Wear Analysis of Coated Carbide tools in Hard Turning

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Abstract
The use of high strength and heat resistant materials is increasing day by day in aerospace, automotive, steam turbines and nuclear applications. This paper presents an experimental investigation of finish hard turning under dry conditions using coated carbide tools. In this study the effect of workpiece hardness, cutting speed and feed on tool wear during turning of hardened AISI 1045 steel has been reported. Workpiece hardness and cutting was observed to be a highly significant factor to affect the tool performance. Finally different wear mechanisms under different conditions were reported. It has been observed that catastrophic tool wear occurred particularly at highest cutting speed used. Further the tool wore rapidly at high degree of workpiece hardness

Keywords
Hardened Steel, Tool Life, Wear Mechanisms, Coated Carbide Tools

I. Introduction

These days materials having higher strength with high melting temperatures are preferably used for variety of applications like aero engines/ steam turbines/ Bearing industry and other automotive related applications [1-2]. These materials include super-alloys, refractory metals and hardened steels etc [3-4].Thus during machining of these materials friction and heat generation at the cutting zone are the frequent problems, high cutting forces and poor surface characteristics are common [5]. The preferable tool material used for machining of these workmaterials is CBN tool. CBN has a hardness and wear resistance second only to diamond and it has a good thermal resistance, a high coefficient of thermal conductivity, good chemical stability and high hot hardness [4]. But the cost associated with manufacturing of CBN tool materials is very high, which has focused the attention of researcher to look for economical tool material alternate. Within a particular range of workpiece hardness, coated carbide has been explored in hard turning, which are quite economical in comparison to the CBN. Author investigated the performance of coated carbide, CBN-H and mixed ceramic tool in hard turning of W320 steel with five values of speed (60,90, 120, 150, 200 m/min) with three values of feed (0.03,0.06, 0.1 mm/rev) at constant depth of cut of 0.1mm. The results indicated that the performance of coated carbide tool was comparable with that of CBN up to speed of 120m/min. At the highest cutting speed, performance of coated carbide tools deteriorated drastically, on the other hand CBN tool gave optimum performance [6]. Lot of work has been reported in the past in order to improve the effectiveness of machining of hard to machine materials but particularly with CBN and ceramic tools. Further the work related to testing the performance of carbide tools in hard turning is scant. Thus in this study the aspects related to tool performance like, the tool life and tool wear mechanisms during turning of hardened AISI 1045 steel at three levels of hardness: 37, 45 and 52 HRC, respectively, using CVD applied multi-layer TiCN/Al_2O_3/TiN. This work also study the affect of variation of cutting speed , feed and degree of workpiece hardness on tool life Different tool wear mechanisms considering the effect of work material hardness, cutting speed and feed are discussed with the images taken by digital and scanning electron microscope.

II. Experimental Procedures

The workpiece material used in this study was AISI 1045 steel with three levels of hardness as 38, 45, 52 HRc. Hardness was maintained uniform throughout the cross section with a maximum variation of±1 HRC by a hardening and tempering process. Round bars of 55mm diameter and 300mm length were selected, so that L=D ratio should not exceed 10 as per ISO 3685 standards [7]. Longitudinal turning of the workpieces, on a CNC lathe using fresh cutting edge of different inserts in each combination of speed, feed, and workpiece hardness, was performed under dry conditions. As recommended by the tool manufacturer, a chemical vapor deposition (CVD) coated carbide grade with innermost coating layer of TiCN (Titanium carbonitride), intermediate layer of Al_2O_3 (Alumina oxide), and outermost layer of TiN (Titanium Nitride) having wiper geometry with designation CNMG120408-WF (GC4205) was used. This grade has adequate wear resistance [8]. All the inserts having 0.8mm nose radius were selected. The cutting inserts were clamped to a right-hand tool holder with ISO designation having -6º rake angle, -6º clearance angle, and 95º approach angle.

In turning cutting speed is the most dominant factor influencing tool life, followed by feed and depth of cut [5,9].In this study, on the basis of literature and recommendations of the tool manufacturers the cutting speeds selected were 70m/min, 130m/min and 190m/min. The feeds were .08mm/rev,.16mm/rev and .24mm/rev and with constant depth of cut as 0.2mm [5,8]. As shown in Fig .1 the tool flank wear in all the cases were not uniform on the cutting edge. Thus instead of VBavg, VBmax was quantified in this study. A flank wear criterion of VBmax=0.2mm was chosen to evaluate the tool life. The selection of low VBmax, instead of VBmax=0.6mm stipulated in ISO 3685 [7], is consistent with finish hard turning applications.

Fig. 1: Coated Carbide Tool After 6min of Machining at v=70m/min, f=0.08mm/rev and W.H=37HRc

Each single pass consisted of axial cutting length 280mm and after every 140mm of workpiece length, the amount of maximum flank wear (VBmax) was recorded. The experiment was terminated when the following condition was arrived: VBmax ≥200 mm,.

Maximum tool flank wear was measured using optical microscope having image analysis software. The worn tools were also evaluated using Scanning Electron Microscope (SEM) at regular intervals in order to understand the wear modes and mechanisms that affect the tool performance.

III. Results And Discussions

In this section, experimental findings are presented. Plots showing the, tool at three levels of workpiece hardness, cutting speed and feed are presented. Wear mechanisms of tools under different cutting regimes are explained with the help of SEM and a digital microscope images.

A. Analysis of Tool Wear

According to standard ISO 3685, the time at which the tool ceases to produce a workpiece of desired size and surface quality usually determines the end of useful tool life [7].

Maximum tool flank wear was measured using optical microscope having image analysis software. The worn tools were evaluated using scanning electron microscope/ microscope at regular interval in order to understand the wear modes and mechanisms that affect the tool performance. Each set of experiments replicated twice and average value of VBmax was evaluated. Progression of maximum flank wear (VBmax) with machining time in minutes at different cutting speeds and feed rates with different levels of workpiece hardness is presented in Figs. 2(a,b,c), 3(a,b,c) and 4(a,b). From the graphs it is indicated that in all cases tool life is significantly affected by degree of workpiece hardness followed by cutting speed and then by feed rate [5-6]. At low and medium cutting speed, the progression of flank wear in first few minutes of machining was gradual. In all the cases tool life of carbide inserts decreases as the cutting speed increases for all feed rates and workpiece hardness because with increase in cutting speed for a given time the cutting temperature increases, which leads to rapid tool [4, 7]. At the highest speed used the tool life was low in comparison to other two speed selected. The maximum tool life was achieved at lowest degree of workpiece hardness, because the material strength to be machined is low at low degree of hardness, which resulted in longer tool life [10]

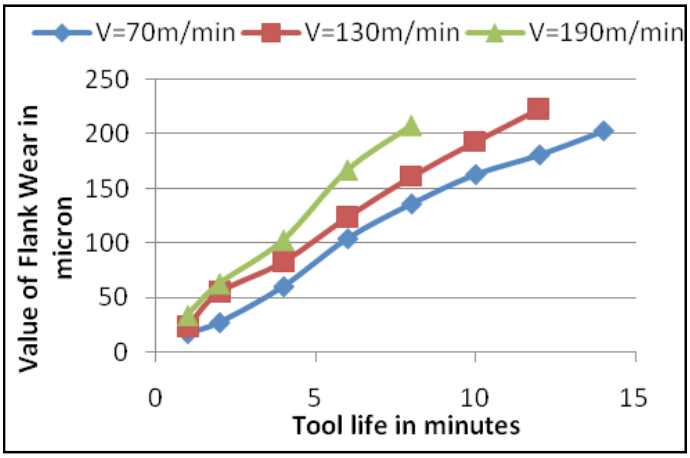

Fig. 2(a): Progression of Tool Life at f=.08mm/rev, WH=45HRc on Different Cutting Speeds

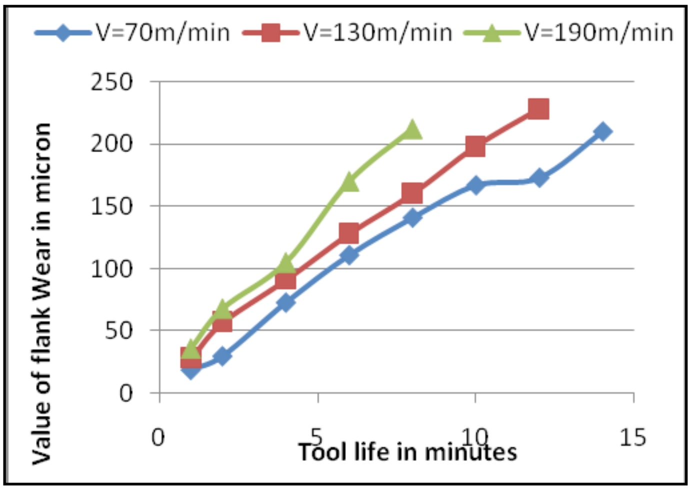

Fig. 2(b): Progression of Tool Life at f=.16mm/rev, WH=45HRc on Different Cutting Speeds

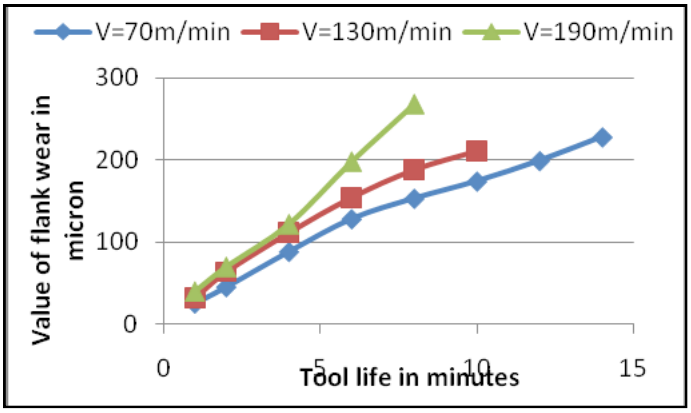

Fig. 2(c): Progression of Tool Life at f=.24mm/rev, WH=45HRc on Different Cutting Speeds

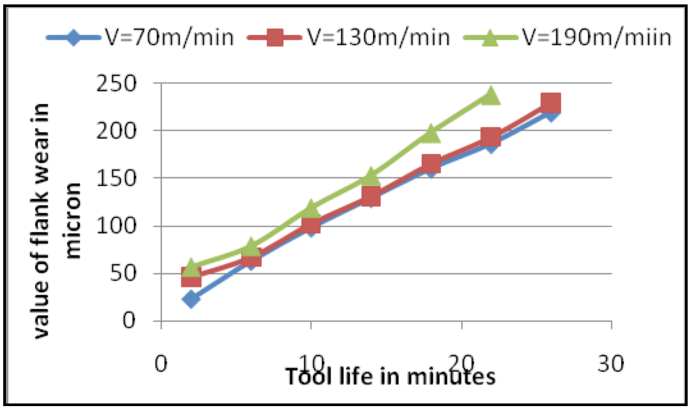

Fig. 3(a): Progression of Tool Life at f=.08mm/rev, WH=38HRc on Different Cutting Speeds

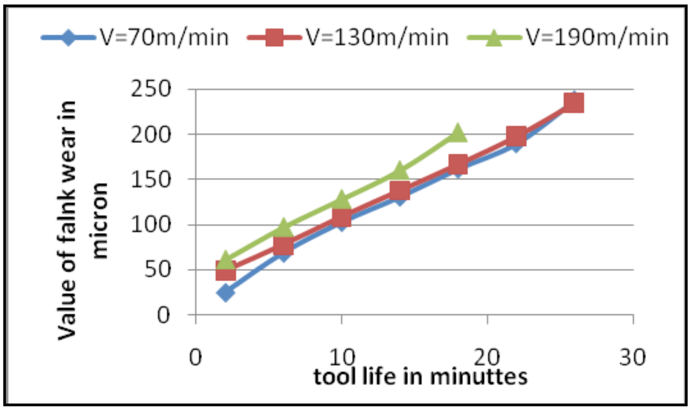

Fig. 3(b): Progression of Tool Life at f=.16mm/rev, WH=38HRc on Different Cutting Speeds

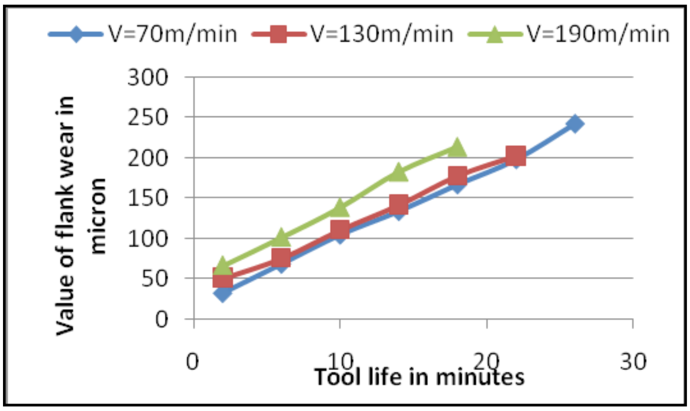

Fig.3(c) Progression of Tool Life at f=.24mm/rev, WH=38HRc on Different Cutting Speeds

At highest degree of workpiece hardness, the tool life achieved under all circumstnaces was very short.Because at highest speed the mechanical and thermal loading led to dteroriation the tool life of cutting tool. As indicated in the fig. 4(a,b) the tool life achieved under highest cutting speed with both the feed is less than two minutes. Also at other two speed used the tool life is nearly two minutes.

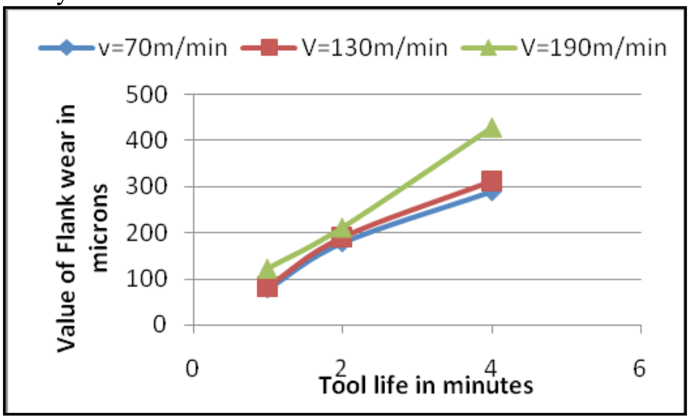

Fig. 4(a): Progression of Tool Life at f=.08mm/rev, WH=52HRc on Different Cutting Speeds

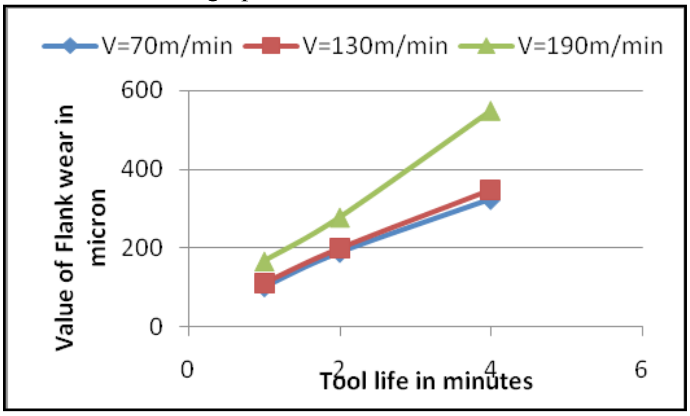

Fig. 4(b): Progression of Tool Life at f=.24mm/rev, WH=52HRc on Different Cutting Speeds

Under all cuting speed and hardness range used the ther is marginal differnce between the tool life achieved at f=.08mm/rev and f=.16mm/rev, while the significant differnce in tool life was observed at highest feed. The tool life is low at highest feed selected. So the study reveals that the too life of coated carbide tools is sginificantly affected by work piecec hardness, followed by cutting speed and then feed.

B. Tool Wear Mechanism

As shown in fig. 5, both flank wear and crater wear were observed for both the inserts tested under all cutting conditions. The tool wear zone occurred mostly near the tool nose radius, as depth of cut selected was quite low in comparison to the nose radius of the tool [4,6]. Both crater wear and flank wear near the nose of the tool occurred during the whole machining study with both the inserts on all types of surfaces.

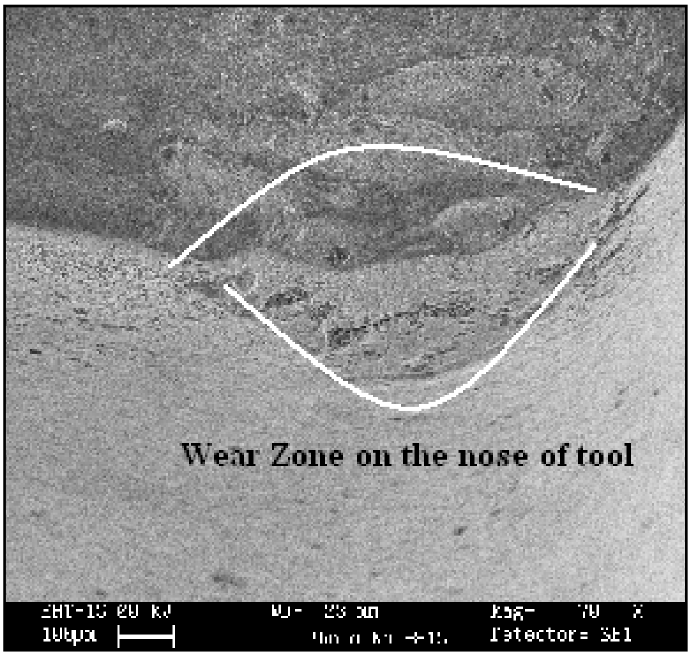

Fig. 5: The Cuting Insert After 3minutes of Machining at v=70m/min,f=.08mm/rev and W.H.=38HRc.

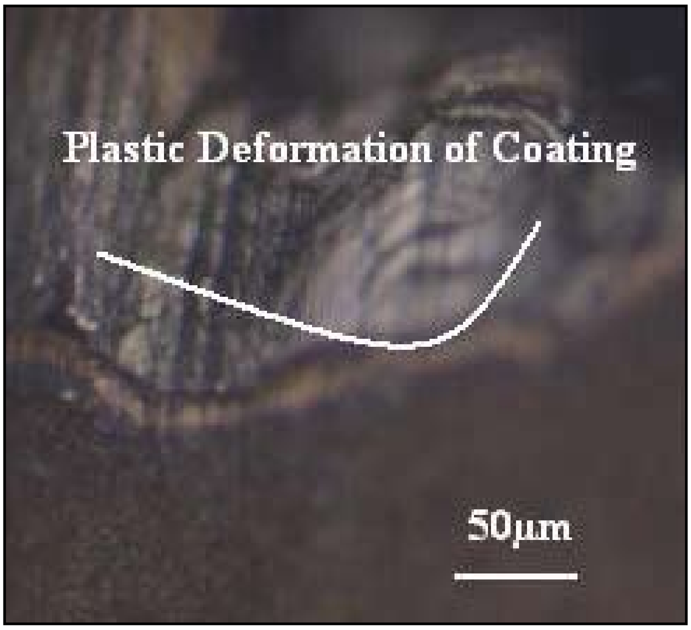

Fig. 6: The Cuting Insert After 2minutes of Machining at v=130m/min, f=.24mm/rev and W.H.=45HRc.

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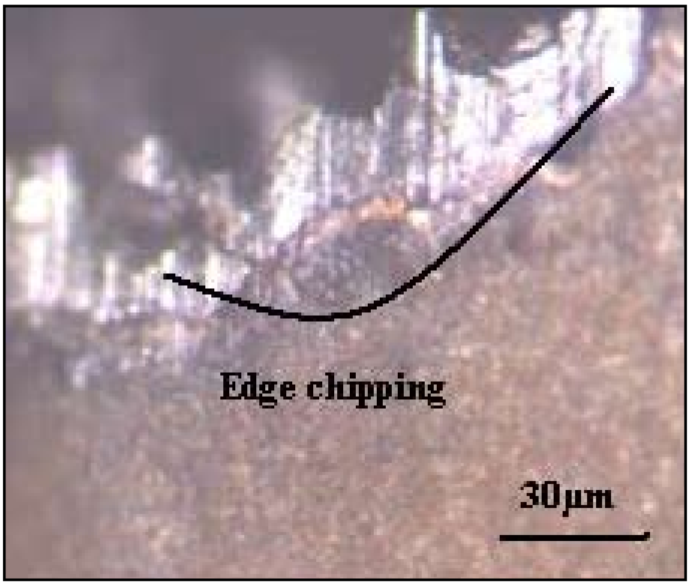

Fig. 7: Edge Chipping of Insert at v=190m/min, f=.24mm/rev and W.H=52HRc

As shown in figs. 6 and 7, during the turning of the with carbide inserts, particularly at higher cutting speed (190m/ min), significant plastic defromation, chipping and breakage of cutting edge was observed. This kind of rapid tool wear with chipping/fracture was due to the high temperature generated and high mechanical loading on the tool edge during cutting. Failure of the tool edge started with propagation of cracks at higher speed [6,10].

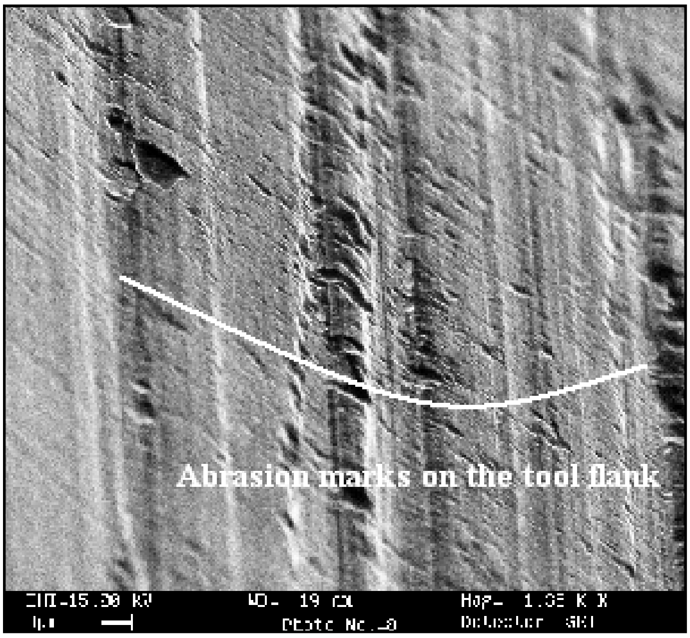

Fig. 8: The Cuting Insert After 2minutes of Machining at v=90m/ min,f=.16mm/rev and W.H.=45HRc

During turning at 90m/ min cutting speed, abrasive marks were observed on the flank face as shown in Fig. 8, which occurred due to rubbing of hard carbides in the workpiece material on the tool edge [4, 6].

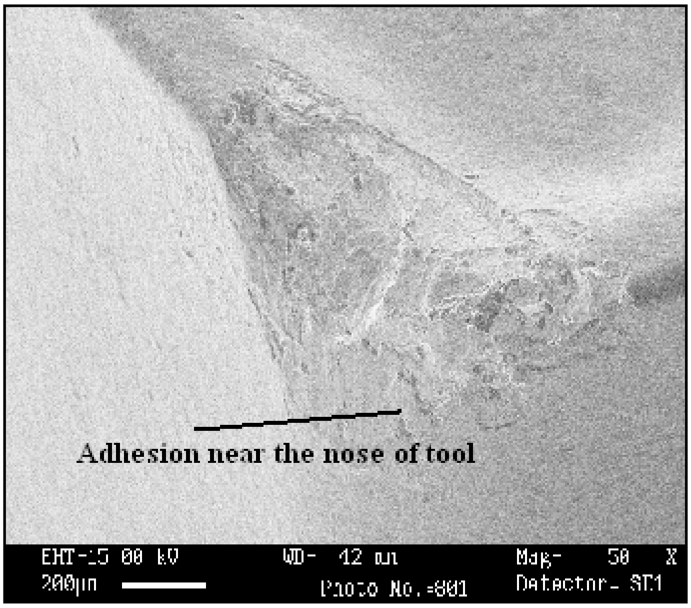

Fig. 9: The Cuting Insert After 3minutes of machining at v=130m/ min,f=.16mm/rev and W.H.=45HRc

As shown in Fig. 9, adhesion followed by plastic deformation was observed at 130 m/min cutting speeds during turning of the continuous surface. Due to increase in the cutting speed, the temperature at the work tool interface increased, which promoted adhesion wear [11-12]

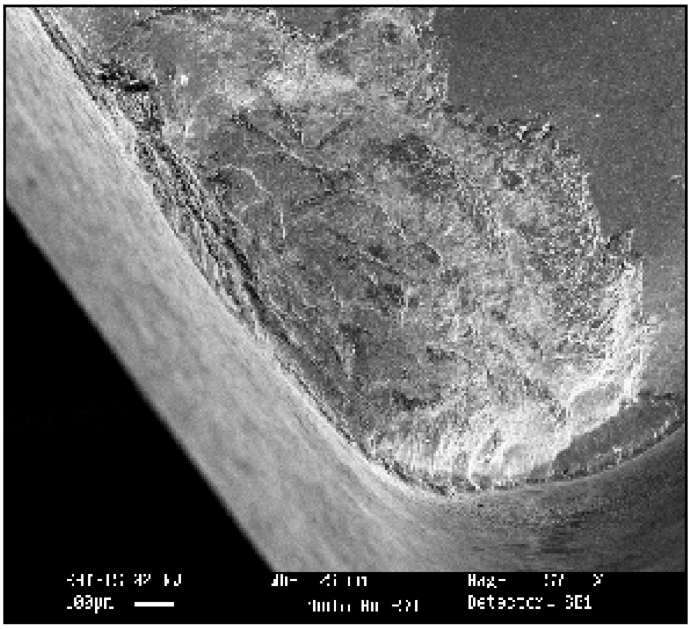

Fig. 10: The Cuting Insert After 1minutes of machining at v=190m/ min, f=.24mm/rev and W.H.=52HRc

Significant crater wear was also obserevd in particular at highest cutting speed, thi sis mainly due to removal of wear resitant coating from the surface [10]

The main wear mechanism involved with carbide inserts was abrasion and adhesion followed by plastic deformation at low to medium speed. On the other hand, rapid tool wear with chipping/ breakage of the tool edge was observed at higher cutting speeds, which led to the end of tool life.

IV. Conclusion

The life of the carbide tool was sensitive to both cutting speed and degree of workpiece hardness. At highest degree of workpiece

hardness, the tool life achieved under all circumstnaces was very short. However, coated carbide can become economical alternative to costly CBN at low and medium range of cutting speed, which was in this study as 70m/min and 130m/min and particular range of workpiece hardness that is in this case below 50HRc.
With the carbide tool, abrasion and adhesion followed by plastic deformation were the main types of wear at low and medium cutting speeds, while chipping and breakage of tool edges were observed at higher cutting speeds.

Refrences

[1] K.A. Venugopal, S. Paul, A.B. Chattopadhyay,"Growth of tool wear in turning of Ti-6Al-4V alloy under cryogenic cooling". Wear, Vol. 262, 2007, pp. 1071–1078.
[2] S. Sun, M. Brandt, M.S. Dargusch,"Machining Ti–6Al–4V alloy with cryogenic compressed air cooling". International Journal of Machine Tools and Manufacture, Vol. 50, 2010, pp. 933-942.
[3] E. Ezugwu, J. Bonney, Y. Yamane,"An overview of the machinability of aeroengine alloys", Journal of Materials Processing Technology, Vol. 134, 2003, pp. 233-253.
[4] Manu Dogra, V. S. Sharma, A. Sachdeva, N. M. Suri, J.S. Dureja,"Tool Wear, Chip Formation and Workpiece Surface Issues in CBN Hard Turning: A Review", International Journal of Precision Engineering and Manufacturing- Springer, Vol. 11, No. 2, April 2010, pp. 341-358.
[5] Suresh R, Basavarajappa S, Gaitonde VN, Samuel GL. Machinability investigations on hardened AISI 4340 steel using coated carbide insert. Int J Refract Met Hard Mater 2012, 33, pp. 75–86.
[6] Sales, W.F. Costa, L.A. Santos, S.C. Diniz, A.E. Bonney, J. Ezugwu, E.O.,"Performance of coated, cemented carbide, mixed-ceramic and PCBN-H tools when turning W320 steel", International Journal of Advanced Manufacturing Technology, 41(7-8), pp. 660-669, 2009.
[7] International Organization for Standardization. Tool-Life Testing with Single Point Turning Tools. ISO 3685–1993 (E), 2nd Edition; ISO: Geneve, Switzerland, 1993.
[8] Jiang, W. More, A.S. Brown, W.D. Malshe, A.P.,"A cBN-TiN composite coating for carbide inserts: Coating characterization and its applications for finish hard turning", Surface Coatings Technology, 201, pp. 2443–2449, 2006.
[9] Ko, T.J.; Kim, H.S. Surface integrity and machineability in intermittent hard turning. International Journal of Advanced Manufacturing Technology 2001, 18, pp. 168–175.
[10] Satish Chinchanikar, S.K. Choudhury,"Investigations on machinability aspects of hardened AISI 4340 steel at different levels of hardness using coated carbide tools, Int. Journal of Refractory Metals and Hard Materials 38 (2013), pp. 124–133.
[11] More AS, Wenping J, Brown WD, Malshe AP (2006) Tool wear and machining performance of cBN–TiN coated carbide inserts and PCBN compact inserts in turning AISI 4340 hardened steel. J Mater Process Technol 180, pp. 253–262
[12] Noordin, M. Y., Kurniawan, D., Sharif, S.,"Hard turning of stainless steel using wiper coated carbide tool", Int. J. Precision Technol., 2007, 1(1), pp. 75–84.

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