Tool Wear and Surface Roughness in Turning AISI 8620 using Coated Ceramic Tool

SThamizhmanii*, K. Kamarudin, E. A. Rahim, A. Saparudin, S. Hassan

Abstract **- The purpose of this research paper is to study the tool wear and surface roughness of AISI 8620 material using coated ceramic tool by turning process. Ceramic cutting tools have outstanding material hardness, resistance to high temperatures, wear resistance, chemical stability and hot hardness. Ceramic tool with Al2O3 + TiC (golden) coating was used to investigate the surface roughness and tool wear on AISI 8620 material without coolant. The tests were carried under various combinations of cutting speed, feed rate, and depth of cut and fixed time period. Surface finish is an important attribute in any machining operation. Surface roughness decreased when the cutting speed was increased and tool wear was not noticeable for a few tests. It increased rapidly at higher cutting speed, feed rate, higher depth of cut and increase in time. The flank wear, crater wear and nose wear were measured. During turning, built up edge formed and was due to diffusion of the work piece material.**

Key words: **Surface roughness, Coated ceramic tool, Image Pro-Express software, Wear by area.**

I. INTRODUCTION

Advances in ceramic processing technology have resulted in a new generation of high performance ceramic cutting tools exhibiting improved properties such as fracture strength, toughness, thermal shock resistance, hardness and wear resistance. Aluminum oxide is widely used as ceramic cutting tool and it is strengthened by the addition of particles like zirconium oxide, titanium carbide and titanium nitride to improve their properties [1]. In actual turning process, however, the quality of the work piece is greatly influenced by the cutting parameters, tool geometry, tool material, turning process, chip formation, work piece material, tool wear and vibration during cutting [2, 3-19]. A high quality product with longer tool life may be achieved by proper selection of machining parameters and by direct monitoring of the cutting process [4] and much work remains to be done before all the factors contributing to the surface finish and tool life can be controlled [5-7]. Tool wear and its propagation influence the value of surface roughness and cutting tool vibration [7].

II. EXPERIMENTAL SET UP AND CUTTING CONDITIONS

A. Experiments

The tests were carried in a Harrison M 300 conventional lathe having fixed spindle speed and feed rate. The cutting conditions are shown in the table 1. Many researchers have Conducted researches in conventional lathe [8]. In this experiment, measurement of tool wear was measured using Nikon measuring microscope provided with Image Pro-Express version 5.1software designed to run under Microsoft Windows 32 bit system which can capture the area of the wear and the wear caused by various parameters was measured using the image software and 90 to 95 % area was covered. The various equipments used for experiments are shown in the table 2. All the tests were conducted under dry cutting. The tests were conducted using time as the factor and 2, 3, 4, and 5 minute was fixed for turning.

All Authors are with the Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Batu Pahat, Johor, Malaysia.
*Corresponding Author
Email: thamizhmaniis@yahoo.com / siva@kuittho.edu.my

B. Work Piece Materials

The work piece selected for this research was commercially available AISI 8620 grade steel. It is case hardened material and the alloying elements are shown in the table 3. In this research, AISI 8620 soft material with hardness between 12 to 16 HRc was used. The work piece was cut to 300 mm length from a 1000 meter rod having 50 mm diameter. The work piece was centered on both sides to accommodate in lathe centers. The work piece was then skin turned to remove the black color. The size of the work piece was maintained between 48 to 49.5 mm.

Table 1. Various cutting parameters

Tests	Cutting speed (m/min)	Feed (mm/ rev)	Depth of Cut (mm)	Time (Min.)
1	57	0.03	0.50	2,3,4,5
2	57	0.04	0.50	2,3,4,5
3	57	0.05	0.50	2,3.4,5
4	83	0.03	1.00	2,3,4,5
5	83	0.04	1.00	2,3,4,5
6	83	0.05	1.00	2,3,4,5
7	123	0.03	1.50	2,3,4,5
8	123	0.04	1.50	2,3,4,5
9	123	0.05	1.50	2,3,4,5

Table 2. Lists of equipment.

Harrison M 300 lathe
Nikon- Measuring microscope with Image –Pro Express Version 5.1 –Window 32 bit system
Mahr Perthometer Concept V7.10 –Surface roughness tester
Scanning Electron Microscope JSM-6380 LV

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Table 3. Alloying elements in AISI 8620.

Carbon %	Mn. %	Cr. %	Ni. %	Mo. %	Si. %	S. %	P. %
0.18 / 0.23	0.70/0.90	0.40/ 0.80	0.40/0.70	0.15/0.25	0.20/0.35	0.04 max.	0.04 max.

C. Cutting Tool

Ceramic inserts with appropriate edge preparation with various coatings are used for applications especially in turning. One such insert was manufactured by Kyocera Corp. International and named as A66N. This is having combination of Al2O3 + TiC with TiN golden coating. Tool older PCLNR2020K12 was used for the experiment.

III. RESULTS AND DISCUSSION

A. Flank Wear

Flank wear in the ceramic cutting tools is mechanically activated wear usually by the abrasive action of the hard work piece material with the ceramic tools. The flank wear is characterized by the abrasive groove and ridges on the flank face [6]. The flank wear of cutting tool has a significant effect on the quality of the machined surface. Flank wear has a detrimental effect on surface finish, residual stress and micro structural changes, shape of tool, cutting conditions. The high temperature generated between the cutting face and work piece causes abrasive and or adhesive wear. These types of wear affect the tool materials properties as well as work piece surface. Konig et al [9] found that different work materials such as hardened alloy steel, case hardened

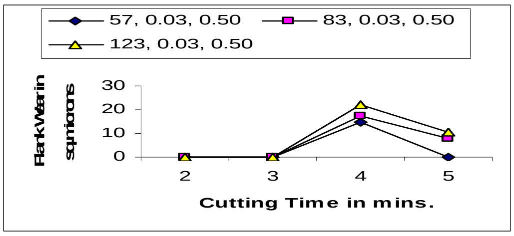

Figure1. Cutting time Vs Flank wear

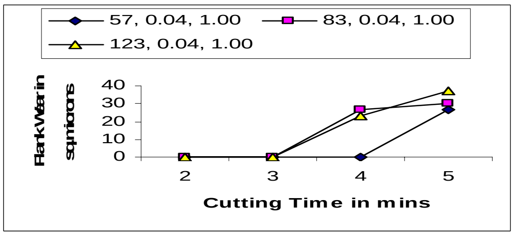

Figure 2.Cutting time Vs Flank wear

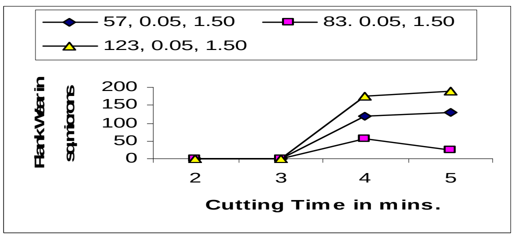

Figure 3.Cutting time Vs Flank wear

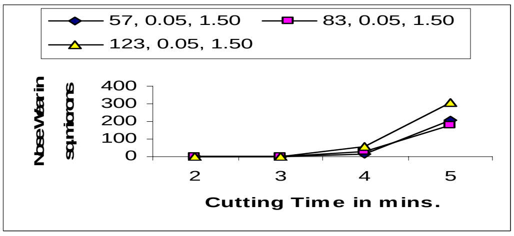

Figure 4.Cutting time Vs Crater wear

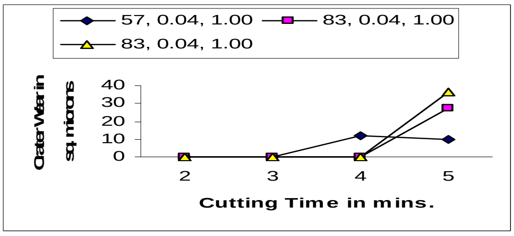

Figure 5. Cutting time Vs Crater wear

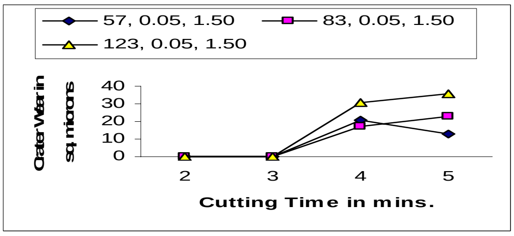

Figure 6. Cutting time Vs Crater Wear

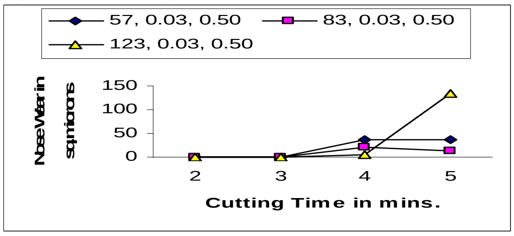

Figure 7. Cutting time Vs Nose wear

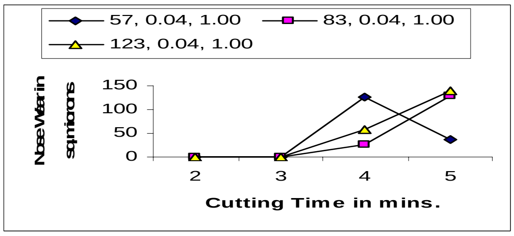

Figure 8. Cutting time Vs Nose Wear

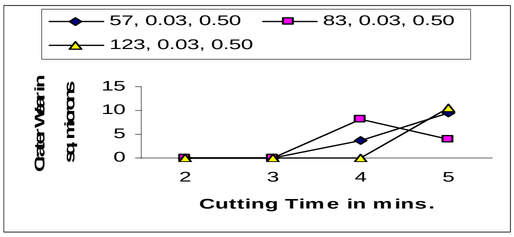

Figure 9. Cutting Time Vs Nose wear

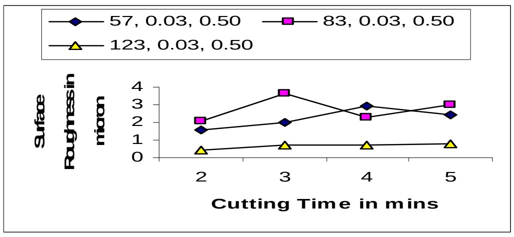

Figure 10. Cutting time Vs Surface Roughness

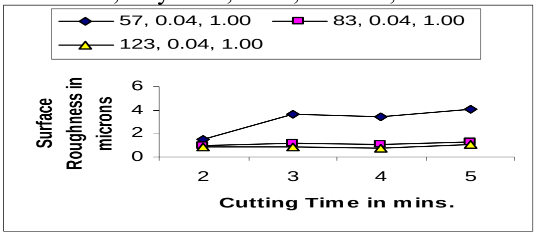

Figure 11. Cutting time Vs Surface Roughness

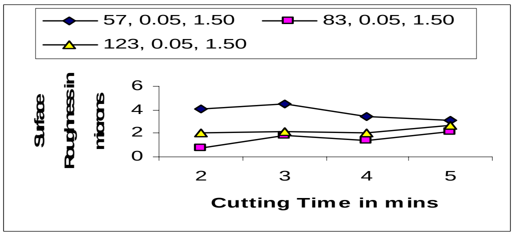

Figure12. Cutting time Vs Surface Roughness

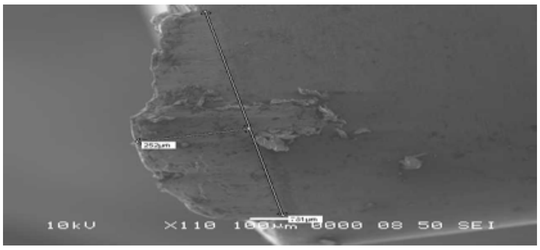

Figure 13. SEM image shows the formation of built up edge on flank wear at speed of 123 mm /min, feed 0.04 mm/ rev and doc of 1.00 mm.

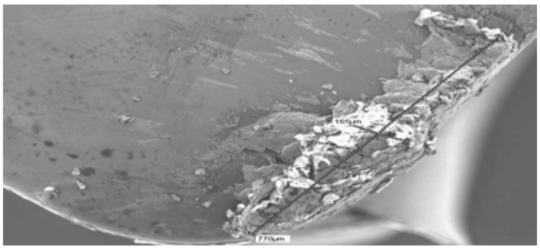

Figure 14. SEM image shows the formation of built up edge on rake side at cutting speed of 123 m/min, feed of 0.40 mm /rev, doc – 1.00 mm

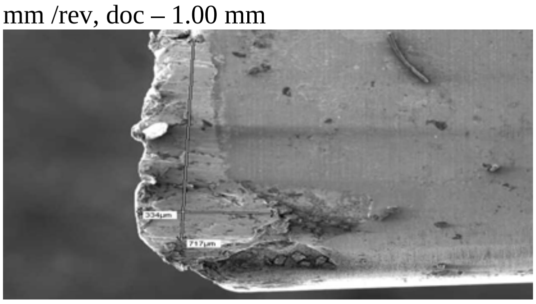

Figure 15. SEM image shows the formation of built up edge at cutting speed - 123 m /min, feed of 0.05 mm / rev, doc 1.50 mm.

steel, nitriding steels, high speed steel, with same hardness 62 HRC, when machined under the same cutting conditions, showed varying tool wear rate. Its wear mechanism is very complex. Adhesion of the tool and work piece increases at higher temperatures. Adhesion wear occurs when hard inclusions of work materials or escaped tool particles scratch the flank and work piece as they move across the contact area as well [10]. The penetration of cutting edge is better than hardened material; there are more chances for abrasion between cutting edge and work piece. It is from the figures 1, 2 and 3 that the flank wear increased against cutting time and cutting speed. The reasons for increase in flank wear were due to increase in temperature at the cutting edge due to more contact time between tool and work piece. The temperature may influence to lose its hardness and wear. When the cutting speed was lower, the flank wear was lower and as these parameters are increased, the flank wear also increased. However, it had not reached the value of 0.40 mm. The maximum flank wear was 37,885 μm² at cutting speed of 123 m / min, with feed rate of 0.05 and depth of cut 1.50 mm at 5 minute turning. This is due to more contact between cutting tool and work piece.

B. Crater Wear

The most important factors which contribute to crater wear are the tool – chip interface temperature and the chemical affinity between the tool and work piece materials. It is due to high contact stress and high interface temperature. Diffusion wear plays a major role in crater wear. Crater wear involves chemical reaction between the work piece chip material and the ceramic tool material, and the process is activated by high cutting speed. Brandt and Mikus [11] observed that the crater wear of alumina based ceramic tools was predominantly dependent upon superficial plastic deformation while machining steel. The factors influencing flank wear also influence crater wear. The crater wear is not going to affect the surface roughness but cutting edge may chip off when it is formed near the cutting edge. At higher cutting speed, feed and depth of cut, the crater formation is inevitable. The maximum wear area was found as 212 x10³ μm². The crater wear is shown in the figure 4, 5 and 6. The crater wear also increases due to increase in cutting speed and time. This is also due to increase in the temperature at the cutting edge as the turning speed increases. Crater wear is usually dominant when high cutting speeds and large feed rates are considered [12]. The crater wear was measured as 35,920 μm² at cutting speed of 123 m / min, with feed rate of 0.05 and depth of cut of 1.50 mm at 5 minute turning.

C. Nose Wear

The cutting nose experiences high temperature and machining stresses. This causes the tool material to undergo thermal softening and subsequent deformation. The occurrence of a smooth nose wear with deformed material in the wear boundary could be attributed to small scale discrete plastic deformation caused by the sliding action of the machined work surface on the tool nose. Tool nose radius, one of the geometry parameters, has not been systematically investigated, probably due to its intuitive effects on part surface finish: the larger the tool nose radius, the finer the surface finish [13]. The nose wear increased as the turning time and cutting speed are increased. It is known that during the wear process, a material would undergo the stages of yielding, plastic deformation, cracking and consequent material dislodging. Nose wear is known to affect the dimensional accuracy. The worn out cutting edge acted as larger nose radius and produced better surface roughness. The nose wear obtained by the tests are shown in the figure 7, 8 and 9. The nose wear was measured as 30,890 μm² at cutting speed of 123 m / min, with feed rate of 0.05 and depth of cut 1.50 for 5 minute turning.

D. Surface Roughness

Surface roughness is the primary concern for any part after machining. Selvam has studied the effect of the vibrations; chatter and cutting speed on surface finish [15]. Chandiramani and Cook in their investigation on the effect of varying cutting speeds on the surface finish found an intermediate region of deterioration on surface finish due to the formation of built up edge [16]. Karmakar [17], however, did not observe this in a study on ceramic tools.
The theoretical expression for the surface roughness Ra is given by:

$$Ra = f^2 / 18\sqrt{3r} \qquad (1)$$

where f is the feed rate and r is the cutting edge radius. This model is based on a perfect geometric model. It is known from the formula that feed rate is the main parameter that influences the surface roughness [18]. For each time of turning, roughness was measured followed by measuring the wear. The figures 10, 11 and 12 show the surface roughness against cutting time. The longer cutting time leads to tool wear. When the cutting speed was 123 m/min with feed rate of 0.03 and depth of cut 0.5, the surface roughness was lower in value but almost equal for the same parameters. Refer figure 10. The experiments show that when the cutting speed, feed rate and depth of cut are increased the surface roughness value decreased. By introducing an insert with chip breaker may solve the problem of long curled chips. When machining at lower cutting speed, feed and depth of cut, small and closely formed chips are produced.

E. Built- Up- Edge.

As the cutting speed increases, the friction between chip and tool will increase and when this becomes large enough to cause to a shear fracture in the vicinity of the tool face, a built up edge is formed. There is no formation of built up edge at low cutting speed since the temperature of the face of the chip is then not sufficient to cause the chip surface to behave in a ductile manner [19]. The built up edge theory states that a rough surface is obtained at lower cutting speed and a smooth surface at higher speed. This phenomenon is seen on the cutting tool's surface as a consequence of a low-speed machining process. Some researches have stated that this built up edge occurrence may be eliminated by increasing both cutting speed and feed rate [20]. From the experiments the built up edge formed at cutting speed of 123 m / min, with feed of 0.04 and depth of cut 1.00 mm and another at cutting speed of 123 m / min, with feed rate of 0.05 mm / rev and depth of cut of 1.50 mm. The formation of built up edge was due to high temperature and also due to diffusion of work piece material on two cutting tool. Similar built up edge formed at cutting speed of 123, feed rate of 0.05 and at depth of cut of 1.50 mm. These are shown in the figure 13, 14 and 15. The built up edge was formed at cutting speed of 123 m / min, with feed rate of 0.04 and depth of cut 1.00 mm has produced better surface roughness than other tests. This is shown in the figure 11. The formation of built up edge formed as another cutting edge with larger nose radius and produced a better surface at higher cutting speed.

IV. CONCLUSIONS

The surface roughness and wear mechanism of coated ceramic cutting tool on machining AISI 8620 was investigated and conclusions are given below.
1. It was found from the experiments that higher cutting speed, feed and depth of cut, produced better surface finish for longer cutting time.
2 The worn out tool has produced better surface roughness than new tool initially. The cutting edge of the worn tool acting like un-uniformly larger nose radius which produced better surface.
3. The flank wear increased when the cutting speed and feed rate and depth of cut was increased which may be due to abrasive action between the tool cutting edge and work piece, and temperature generated between cutting edge and work piece.
4. Built up edge was formed while machining work piece at cutting speed of 123 m /min at feed rate of 0.05 mm /rev for 4 min. time having 1.0 mm depth of cut. The size of the built up edge was 671 µm and 172 µm on the rake side. The built up edge has formed due to high temperature and diffusion of the work piece material and this has taken place non-uniformly.
5. The relation between maximum flank wear values of 0.40 mm with respect to area of the flank wear is another area for further research which has not been established in this research work.

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