Experimental Study of the Properties of Tungsten Carbide Tool on Croyogenic Treatment

Bibek Kafle[1] Akhalesh Yadav[2] Ram Thapa[3] Amit Kumar Sah[4]
[1,2,3,4]Department of Mechanical Engineering
[1,2,4]TKM College of Engineering, Kerela, India [3]Suresh Gyan Vihar University ,Jaipur, India

Abstract— Cryogenic treatment is widely researched areas over the past decades on improving mechanical properties. However, the focus was directed mainly on tool steel. Tungsten carbide is one of the important cutting tools mainly used for hard material machining operation. In this paper, we intended to focus on the mechanical properties like hardness, wear behaviour of tungsten carbide before and after cryogenic treatment for 45 hours for our experimental purpose. Moreover, we also concluded cryogenic treatment of 18hours is not sufficient for required improvements.

Key words: Cryogenic, Hardness, Roughness, Wear, Tungsten Carbide

I. INTRODUCTION

Material with improved mechanical properties is the need of every time. Heat treatment like annealing, tempering, quenching was in practise since medieval limes. The search of novel method to do so is the hot topic of these days. Researchers are turning towards cryogenic treatment as a supplement to heat treatment process. Cryogenic treatment refers to production of icy cold. Cryogenic refers to temperature below 183k. Moreover, there are shallow and deep cryogenic treatments. A lot of research is being carried out in steel tools and not much work is done on tungsten carbide (Candane et al, 2013). So, we focused our experimentation on tungsten carbide cutting tools, which is a widely used cutting tool. Young et. al (2006) observed at the higher cutting speed over the large machining time, cryogenic tools showed no improvement in wear resistance over untreated tools. The reason may be high heat production at high cutting counteracts the changes of micro structural changes that had happened in cryotreatment.

Bryson, B. (1999) put forwarded that increase in holding strength of Co binder after cryogenic treatment leads to increase in tool life. Ready et. al (2011) performed the effect of different cutting speeds on flank wear, cutting force and surface during dry machining for both untreated and cryotreated tungsten carbide tools. They saw when cutting speed range from 200m/min to 350m/min with 15 min of turning there was significant reduction in flank wear for cryotreated tools compared to untreated tools. They also observed because of this low wear, cutting force decreases by significant percentage. Simranpreet et. al (2008) carried their experiment on cryotreated tungsten carbide for continuous and intermittent mode in dry and wet conditions. They noted at low cutting speed it is better to perform continuously rather than intermittently in dry condition because temperature of tool does not increase much. Thornton et. al (2013) found that there was increase (9.2%) in hardness whereas toughness was found to be decreased. However, wear resistance behaviour of treated and untreated tungsten carbide depends on the cutting parameter. In the study done by Kalsai et. al (2012) hardness increment was highest (15.2%) for cryotreated tools with one tempering cycle. Cryo treatment followed by 2nd and 3rd tempering cycle showed maximum wear resistance behaviour.

II. CRYOGENIC TREATMENT PROCEDURE

The liquid nitrogen is generated from the nitrogen plant. Inside the chamber cooling occurs at rate of 2 degree celcius per minute from the room temperature to a temperature of -196 degree celcius. Here, tungsten carbide tools are treated for 18 hours and 40 hours with continuously supply of liquid nitrogen.

Fig. 1: Vessel for Cryotreatment

The experiment is carried out with simple turning operation in CNC lathe with both untreated and cryotreated tungsten carbide tools for work specimen AISI 1045 steel tool.

Fig. 2 Tool Set Up in CNC Lathe

Chemical composition of work piece is

Standard	Grade	C	Mn	P	S	Si
BS 970	AISI 1045	0.36-0.44	0.60-1.00	0.05	0.005	0.10-0.40

Table 1: Chemical Composition of Work Piece

The dimension of work piece is maintained such that length/diameter ratio is less than 10 as per ISO standard. Double-sided 800 rhombic inserts, positive rake angle that varies along the side to negative in order to prevent chipping.

After machining continuously for 20 minutes without coolant we have calculated the mass loss in cutting tools. Mass loss is the measure of wear rate. Researchers have correlated mass loss with wear rate. Analytical Balance Himadzu, S AUW22 DECTA 0.0001 GM is used for accurate mass loss with least count of 0.0001gm.

Fig. 3: Analytical Balance for Mass Measurement

For hardness we used Rockwell hardness test method with diamond cone as indenter.

Though many researchers focused on the influence of one or two parameters in performance characteristics, we here focused on effect of cutting speed, feed rate and depth of cut. Low, medium and high values are choosen for analysis.

Cutting Speed (mm/min)	Depth of Cut	Feed rate (mm/rev)
180	2	0.2
210	3	0.4
250	4	0.6

Table 2: Cutting parameters

Table shows the Taguchi orthogonal array selector which shows the orthogonal array of the parameters and levels. For three parameters and three levels L9 orthogonal array was selected from the array selector.

Sl.No	Depth of Cut (mm)	Feed Rate (mm/rev)	Cutting Speed (mm/min)
1.	2	0.2	180
2.	2	0.4	210
3.	2	0.6	250
4.	3	0.2	210
5.	3	0.4	250
6.	3	0.4	180
7.	4	0.2	250
8.	4	0.4	180
9.	4	0.6	210

Table 3: L9 Orthogonal Array

III. Result & Discussion

After doing simple turning operation for 20 minutes of continuous machining without coolant for both untreated and treaded carbide tools, the table of same is plotted below. Mass loss is the measure of wear rate.

Sl.no	Depth of cut(mm)	Feed Rate(mm/rev)	Cutting speed(m/min)	Mass loss ΔM-un(gm)
1.	2	0.2	180	0.0012
2.	2	0.4	210	0.0008
3.	2	0.6	250	0.0014
4.	3	0.2	210	0.0026
5.	3	0.4	250	0.0010
6.	3	0.6	180	0.0007
7.	4	0.2	250	0.0005
8.	4	0.4	180	0.00134
9.	4	0.6	210	0.00037

Table 4: Mass Loss in Untreated Tools under Different Cutting Conditions

Sl.no	Depth of cut(mm)	Feed Rate(mm/rev)	Cutting speed(m/min)	Mass loss ΔM-tr(gm)
1.	2	0.2	180	0.00031
2.	2	0.4	210	0.000331
3.	2	0.6	250	0.00071
4.	3	0.2	210	0.00047
5.	3	0.4	250	0.0016
6.	3	0.6	180	0.00019
7.	4	0.2	250	0.00082
8.	4	0.4	180	0.00010
9.	4	0.6	210	0.00027

Table 5: Mass Loss in Treated Tools under Different Cutting Conditions

By using minitab 17 software graphs are plotted on mass loss vs. cutting parameters.

As above, we can deduct that the effect of cryogenic treatment vanishes at higher cutting speed the same result was obtained by Young et. al (2006).

We can analyse the date using bar diagram at particular cutting conditions.

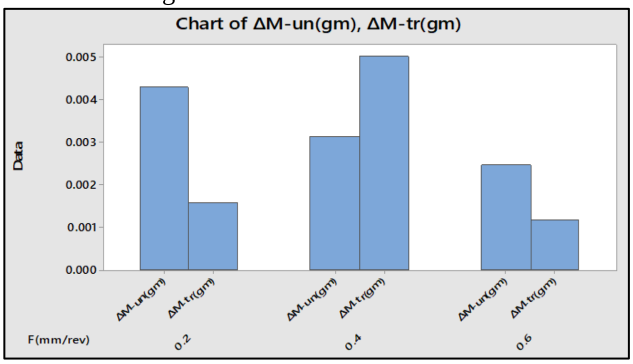

Fig. 4: Mass Loss for Untreated and Treated Tools after 20 minutes of machining at different feed rate

At, feed rate of 0.2mm the reduction in mass loss is about 65.9%. At feed rate of 0.4mm and 0.6mm the reduction in mass loss is about 60%. As there is only minimum variation (5%) over the whole range of feed rate so we can conclude that feed rate doesn't have big hand on the wear loss. The same conclusion was made by Bryson (1999).

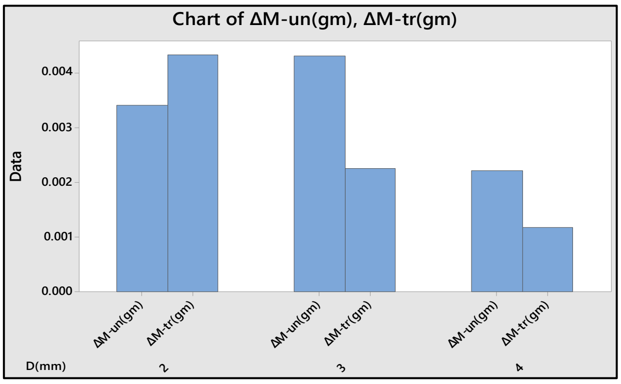

Fig. 5: Mass loss for untreated and treated tools after 20 minutes of machining at different depth of cut

At low depth of cut the the mass loss is more for cryotreated tools by 26.5% whereas at higher depth of cut 3mm and 4mm the mass loss for cryotreated tools is lower by 45%.

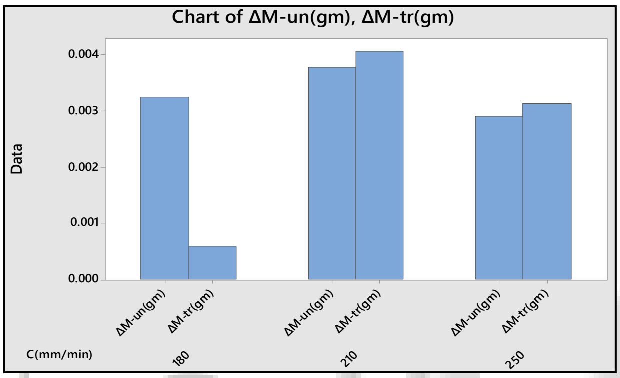

Fig. 6: Mass Loss for Untreated and Treated Tools after 20 Minutes of Machining at Different Cutting Speed

At 180 m/min, cutting speed the reduction of mass loss is about 85.3%. Whereas at cutting speeds 210 m/min and 250 m/min, the increment in mass loss are about 5.7% and 11.1% respectively.

We can derive that at low cutting speed the effect of cryogenic treatment is felt more. With increase in speed, the effect tends to vanishes (Young et al, 2006). The reason may be high heat production at high cutting speed counteract the changes of micro-structural changes that had happened in cryotreatment.

Moreover, to felt the effect of cryogenic treatment at high cutting speed we have to go for post heat treatment process. Generally three times tempering after cryogenic treatment is found to be most efficient (Kalsai et. al , 2012). After taking hardness value in Rockwell machine we got the following

Sl.no.	Untreated in HRc	18 hrs treated in HRc	40 hours treated in HRc
1.	60	74	76
2.	72	66	71
3.	56	66	74
4.	66	62	85
5.	67	60	79
AVG	64.2	65.6	77

18 hours treatment, % increase in hardness
= $((HRc)_{final} - (HRc)_{initial})/(HRc)_{initial}$
= (65.6- 64.2)/64.2
=2.2%

For 40 hours treatment, % increase in hardness
= $((HRc)_{final} - (HRc)_{initial})/(HRc)_{initial}$
= (77- 64.2)/64.2
=19.9%

IV. Conclusion

Like HSS, the effect of cryogenic treatment is felt only at low cutting speed i.e. its effect vanishes at higher cutting speed. And there is small effect of depth of cut and feed rate in the mass loss. We can logically conclude that there may be optimum cutting conditions..

The hardness of 40 hours cryo treated tools is found to increase by 19.9%. The hardness of 18 hours cryo treated tools is found to increase by 2.2% which shows 18 hours treatment is insufficient. So, cryogenic treatment is beneficial for improvement in mechanical properties like hardness, wear resistance. This may lead to the reducing machining cost by increasing tool life.

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