Effect of Cryogenic treatment on Tool Wear, Chip Thickness of Uncoated Carbide Insert during Machining with AISI304 Stainless Steel

Nagraj Patil, Gopalakrishna K, Sangmesh B,

Abstract*: *The cutting tool in the manufacturing industry is a key factor. The fulfilment of machining operation mainly depends on the tool material to improve the cutting life of the tool during machining with austenite stainless steel, however the austenite stainless steel difficult to machine and less amount of heat dissipation during machining in order to overcome. The aim of the investigation is to apply; the cryogenic treatment (CT) to the tungsten carbide insert, besides no study has been claimed on the chip thickness (tc), tool wear of machining with AISI 304. The machining test was conducted by three different speed and unchanged feed rate and depth of cut. The maximum flank wear was measured by using digital microscope also measured the chip thickness for both insert. The experimental results found that to reach the maximum flank wear for CT insert in all three speed was less in comparison with untreated insert (UT), chip thickness was also less in case of CT insert, built up edge were clearly observed in the UT insert, over all CT insert performed more desirable in compared with UT. The improvement in the microstructure properties of the CT insert owing to development of Eta (η) phase carbide and homogenous distribution in the tungsten carbide material, SEM and XRD tests are confirmed these results.

Key words*: *Flank wear, CT, Chip thickness

I. INTRODUCTION

Tool life is most important for machining economics. If a work material creates more rapid tool wear, the life of the tool will reduces. Machining cost will involve increased cost of the tools and greater production time lost during tool changes. The machining operation results in higher heat generation leads to reduction in tool life, surface properties of the machined parts and growth of tool wear [1]. By keeping all these difficulties the machining industries are continually making an effort for finding new material and new cooling technique that gives the better tool life. In recent days, there has been an increase in CT application for different types of cutting tool the CT technique enhances the tool performances, such as reduction in cutting temperature, improved wear resistance and surface quality. Previous researchers have worked on CT technique to improve its properties of carbide insert in this regard, K H W Seah et al [3] investigated on six different types of cutting insert, found that CT and cold-treated insert showed elevated wear resistance in contrast with UT. Similarly, Hejia Zhang et al [4] analyzed the consequence of deep CT on different percentage of cobalt (Co) in tungsten carbide insert; the cryogenic effect was more on the low cobalt carbide insert than the high percentage of cobalt. In another study, Simranpreet Singh Gill et al [5] reported that the CT enhances the life of the coated tungsten carbide insert in comparison with UT, and they have recommended that the TiAlN coated insert is not suitable for deep CT. A.Y.L. Yong et al [5] reported that improvement of tool lives of cryogenically treated tool in comparison with untreated tool during intermittent machining. Likewise, Nursel Altan Özbek et al [6] investigated the CT on carbide insert at different holding temperature. The experimental results were observed that for a holding time of 24hours the wear resistance was best in comparison with other holding times. This improvement was verified through hardness test and XRD analysis. Similarly, Hui-Bo He et al [7] conducted a study on different machining parameters that influences on the cutting temperature during machining with AISI 304. The experimental results revealed that cutting temperature increase with increase with speed also investigated the optimal parameters for cutting temperature. In another study, N.R. Dhar et al [8] claimed the cryogenic cooling method showed significant improvement in the tool life in comparison with other conventional. It was reported that the precooled cryogenic method enhance the tool life in comparison with other method. However more detailed research attempt on the fundamental of the cryogenic machining of the carbide insert on stainless steel are still required. Besides, due to not having enough considerable experimentation, the precise response of the AISI 304 steel in terms of growth of flank wear, chip thickness, is not clearly available in the previous literature survey. Accordingly, the aim of this investigation is to assess the performance of CT insert.

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Nagraj patil, Department of Mechanical Engineering, School of Engineering and Technology, Jain Deemed-to-be University Bangalore - 562112,Karnataka,India

Research Scholar, Visvesvaraya Technology University, Belagavi - 590018, Karnataka, India

Gopalakrishna K, Centre for Incubation Innovation Research and Consultancy, Jyothy Institute of Technology, Bangalore – 560082, Karnataka, India

Sangmesh B, Department of Mechanical Engineering, BMS institute of Technology and Management, Avalahalli, Yelahanka, Bangalore-560064, Karnataka, India

II. INVESTIGATIONAL METHOD

Commercial available AISI 304 stainless rod having a dimension of 40mm diameter and 300mm length was used as workpiece material for turning operation performed in the CNC machine. The length to diameter proportion was considered for the experiment to meet the ISO 3685 standard. Seco CNMG 120408 Grade MF3 029 uncoated carbide insert and DCLNR 2525 M12 tool holder were considered for the machining tests. The uncoated carbide insert were cryogenically treated at a temperature -176°C for 24hr. after the CT the inserts temperate at a 200°C for 2hr to minimize internal stresses produced during CT Figure 1 shows the CT process. In order to evaluate the performance of cryogenically treated in comparison with UT, in terms of progress of tool wear, chip thickness.

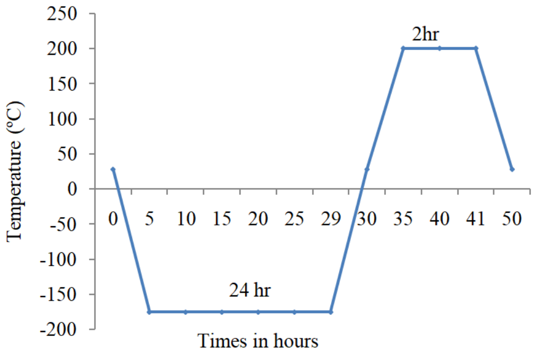

Figure 1. CT process

The entire machining test was conducted on CNC lathe, at different speed of (100.52m/min, 125.66/min, and 150.79/min), at a feed rate of 0.14mm/rev and depth of cut 0.5mm were kept constant. The machining test was carried out to measure the flank and crater wear of CT and UT insert, machining test was interrupted at every 4min interval of time, to study the development in the flank and crater wear. However, flank wear was obtained at higher cutting speed. The greatest amount of flank was evaluated using digital microscope (Dinocapture 2.0 Model: AM3113T, Magnification Range: 20X-250X). The tool life was measured according to the ISO 3685-1993 standard [9]. The EDX test was performed to identify the weight percentage of different elements adhered on the tool during machining. The chip thickness of the CT and UT was measured by using digital microscope. Figure 2 shows the experimental set for machining test.

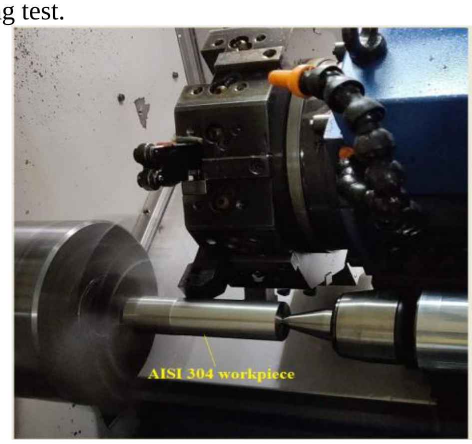

Figure 2 Experimental set for machining test

III. RESULT AND DISCUSSION

3.1 Material Characterization with the use of SEM and EDX

Figure 3a and 3b shows the microstructure of CT and UT. It was clearly seen from the SEM images, generally four different phases were observed alpha (α), beta (β), and gamma (η) phases were observed alpha phase contains tungsten carbide, beta phase contains cobalt binder, and gamma phase contains multiple carbides. From the SEM images it's clearly depicts the presence of dark gray which indicates the presence of Eta (η) phase carbide and precipitation of cobalt binder, the presence of Eta (η) phase carbide provides a greater wear resistance compared with UT. Similarly the presence of Eta (η) phase carbide was also observed in the previous researchers [13].

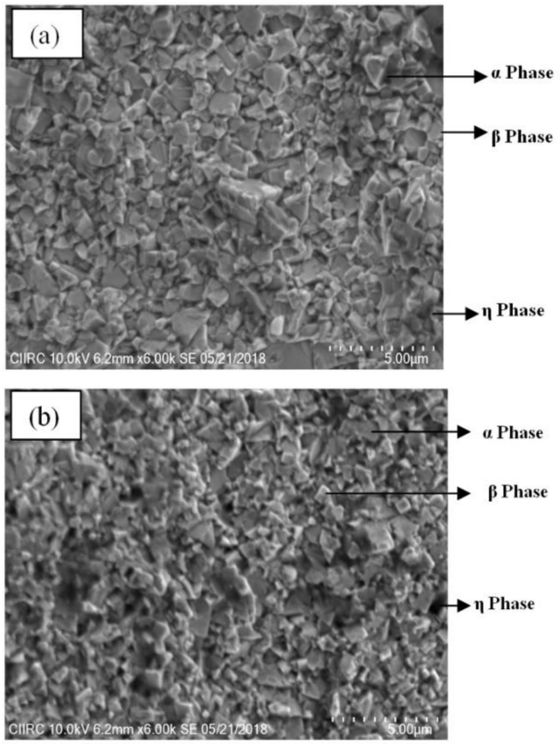

Figure 3. SEM images of carbide insert before and after deep CT (a) CT (b) UT

Figure 4a and 4b showed the EDX analysis for both CT and UT. The EDX test was conducted before and after CT, it was confirmed from the EDX test the CT insert showed in the concentration of cobalt (Co) and carbide (C) particles and decrease in the tungsten (W) in comparison with UT insert. The reduction in the tungsten carbide components (alpha phase) which is more stable form and in turn increase wear resistance. The weight % of the CT insert is excessive than the UT it was clearly indicated in the Figures. The increase in the percentage of C and Co leads to development of Eta (η) phase carbide which is hard in nature, which in turn growth in the wear resistance of the insert. Previous researcher also claimed that the precipitation of Eta (η) phase carbide was observed in the CT insert [5].

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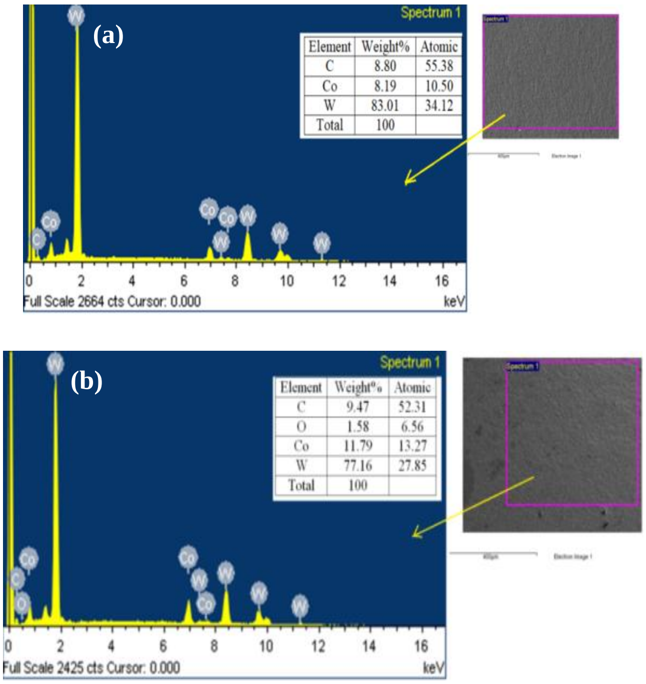
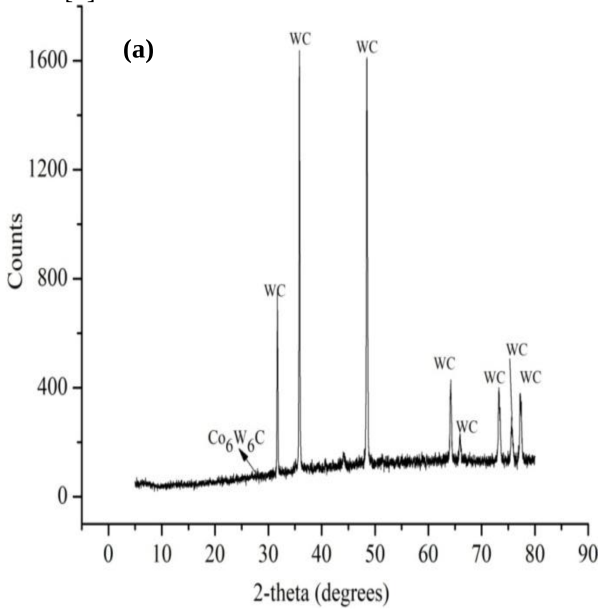


Figure 4b. EDX analysis (a) UT (b) CT inserts

3.2 XRD Analysis

The Figure 5a and 5b showed the X-ray diffraction (XRD) spectra of both CT and UT, XRD study was conducted to inspect the structural changes in the both CT and UT. After CT the transformation of phase takes place from austenite to martensite which leads to the generation of the Eta (η) phase carbide. Nearly at 28° the peak were observed for the CT insert. Some other researcher also confirmed that the CT, increase the cobalt binder and Condensation of Eta (η) phase carbide [6].



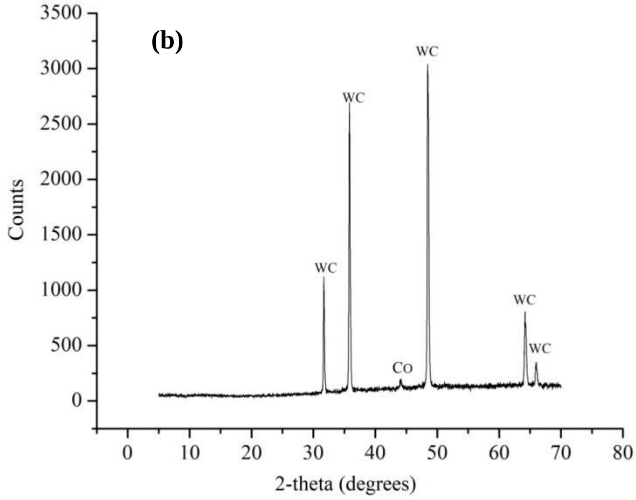


Figure 5 XRD profile (a) CT (b) UT inserts

3.3 Cryogenic treatment effect on tool wear

3.3.1 Flank wear

The development of wear of CT and UT insert over machining time during machining with all speed shown in Figure 6 and 7, respectively. From figures, it shows clearly the development of flank Wear were divided into three regions, initial region where the sharpness of the cutting edge is quickly broken down and a limited size of wear is established, further increase in the cutting time the wear rate becomes uniform, finally the rapid growth in the wear observed at larger speed [10]. The wear is mainly caused due to adhesion, adhesion wear caused due machined surface and tool flank area. In this investigation the progress of maximum flank wear ($V_B$max) of both CT insert and UT at feed rate of 0.14mm/rev and a speed of 100.52, 125.66 and 150.79m/min shown in Figure 6 and 7 respectively

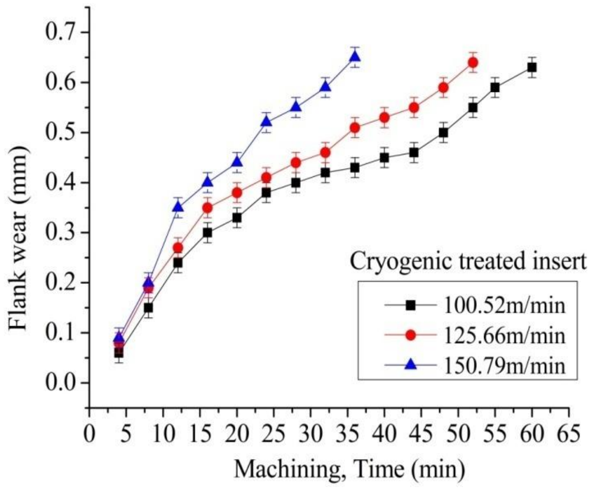


Figure 6: **Flank wear (VBmax) vs machining time of the CTinsert**

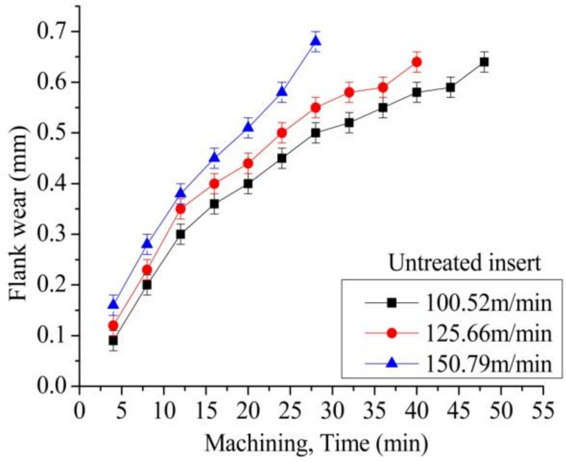


Figure 7: **Flank wear (VBmax) vs machining time of the UT**

.The machining were carried out up to the tool reaches its tool life criteria (V_{Bmax}=0.6mm) by considering constant feed and depth of cut. Initially the flank wears growth very rapidly at all speed. However, at all speed the CT insert performed better in comparison with UT. The tool life of the cryogenically treated and UT were shown in the Table 1 the treated insert showed longer tool life in comparison with UT insert under dry machining conditions. The growth of the flank wear were measure by using digital microscope at every 4 minute of equal internal of time, the UT reached maximum flank wear very early in comparison with UT. The CT insert improved its mechanical properties due to transformation austenite phase to martensite phase which leads increase its wear resistance properties it was also claimed by the other researcher [11].

Table 1 Tool life Comparison between two inserts (V_{Bmax}=0.6mm)

Cutting speed (m/min)	Cutting insert	Machining Time (Min)
100.52	CT	48
	UT	39
125.66	CT	30
	UT	25
150.79	CT	24
	UT	22

Under some conditions, usually at relative lower speed, during machining the friction was generated, this friction is so significant that the chip fragments adhere on the tool face. The presence of this chip fragments material further increases the friction and this friction leads to building up of layer of chip material. The consequence pile of material is introduced as built up edge. In this study machining test were conducted to recognize the adhesion wear for both CT and UT with speed of 100.52m/min, feed rate of 0.14m/min. Figure 8(a) shows the EDX spectra of CT insert, the foreign particle are 9.48%Fe, and 3.70%Cr were adhered on the tool. Similarly the Figure 9(b) shows the EDX test on tool surface area 16.80Fe%, 4.57Cr% was observed. However, it was noted that the CT insert showed less % of workpiece components on its tool rake surface. This was achieved attributable to boost its mechanical properties and enhanced thermal conductivity of the insert the similar result was also claimed by Bhatt et al [12].

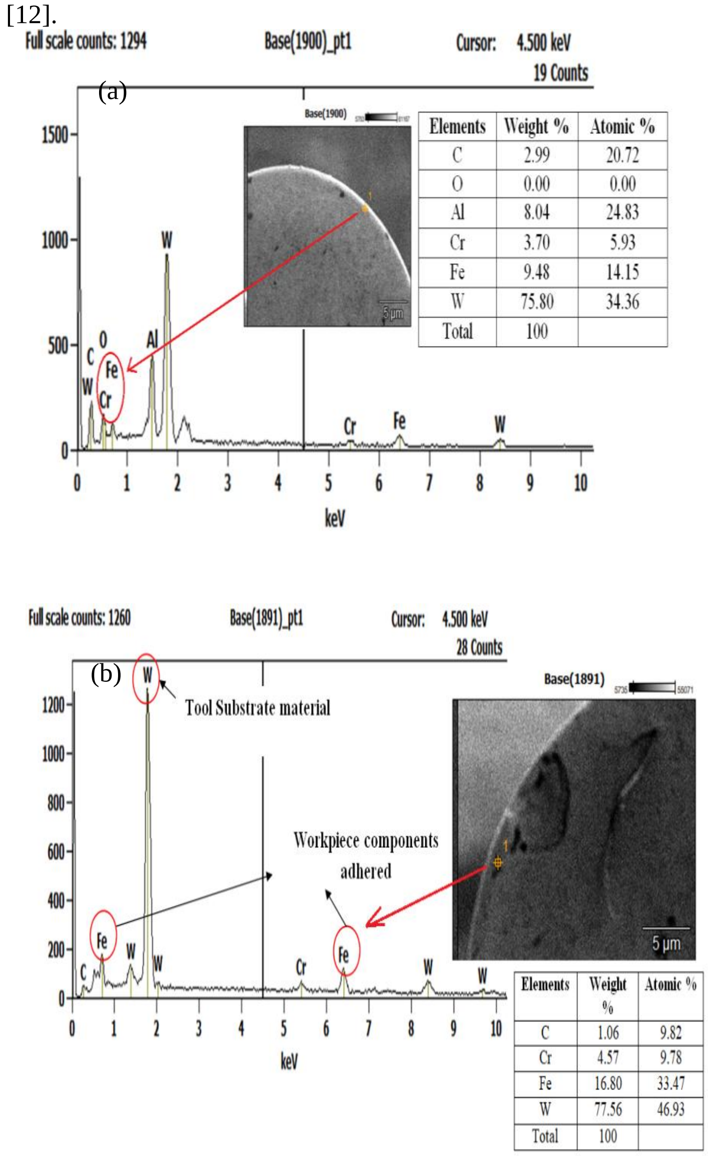


Figure 8: Shows the EDX spectra at a speed of 100.52m/min, feed rate of 0.14mm/rev (a) CT (b) UT insert

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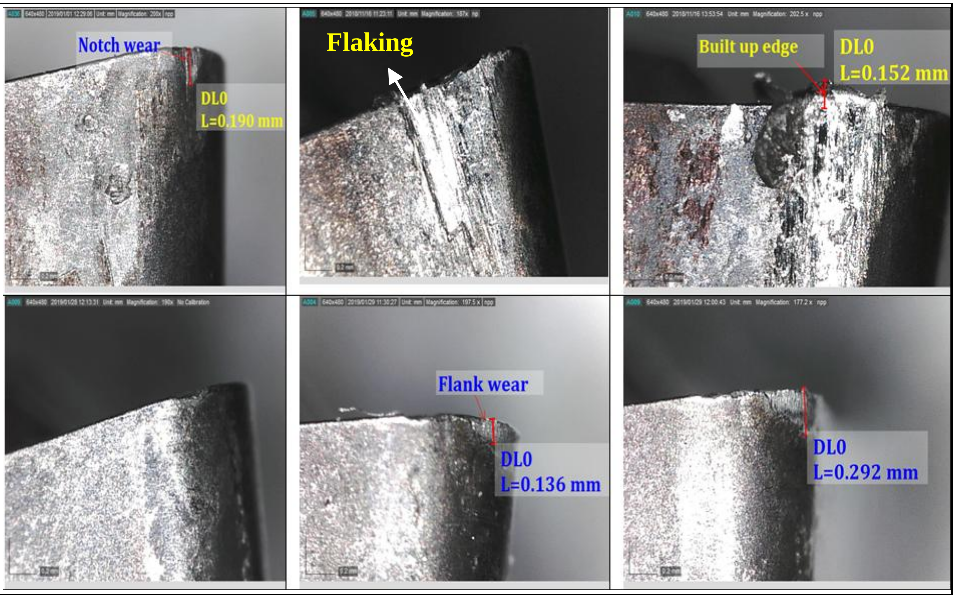
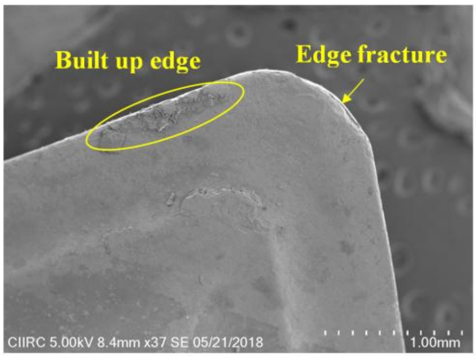


Untreated inset			
CTinsert			
	100.52m/min (10min)	125.66m/min (10min)	150.79m/min (10min)

Figure 9 Growth of flank wear at different cutting speed

Wear land of both CT and untreated inset were shown in the Figure 9. The flank wears and of both cutting insert for all speed were compared at constant machining period of 10min. The both cutting tool were machined at all three speed. It was observed notch wear 0.190mm in UT however, in the CT insert the cutting edges were protected at a speed of 100.52m/min, further increase in the speed from 100.52m/min to 125.66m/min flaking were observed on the UT in other hand the cryogenic insert showed less flank wear (0.136mm). At higher speed 150.79m/min the built up edge were observe for the UT, in this contrasts the CT insert shows no built up edge. Over all it was conclude that the cryogenic insert showed more desirable performance in comparison with UT. This was also supported by EDX test the UT showed a greater percentage of workpiece components on the tool rake of the cutting insert, the CT insert improved its microstructure properties after treatment attributable to formation of Eta phase carbide, this was also supported by XRD and EDX test.

3.4 Crater wear



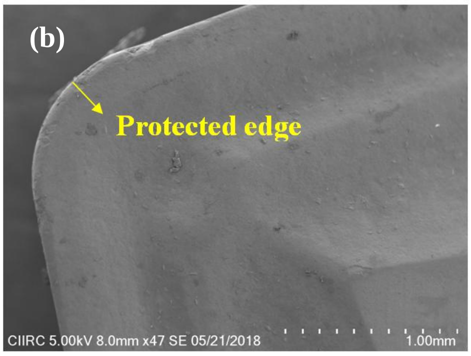


Figure 10 SEM image at a speed of 100.52m/min (a) UT (b) CT insert

The SEM images of the both CT and UT were shown in the Figure 10. In metal cutting operation highest temperature occur along the tool rake surface; sometimes this temperature can be of order 1000°C. Mainly in the carbide insert solid-state diffusion at this temperature can cause rapid wear. Usually the crater wear formed on the rake surface of the tool, this factor determines the cutting tool life. In this study carbide insert were CT the SEM images shows the machining operation at a speed 100.52m/min it from Figure 11(b) it was observed that there is no built up edge were seen on the tool of the insert the cryogenic insert prevented the built up edge in comparison with UT. The CT insert showed enhanced wear resistance due to development of Eta (η) phase particles and densification of cobalt binder (Co) [13].

3.5 Chip thickness

The microscopic images of the chip thickness of the CT insert and UT were shown in the Figure 11. It was confirmed that average tool chip thickness decreases with increase in the speed tough the average t_c for both tool decreases with increase in the speed. At a lower speed 100.52m/min it was observed that chip thickness of the CT insert (0.685mm) was less in comparison with UT (0.849mm). Further increase in the speed the CT insert showed less t_c in comparison with UT, Figure 12 Cleary shows that for all three different speed the CT insert showed lesser amount of t_c the lesser t_c caused by increase in the heat dissipation capacity of the carbide insert which leads to the lesser heat generation during machining which enhance the wear resistance properties.

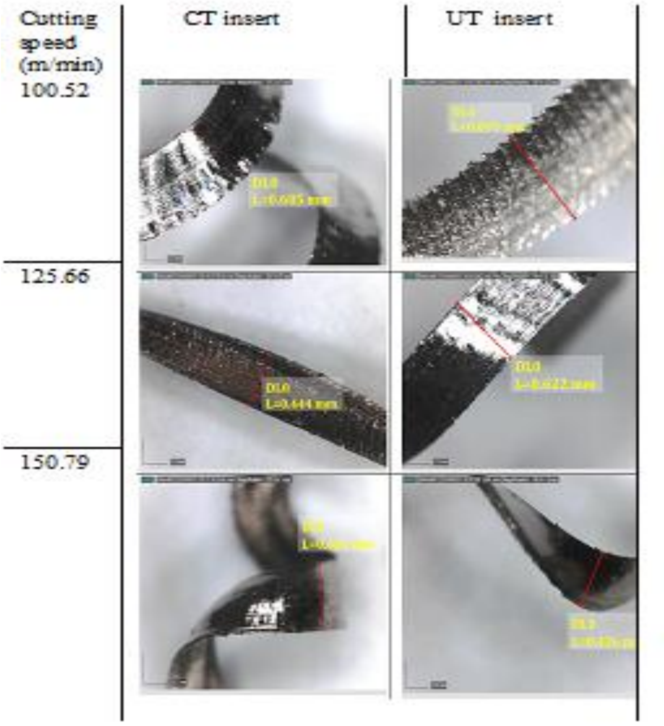


Figure 11 chip thickness variation with different cutting speed

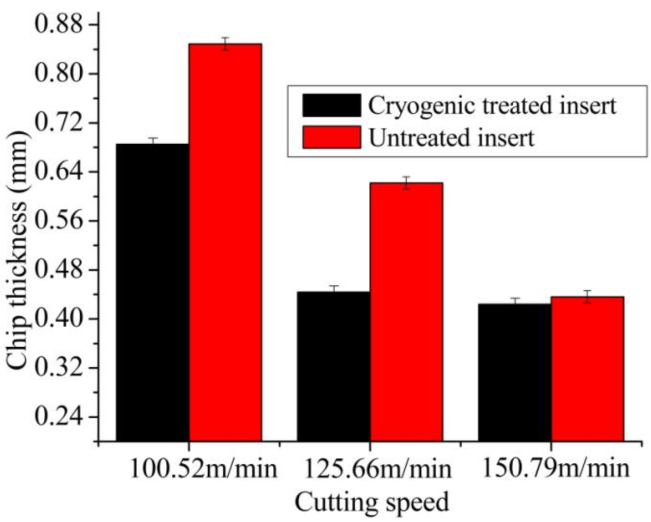


Figure 12 Cutting speed Vs chip thickness

CONCLUSION

CT applied for uncoated tungsten carbide of machining with AISI 304 under dry machining conditions the following conclusion was drawn.

1. The CT carbide insert shows the generation of Eta (η) phase carbide and homogenous distribution in the tungsten carbide substrate in comparison with UT which was confirmed from EDX and XRD test.
2. The maximum flank wear was more for UT in comparison with CT insert
3. Built up edge were observed on the rake face of the UT it was confirmed from the EDX test and microscopic test.
4. SEM images indicated the CT insert showed improved wear resistance.
5. The t_c of the CT insert was less in all cutting speed in comparison with UT.

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