Kumar Reddy[2] Jayam Sree Hari[3]
[2,3]M.Tech Student
[1]Department of Production Engineering
[1,2,3]Sri Venkateswara Institute of Technology, Anantapuram, India

Abstract— Among the metal cutting methods, turning is one of the widely used manufacturing processes in industry. In addition to tool and work piece material, cutting speed (V), feed rate (f), depth of cut (d) are the most important cutting parameters which highly affect the performance characteristics. It is necessary to select the most appropriate cutting parameters and cutting tools in order to improve cutting efficiency, process at low-cost, and produce high-quality products. Of the present available cutting tools materials, ceramic or cubic boron nitride (CBN) cutting tools are the best candidates and are widely used in turning the hardened steels owing to their high hardness and high melting point. The turning of hardened steels by selecting the right cutting tools and cutting parameters produces surface finishes with grinding quality. The machining of hardened steel has a number of advantages over the grinding process. Hardened steels are widely used in the automotive industry such as gear, bearing, and tool and die making.

Key words: AISI 52100 Bearing Steel, Ceramics and CBN/TIC Cutting Tools

I. INTRODUCTION

Tool life performances and wear mechanisms of various cutting tools such as mixed alumina ceramic (KY1615), coated ceramic (KY4400) and cubic boron nitride (CBN/Tic) are investigated experimentally under different cutting conditions in turning austenised and quenched AISI 52100 steels. Worn surfaces of the cutting tools are examined by scanning electron microscope (SEM) to find out the effective mechanism of wear. The surface roughness values are measured with surface profile meter and which cutting tool will provide a lower surface roughness values are investigated in the machining of hardened bearing steel AISI 52100. The experimental results showed that tool life decreased with increasing speed for all cutting tools. The longer tool life is obtained for the CBN/Tic cutting tool when machining the hardened AISI 52100 steel. However, the difference among the tool lives decreased considerably with decreasing the cutting speed. In addition, it is observed that the major wear form of the tools is the smooth flank wear for the CBN/TiC tool. However, crater and flank wear are observed for the KY1615 cutting tool while tool nose deformation is observed for the KY4400 cutting tool when machining the hardened steels. CBN/TiC and KY615 tool produced better surface roughness values of Ra than the KY4400 tools in all experimental conditions. On the surface roughness, low and medium cutting speed does not show a significant effect for all tools. But, Ra surface roughness values decreased with the highest cutting speed value. On the other hand; surface roughness value of Ra improved in the lowest depth of cut for all tools.

A. Work Piece Materials

The materials used throughout this work were an AISI 52100 steels. The material was AISI 52100 bearing steel containing 0.99%C, 0.39%Mn, 0.16%Si, 1.40%Cr, and 1.4% Ni and balance Fe. For heat treatment of AISI 52100 steels, the work pieces were austenised at 850oC for 2 h and quenched with oil.

B. CNC Machine

The machine used for the turning tests was a Johnford TC35 Industrial type of CNC lathe machine. The lathe equipped with variable spindle speed from 50 rpm to 3500 rpm, and a 10 kW motor drive was used for the tests.

C. Cutting Tools

Three types of cutting tools were used for the present work. These are mixed alumina ceramic tools, coated ceramic cutting tools and CBN/TiC cutting tools. One of the tools was a mixed alumina ceramic with a 70% Al2O3+30% TiC matrix, which is designated by KY1615. The other insert was coated using a physical vapor deposition (PVD) method.

Coating substance took place on the mixed ceramic substrate and PVD-TiN coated mixed ceramic with a matrix of 70% Al2O3; 30%TiCN, which is called as KY4400 grade. The insert seating for ceramics: nominal rake angle −6°, back rake angle −6°, clearance angle 6°, approach angle 75°, major tool cutting angle 60° triangle-shaped inserts and 0.8 mm nose radius. The insert was rigidly attached to a tool holder of ISO designation of PTBNR 2525-16. These insert types were TNGA160408- KY1615 and TNGA 160408-KY4400. The geometry angles of ceramic-based tools are commercially available inserts according to ISO code, supplied by Kennametal Inc.

For the turning tests 26, 45-47. The last one was a CBN with TiC matrix, which is designated by CBN/TiC The CBN/Tic tool contains about 50% CBN; 40% TiC; 6% WC; 4% AlN, AlB2. The average grain size was. About 2 m. For the turning test, 55° diamond-shaped inserts with 0.1×20° chamfer were used. The cutting geometry was -20° negative rake angle, −6° side rake angle, 6° clearance angle, 75° approach angle, 80° edge major tool cutting angle and 0.8 mm nose radius. However, the CBN/TiC insert type was CNGA120408-LO-B. These tools are commercially available inserts according to ISO code cutting tools were supplied by SECO Inc. The tool holder of PCLNR 2525-12A was used. Details of characteristics of cutting tools types are given in Table 126, 45-47.

Type ofcutting tool	Tool designation	Chemical composition of material	Hardness (HV)	Thermal conductivity (Wm-1 K-1)
Mixedceramc tool (KY1615)	TNGA160408	Al2O3 (70%) +TiC (30%)	2145	28
Coate	28TNGA160408	Al2O3 (70%) +TiC (30%)	2250	32

ceramic tool (KY4400)		+Tin		
Cubic boron nitride (CBN/TiC)	CNGA 120408	L0CBN (50%) +TiC (40%) +WC (6%AlN, AlB2 (4%)	3660	44

Table 1: The Type, Geometry, Designation and Some Properties of Cutting Tool

II. Project Methodology

In general, two types of wear apply to tool life, i.e., flank wear and crater wear. Flank wear remains the more common measure of tool wear compared with crater wear because of simplicity and ease of measurement. In the tool life experiments, for the purpose of measuring the changes in the flank wear (VB), an optical microscope with a magnification of 5- 100× and an accuracy of 0.005 mm was used. An optical microscope with a digital camera was used into determine the wear types in the cutting tools. Two tool life criteria, recommended by the International Standard Organization, are widely accepted in industry.

The criterion of flank wear was VB=0.2 mm26, 45-47. The surface roughness of the AISI 52100 steel was measured by the aid of a stylus instrument. The equipment used for measuring the surface roughness was a surface roughness tester, MAHR PerthometerM1 type of portable. The surface roughness measured in the paper is the arithmetic mean deviation of surface roughness of profile Ra. In collecting the surface roughness data of the shaft with surface profilometer, five measurements are taken along the shaft axis for each sample and measurement is about 72° apart26, 47.

III. Results and Discussion

A. *Tool Life Performance of Cutting Tools*

The effects of workpiece microstructure, work pieces and cutting tools hardness on machinability of quenched+tempered AISI 52100 steel were investigated with a research project as a whole conducted by Sahin and Motorcu26. In addition, tool life performances and wear mechanisms of KY1615, KY4400 and CBN/TiC cutting tools were determined and evaluated. Taguchi method was selected to minimize the number of experiments, to find out the relationships between independent variables and cutting time and in order to determine the optimal parameter levels provide the highest tool life. In this study, the independent variables are cutting speed, feed rate, depth of cut and tool's hardness.

A standard Taguchi experimental plan with notation L9 (34) was chosen. The experimental design, results for tool lives and signal-to-noise (S/N) ratios are shown in Table 226, 45-47. The rows in the L9 orthogonal array used in the experiment corresponded to each trial and the columns contained the factors to be studied. The first column consisted of cutting speed, the second contained the feed rate and the consecutive column consisted of the cutting tool's hardness. The experiments were conducted twice for each row of the orthogonal array to circumvent the possible errors in the experimental study. In the Taguchi method, the experimental results are transformed into a signal-tonoise (S/N) ratio. This method recommends the use of S/N ratio to measure the quality characteristics deviating from the desired values. To obtain optimal testing parameters, the- higher-the-better quality characteristic for machining the steels was taken due to measurement of the tool life. The S/N ratio for each level of testing parameters was computed based on the S/N analysis 26, 47. Finally, which cutting tool will provide a lower surface roughness values were investigated in the machining of hardened bearing steel AISI 52100. The some findings of this study were presented in an article by Sahin47. This study is a complementary of an article conducted by Sahin and the selected different cutting parameters on the wear behavior of cutting tools were investigated. SEM analysis on the cutting tools in turning of AISI 52100 hardened steels is conducted. Cutting tools providing the lowest average surface roughness values were determined and compared. Table 2 gives experimental design and results for tool lives and their S/N26, 45-47. Figures 1-3 show a variation of flank wear land with cutting time when machining the steels under different cutting speeds and feed rates. These figures were obtained through experimental results data given in Table 1. Figure 1 indicated that the cutting time was slightly longer in machining the steels by CBN/TiC tools than those of other tools at a given cutting conditions, but there was no significant difference among the cutting tools. This is attributed to lower cutting speed and using different feed rates.

During machining steel, the cutting time lasted about 120 min to reach the flank wear criteria of 0.2 mm.

Trial number	Control factors and their uncoded values			Experimental and theoretical values	
	V (m/min)	*f* (mm/rev)	*TH* (HV)	Measured tool life, *T* (min)	*S/N* ratio (dB)
1	100	0.06	2145	114	41.138
2	100	0.084	2250	117.5	41.401
3	100	0.1176	3660	121	41.656
4	140	0.06	2250	108.5	40.709
5	140	0.084	3660	110	40.828
6	140	0.1176	2145	17.5	24.861
7	196	0.06	3660	97.5	39.780
8	196	0.084	2145	10.1	20.086
9	196	0.1176	2250	15.1	23.580
					Mean S/N ratio (dB) 34.893

Table 2: Experimental design and results for tool lives and their S/N ratios 26, 45-47

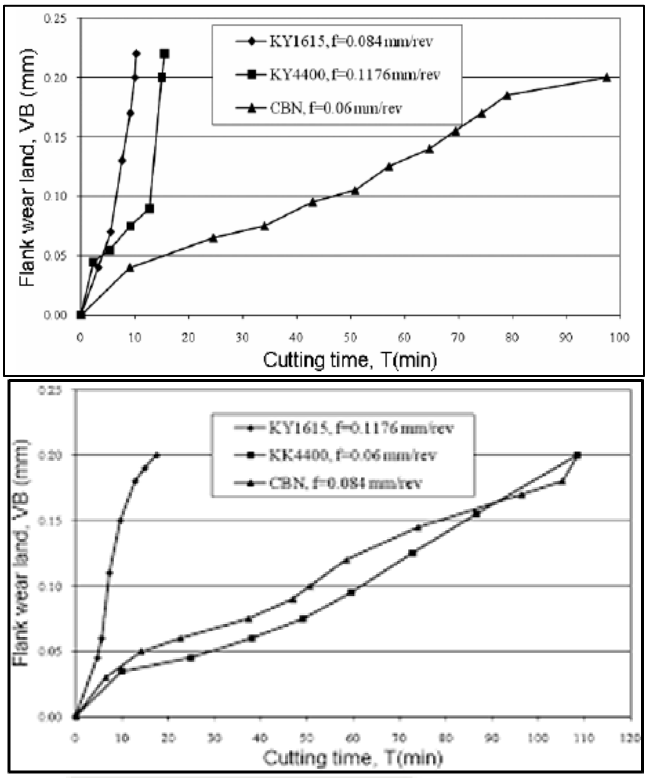

Fig. 1: Variation of flank wear land with cutting time when machining AISI 52100 hardened steels by different cutting tools, tested at a 100 m/min speed and feed

IV. CONCLUSIONS

The wear behavior of Al2O3 ceramic tool, Al2O3 ceramic-coated with TiN tool and CBN/TiC tool on machining of AISI 52100 hardened steels was investigated and surface roughness was compared under various cutting conditions. The cutting speed had the greatest effect on the optimal testing conditions. It is followed by the cutting tool's hardness. The feed rate was also effective on the tool life of the cutting tool.

It was shown that the tool life decreased with increasing cutting speeds in all cutting conditions, but the longer tool life was obtained for the CBN/TiC cutting tool. Moreover, it was observed that SEM image of worn surface of the CBN/TiC cutting tool exhibited a smooth flank wear. However, a crater wear and tool deformation were observed for the KY1615 and KY4400 cutting tool when machining the hardened steels. Furthermore, the CBN/TiC cutting tool produced the lowest surface finish, which is about 0.884 _m. However, the KY4400 cutting tool produced the worst surface finish.

Among the cutting parameters, the cutting speed was found to be more effective for the tool life and a neglible effect for the surface roughness, but the feed rate was dominant for the surface roughness.

REFERENCE

[1] Huang Y & Dawson T G, Wear, 258 (2005) 1455-1461.
[2] Benga G C & Abrao A M, J Mater Proc Technol, 143-144 (2003) 237-241.
[3] Lima J G, Avila R F, Abrao A M, Faustin M & Davim J P, J Mater Proc Technol, 169 (2005) 388-395.
[4] Kumar A S, Raja A D & Sornakumar T, Int J Refrac Metals & Hard Mater, 21 (2003) 109-117.
[5] Arbizu I P & Perez C J L, J Mater Proc Technol, 143-144 (2003) 390-396.
[6] Sahin Y & Motorcu A R, Mater & Des, 26 (2005) 321-326.
[7] Brandt G, Wear, 112 (1986) 39–46.