The Effect of Cryogenic Treatment on Tungsten Carbide

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Abstract

This paper explicates the influence of cryogenic treatment on tungsten carbide. So many studies have been reported on cryogenic treatment on tool steels but very fewer studies are carried out on tungsten carbide. Actually, tungsten carbide cutting tools are in common practice these days. The intent of this study was to investigate the variance in performance of cryogenically treated and untreated tool inserts during orthogonal turning of C-45 steel. This study will determine the ideal cutting conditions for turning and will peep into the method of cryogenic treatment and its effect on the properties of tungsten carbide. It has been perceived that the cryogenically treated tungsten carbide tools have better life as well as performance when compared with untreated one under similar working parameters.

Keywords – Cryotreated, Deep Cryogenic treatment, Cubic born nitride, Flank wear, Depth of cut, Analysis of variance

Introduction

The technology of cutting tools and inserts has been growing in the present scenario of developing technology of mechanical working of metals. Numerous cutting tool materials have been developed in the recent past. The urge to improve productivity and to machine hard material economically is the need of every company to survive in this competitive market. Tungsten carbide tools are the widely used cutting tools in most of the engineering workshops and tool rooms of modern industry. Tungsten cemented carbide is one of the hardest anti-wear cutting tool materials in which the hard tungsten carbide particles are sintered by heating and cobalt is used as a binding material since it the most efficient material to be used as binding material universally. Tungsten carbide is used extensively for various metal cutting processes more than any other cutting tool material due to its high wear resistance while cutting materials at high speed. Khan & Ahmed (2008) studied that the major needs in machining are high material removal rate, good work surface finish and low tool wear. The purpose of the study was well achieved by minimizing tool wear with the help of efficient cooling system while machining stainless steel. In the experiment, the modified tool having hole in it is used. The liquid nitrogen is used as coolant which passes through the hole provided in cutting tool and cools the machining area while machining stainless steel. The results show that tool life was improved drastically and tungsten carbide tool was found to be very efficient cutting tool for cutting hard material at high speeds. Kaushal *et al.,* (2015) the study is focused on AISI-D2 tool steel. It is realized that when the steel is cold treated by cryogenic treatment at about -196^{0}C, the microstructural changes take place converting austenite to martensite which improves properties like hardness and anti- wear. Bensely *et al.,* (2005) studied that the mechanical parts which are subjected to continuous sliding or rolling friction causes wear and tear to them. Therefore, wear is very crucial factor while considering failure of these mechanical parts. The repeated wear and tear of crown and pinion was the main driving force to study the effects of cryogenic treatment to reduce the wear and to enhance the life of these mechanical parts. The experimentation includes the testing of pin and desk without using any lubricant. During experiment testing was carried out at different speeds on samples. The samples were heat treated and cryogenically treated. The results revealed that wear resistance was considerably improves after deep cryogenic treatment than heat treatment. Liu *et al.*, (2015) the study inspects the outcome of cryogenic treatment on the die-steel. The study explores the effect of quenching process and tempering process on the microstructure after being treated by cryogenic treatment. It concluded that cryogenic treatment certainly improves its hardness and wear and tear capacity hence improves the life of the die-steel. Reddy *et al.,* (2007) studied that the technology of cutting tools and inserts has been rapidly growing in the market. Tools and inserts made of ferrous metals in earlier days, has been replaced by sintered carbides, ceramics and CBN. In recent years, secondary processes like special type of heat treatment processes are employed on coated carbides to improve its tool life through structural changes with the help of heat treatment. Cryogenic treatment is one among the special type of heat treatment process, which has been employed on ferrous metals. Barron (1982) concluded that a cryogenic treatment (-306°F) was applied to C2 tungsten carbide (WC -6% Co) and compared with untreated carbide to determine the effect on the tool life while turning the fireboard. The result of the test indicated that tool life was enhanced considerably using cryogenic treatment. Das *et al.,* (2007) explored the effect of deep cryogenic treatment process on to the steel. The cryogenic treatment was given to the steel between quenching and tempering. The microstructural changes after quenched cryogenic treatment and traditional quenching and tempering process were noted down. The hardness was recorded after Vickers hardness test and found that there were considerable changes in hardness after cryogenic treatment. Molinari *et al.,* (2001) the study evaluates the impact of deep cryogenic treatment on the properties of some tool steels and concluded that there is considerable improvement in tool life and its hardness. The cost on cutting tools was also reduced by half. It was also found that cryogenic treatment improves wear resistance after conventional heat treatment. Stratton (2007) deliberates that cryogenic treatment can increase the wear resistance of the cutting tools. Results indicate that deep cryogenic treatment precipitates the micro sized carbides in the martensite. The austenite also converts into martensite resulting in increase in wear resistance and tool life. Gill *et al.,* (2009) the study examines the effect of coolant while orthogonal turning using cryogenically treated tungsten carbide inserts. The test is conducted to see the flank wear at regular intervals in dry and wet conditions. It is found that cryogenically treated tungsten carbide with chip breaker perform better in wet conditions. The coolant reduces flank wear and increases its life. Yong *et al.,* (2006) the study is conducted to see the influence of cryogenically treated and un-treated tungsten carbide inserts in turning process. Study shows that cryogenic treatment improves the wear resistance of the tool but can be detrimental to the tool life in certain condition. If the cryogenically treated inserts gets heated for a long time it reduces its wear resistance so these can perform well in intermittent turning operations. Putz *et al.,* (2016) the study is piloted on machining Elastometer. The Elastometers are very difficult to machine due to very low young's modulus so cryogenic treatment is used to ease the machining of Elastometers. It is found that cooling of Elastometers before machining improves its machinability. The distortion due to high temperature during cutting operation can be minimized using cryogenic treatment. Pavan (2014) the study is focused on cryogenic treatment of aluminum alloys to increase its mechanical properties and corrosion resistance under high temperature and pressure. The results show that cryogenic treatment enhances the corrosion resistance and strength of aerospace and heat exchanger alloys since they are subjected to high temperature and pressure. Candane (2013) in this paper comparative study is being conducted on high speed steel after traditional heat treatment and cryogenic treatment. During the experimentation the specimens are heated to 1200°C and then cooled at – 84°C and thereafter deep cryogenic treatment is given at -195°C it is found that free austenite after heat treatment was approximately 19% and removed totally after cryogenic treatment. Results reveal that it increases the hardness and improves the microstructure of the material ultimately increases its wear resistance. Mandeep (2014) the study describes deep cryogenic treatment and its usefulness for low carbon steels. During the test the steel is cryogenically treated at about -193°C for 28 hours and then tempered at 150°C. After the cryogenic treatment the steel is tested for hardness at different cutting parameters. Results show that there is substantial upgrading in hardness after deep cryogenic treatment.

Experimentation

Equipment used

Following equipment with given specifications have been used to perform the experimentation:

Lathe Machine with following specifications is shown in Figure 1.

Distance between centers	1500 mm
Height of center	200 mm
No. of speed / range forwarded (Standard)	16/30-1200 rpm
No. of Longitudinal feeds / range	54 from 0.02 to 2 mm
No. of Transverse feeds	54 from 0.015 to 0.5 mm
Standard spindle RPM range	30 to 1250 rpm
Optional spindle RPM range	50 to 2100 rpm

Figure 1: Turning Lathe with various control systems

Tool Holder

The tool holder used for the turning is SCLCR 1616H0918G of widia brand as shown in Figure 2

B	H	l_1	l_2	F
1.000	1.000	6.000	.750	1.250

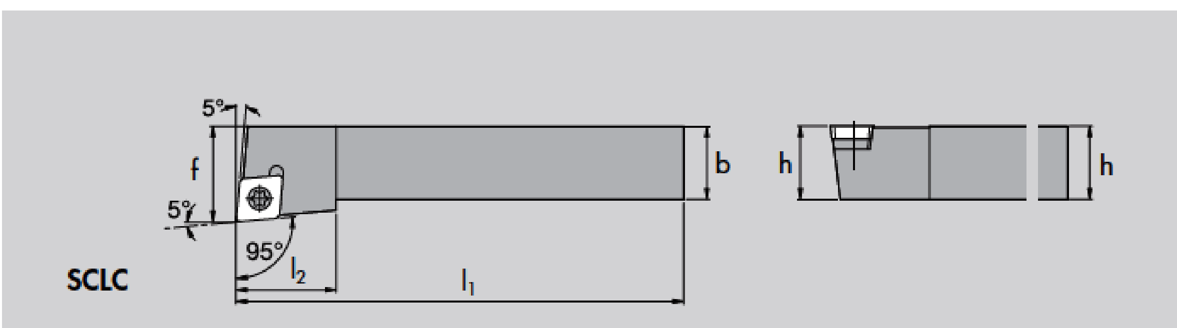


Figure 2: Tool holder for the cutting inserts

Cutting inserts: To perform 32 pieces of tungsten carbide tool inserts (uncoated) of rhomboidal in shape having grade CCMT 090304 were taken and 16 out of 32 were deep cryogenically treated at -196°C. The cryogenic treatment has been done on these tool inserts at Institute of auto parts Ludhiana. The tool inserts were held in above said tool holder provided with screw type holding system. The previous studies have exposed that the cutting speed is the most prominent factor affecting tool life, followed by feed and depth of cut. The cutting inserts used are as shown in Figure 3.

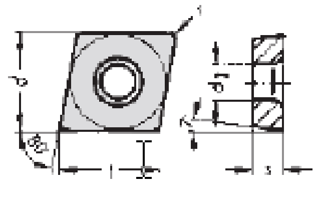


Figure 3: Tungsten carbide cutting insert

Work material

The work pieces used for performing turning operation has been C45 steel rod with outer diameter 60 mm and length 200 mm so that L/d ratio should not exceed 10 as per ISO 3685:93 standard.

Tool maker's microscope

To analyze the tool wear of the used tool inserts tool makers microscope with digimatic heads having following specifications has been used as shown in Figure 4.

- A large working distance – 67 mm and erect image.
- Cross-travel range is 50 x 50 mm. The micrometer heads fitted to the microscope can be replaced by digimatic heads
- A single handle for both coarse and fine focus adjustments.
- Angular measurements can be readily taken by referring to an angle scale disc located in the eyepiece section of the optical tube.
- Micrometer heads read to 0.005 mm in the range of 25 mm. Replaceable with digimatic heads.

Figure 4: Tool makers microscope with digimatic heads

Assumptions for the experiment

- Only one type of tool insert (Rhomboidal) shape was used.
- No coolant was used.
- Ambient temperature was constant (16°C)
- The same machine has been used to carry out all the experiments.
- The financial part has not been taken into account.

Process details (Deep Cryogenic Process)

The process is based on a fixed thermal cycle that involves cooling of the components or tools in a totally organized cryogenic chamber. The material is slowly cooled to -300°F and soaking at that deep cryogenic temperature for 30-40 hours. Thereafter, the material is allowed to cool down very slowly to room temperature. The complete cryogenic treatment cycle can consume 75-80 hours to complete. This procedure of accurately organized temperature profiles prevented any chances of thermal jolt and thermal pressure that could be practiced when a tool or part is exposed to rapid or great temperature fluctuations. In this process liquid nitrogen is used as a refrigerant.

Cryogenic processing is not a substitute for heat treatment, but rather an extension of the heating / quenching / tempering cycle. In most occurrences the cryogenic treatment is followed by a heat tempering process. The tempering procedure varies according to the materials chemical composition, thermal history and/or tools particular service application since every metal has different composition.

The cryogenic setup depicted in Figure 5 consist of a box completely insulated box called as 'cryo box', a thermocouple to record the inner temperature of the box, a motorized fan and nitrogen tank containing liquid nitrogen and solenoid valve to control the gas. The pyrometer is used to record the actual temperature of the material in the chamber.

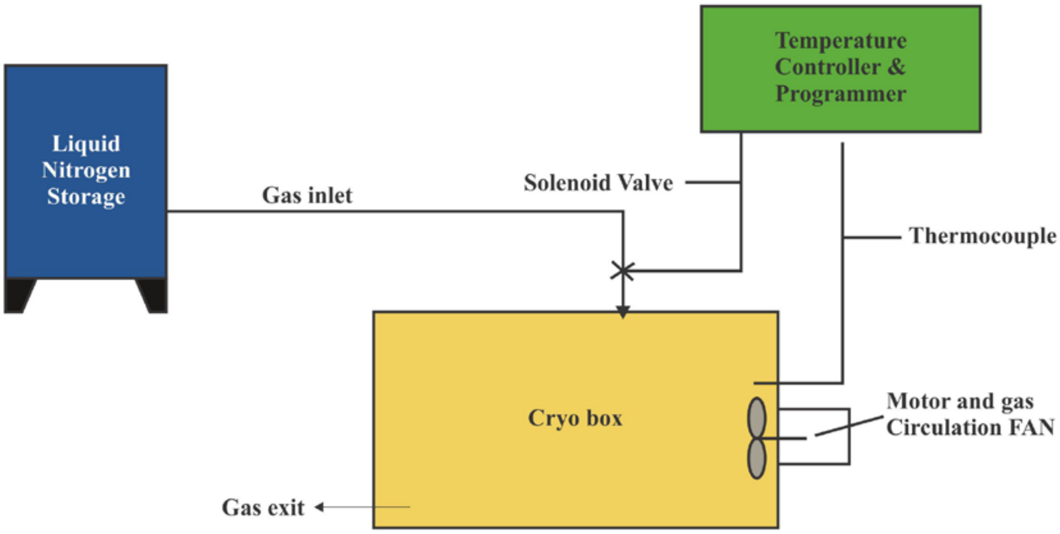


Figure 5: Schematic Diagrams for Cryogenic Treatment

Experimental Procedure

Hot rolled steel stocks (C 45) of initial diameter 60 mm were taken for experimental work. The uncoated tool inserts of tungsten carbide cryogenically treated as well as untreated were tested by performing orthogonal turning on C 45 rod on an HTM lathe. Then the cutting tool bits were tested for continuous turning operations as shown in Figure 6. This was to avoid the flank wear under various turning operations.

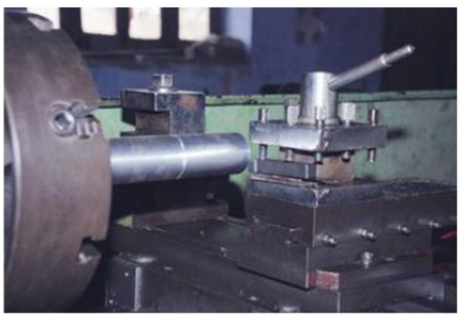


Figure 6: Turning of C 45 Rod with cryotreated / untreated cutting tool inserts

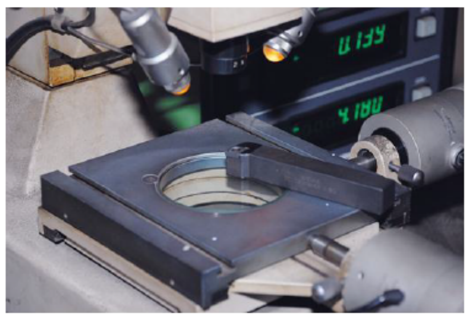


Figure 7: Analysis of tool wears using digimatic head on tool makers micro scope

The tool bits which were cryogenically treated then tested at many different cutting speeds, feeds and depth of cuts. The inserts were tested for continuous cuts and after each cutting operation the maximum flank wear VBmax was instantly measured with the help of Mitutoyo tool maker's microscope, since the width of flank wear was not regular along the cutting edge as shown Figure 6 and Figure 7. About thirty two experiments have been carried out at different cutting speeds, feed and depth of cut using both cryogenically treated and untreated tool inserts. The work pieces used were of C 45 steel having dimension of 60 mm. and 200 mm. length so that L/d ratio should not exceed 10. The tool holder used for turning is SCLCR 1616H0918G.

Experiments

Table 1: Observations of cutting parameters using cryotreated / untreated cutting inserts

Sr No	A: Cutting Speed	B:Feed(mm/rev)	Depth of Cut(mm)	Cryo-Treated	Flank Wear(mm)
1	60	0.2	0.25	0	0.03
2	225	0.2	0.25	1	0.01
3	225	1	0.25	1	0.06
4	225	0.2	1	1	0.04
5	225	1	0.25	0	0.1
6	60	0.2	0.25	1	0.01
7	60	1	0.25	1	0.02
8	60	1	1	0	0.05
9	225	0.2	1	0	0.06
10	225	0.2	1	1	0.04
11	60	1	0.25	0	0.04
12	60	0.2	0.25	1	0.01
13	225	0.2	0.25	0	0.04
14	60	0.2	1	0	0.05
15	60	1	1	1	0.02
16	225	1	1	0	0.12
17	60	1	1	1	0.03
18	225	0.2	0.25	0	0.05
19	225	1	0.25	0	0.12
20	225	0.2	0.25	1	0.02
21	225	1	1	1	0.06
22	225	1	0.25	1	0.05
23	60	0.2	1	1	0.02
24	225	1	1	0	0.13
25	60	1	1	0	0.08
26	60	0.2	1	0	0.05
27	60	0.2	0.25	0	0.03
28	60	1	0.25	1	0.02
29	225	1	1	1	0.06
30	60	1	0.25	0	0.04
31	225	0.2	1	0	0.07
32	60	0.2	1	1	0.03

Anova

The data presented in the Table 1 is analyzed. An analysis of variance (ANOVA) is conducted. The objective is to determine factors that are statistically significant. The ANOVA table given in Table 2 also indicates the significance of the model obtained.

Table 2: Factorial Model using Anova method

Response:	**Flank Wear**						
ANOVA for Selected Factorial Model							
Analysis of variance table [Partial sum of squares]							
	Sum of		**Mean**	**F**			
Source	**Squares**	**DF**	**Square**	**Value**	**Prob > F<**		
Model	0.018972	7	0.00271	8.105474	0.0001	significant	
A	0.005253	1	0.005253	15.71028	0.0006		
B	0.005778	1	0.005778	17.28037	0.0004		
C	0.002278	1	0.002278	6.813084	0.0153		
D	0.004278	1	0.004278	12.79439	0.0015		
AD	0.000528	1	0.000528	1.579439	0.2209		
BD	0.000153	1	0.000153	0.457944	0.5051		
CD	0.000703	1	0.000703	2.102804	0.1600		
Residual	0.008025	24	0.000334				
Lack of Fit	0.003775	8	0.000472	1.776471	0.1561	not significant	
Pure Error	0.00425	16	0.000266				
Cor Total	0.026997	31					

The Model F-value of 8.11 infers the model is important. There is only a 0.01% chance that a "Model F-Value" can be due to noise during operation. Values of "Prob > F" less than 0.0500 specify model terms are noteworthy. In this case A, B, C, D is noteworthy model terms. Values more than 0.1000 specify the model terms are not important. The "Dearth of Fit F-value" of 1.78 indicates the Lack of Fit is not important relative to the pure error. There is a 15.61% chance that a "Dearth of Fit F-value" this large might occur owing to sound. Non-significant nonexistence of fit is virtuous. We intend the model to fit. Different values are shown in Table 3.

Table 3: Mean value of parameters

Std. Dev.	0.018285924	R-Squared	0.702743373
Mean	0.0453125	Adj R-Squared	0.616043524
C.V.	40.35514162	Pred R-Squared	0.471543774
PRESS	0.014266667	Adeq Precision	10.11707172

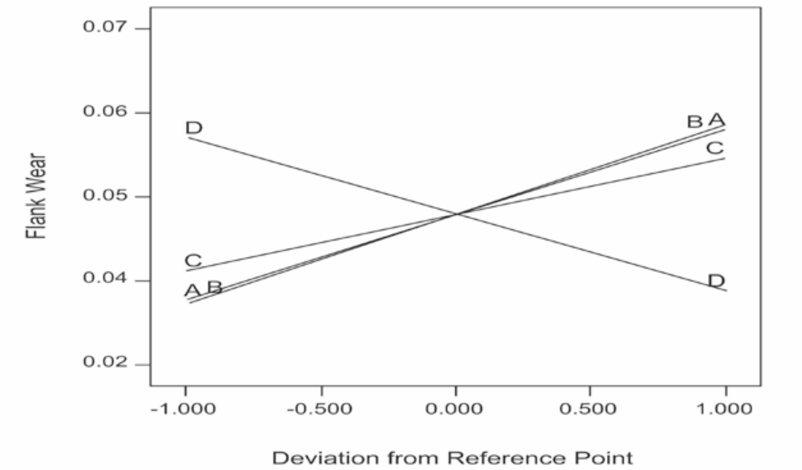
The "Pred R-Squared" of 0.4715 is in rational agreement with the "Adj R-Squared" of 0.6160. "Adeqate Precision" measures the signal to noise quotient. A ratio greater than 4 is needed. Your ratio of 10.117 indicates an adequate signal. This model can be used to navigate the design space.

Flank Wear = -0.017585+2.04545E-004 * Cutting Speed+0.039063 * Feed+0.035000 * Depth of Cut+0.013097 * Cryo Treated-9.84848E-005 * Cutting Speed * Cryo Treated -0.010937 * Feed * Cryo Treated-0.025000 * Depth of Cut * Cryo Treated

Perturbation

The perturbation plot aids you to relate the effects of all the factors at a specific point in the design space. The response is graphically represented by changing only one factor over its range while setting the other factors fixed. By using design expert the reference point are set at the mid-point of all the factors like feed, cutting speed, depth of cut and deep cryogenically treated.

A sheer slope or curving in a factor displays that the response is subtle to the factor. Relatively flat line shows in sensitivity to change in that particular factor.



Actual factors
A. Cutting speed = 142.50 m/min.
B. Feed = .60 mm.
C. Depth of cut = 0.63 mm.
D. Cryo. Treated = 0.50

Figure 8: Deviation from Reference Point v/s flank wear

The Figure 8 indicates perturbation plot which shows the effect of all the cutting parameters i.e. feed, cutting speed, and depth of cut and deep cryogenic factor. Graph portrays that the most dictating factors influencing the life, is the cutting speed followed by feed and depth of cut. The depth of cut has least effect on flank wear. As all these factors increase in their values the flank wear also increases. Deep cryogenic treatment as shown in the graph as factor D clearly indicates that this treatment reduces the flank wear to a great extent. As the fully treated insert has the least flank wear.

X1=C: Depth of Cut

Actual Factors
A: Cutting Speed = 142.50
B: Feed = 0.60
D: = Cyro Treated = 0.50

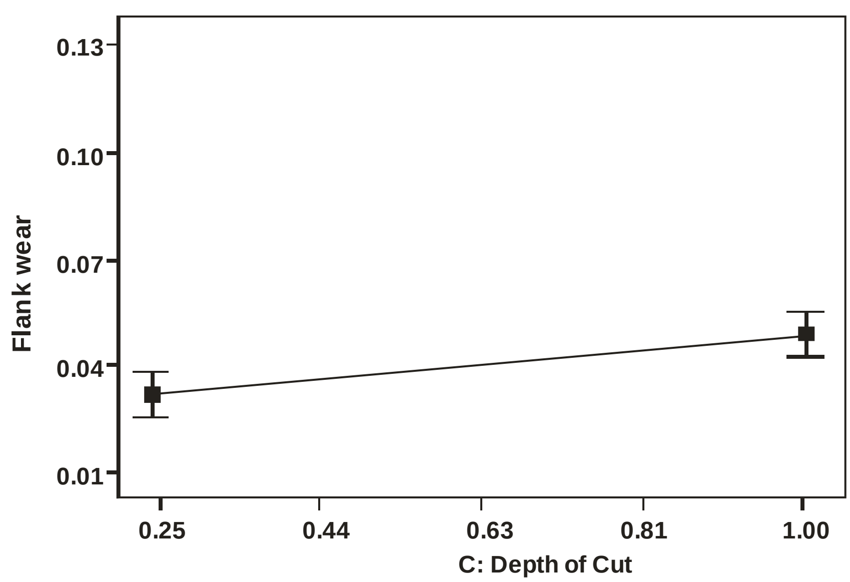


Figure 9: Flank wear v/s depth of cut

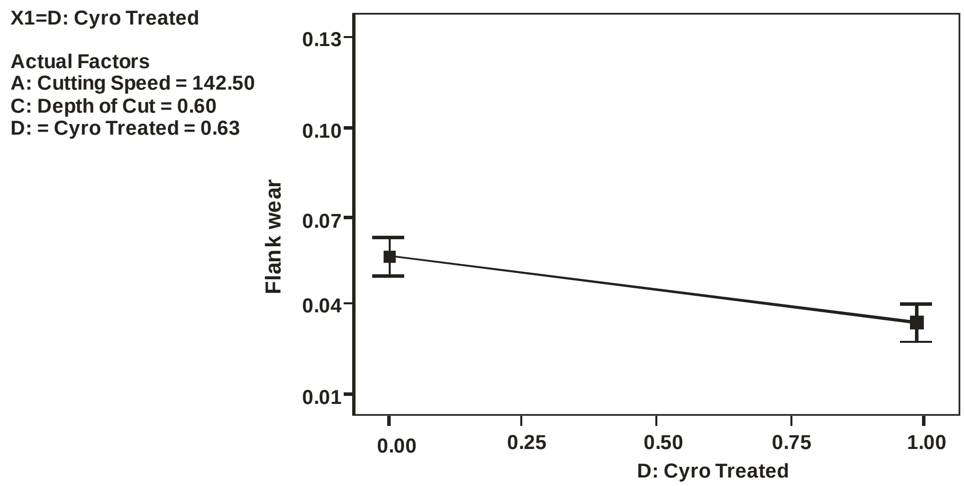


Figure 10: Flank wear v/s cryo treated

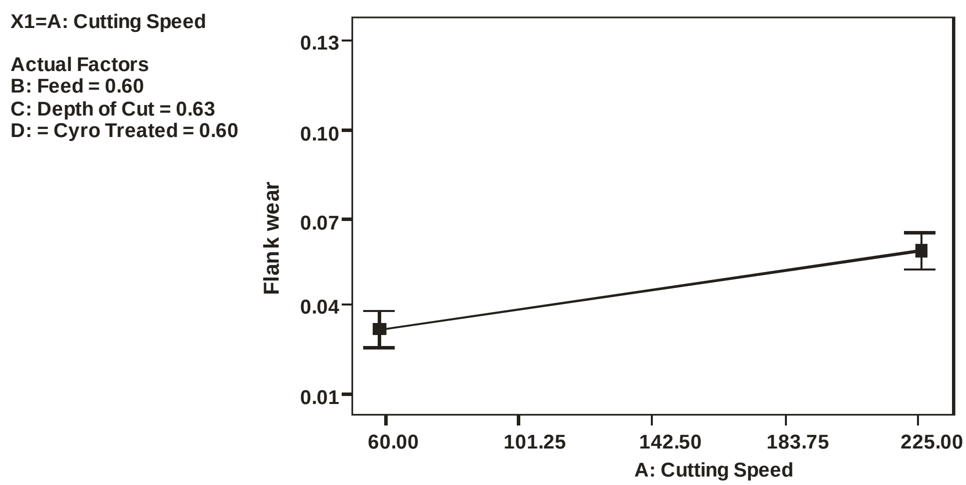


Figure 11: Flank wear v/s cutting speed

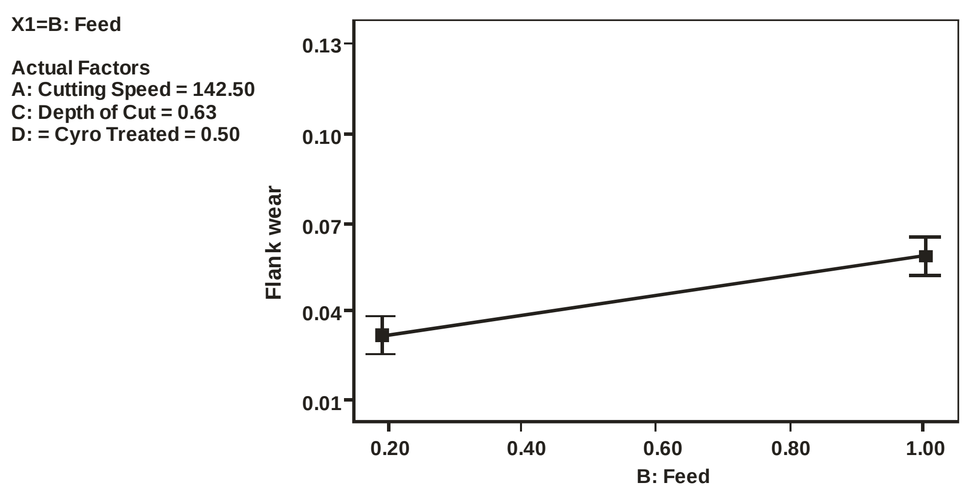


Figure 12: Flank wear v/s feed

One Factor Effecting Plot

The one factor effecting graph shows the linear effect of changing the level of a single factor. Figure 9, 10, 11 and 12 depict the flank wear with respect to varying depth of cut, cryo- treated, cutting speed and feed respectively. It is constructed by predicting the responses for the low (-1) and high (+1) levels of a factor. This is quite evident that speed, feed, depth of cut and cryogenic treatment affect flank wear. Speed and feed affect tool wear more than depth of cut. Cryogenic treatment of tool reduces flank wear and enhances tool life. All these affect can easily be seen through single factor graph. These graphs give very easy understanding of the effects of all these cutting parameter.

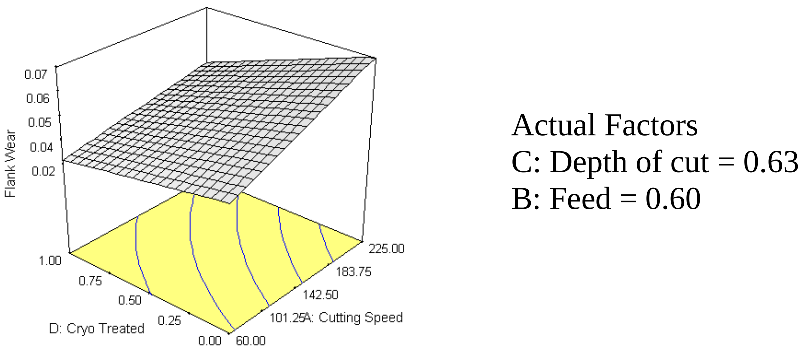


Figure 13: Flank wear v/s deep cryogenic treatment and cutting speed

3-D Interaction graph

The Figure 13 depicts the 3D surface view. By using this view the model can be displayed in three dimensions. This opinion delivers a clear estimation of the surface. The three dimensional surface shows six surface plot. For each such plot, the variables not represented are held at a constant value. The graph allows qualitative determination of a minimum or maximum value of flank wear.

From the graph it can be easily seen that as the cryogenic treatment progresses the flank wear reduces and then cutting speed increases, flank wear also increases. In this graph the factors like feed and depth of cut are constant and the combined effect of rest of two variables (i.e. cryogenic treatment and speed of cutting) can be seen at a time.

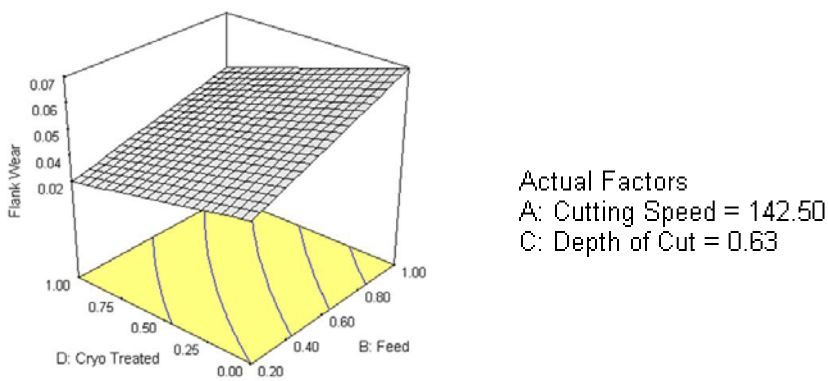


Figure 14: Flank wear v/s Deep cryogenic treatment and feed

Similarly, the above said Figure 14 graph shows the effect of feed and cryogenic treatment on flank wear. These plots are plotted using design expert. The values used to plot the graph are the mid values e.g. the flank wear varies from 0.01mm to 0.13 mm indicates that it has taken .07 mm which is the central value of flank wear. Now in this 3D surface plot cutting speed and depth of cut are kept constant and the effect of feed and cryogenic treatment on flank wear is determined. After cutting speed, feed is the next leading cutting parameter that affects the flank wear. The figure shows that the flank wear increases as the cryogenic treatment decreases and feed increases. Deep cryogenically treated cutting inserts give better results at low feed as the feed increases the flank wear also increases but at much lesser rate as compare to untreated cutting tool inserts.

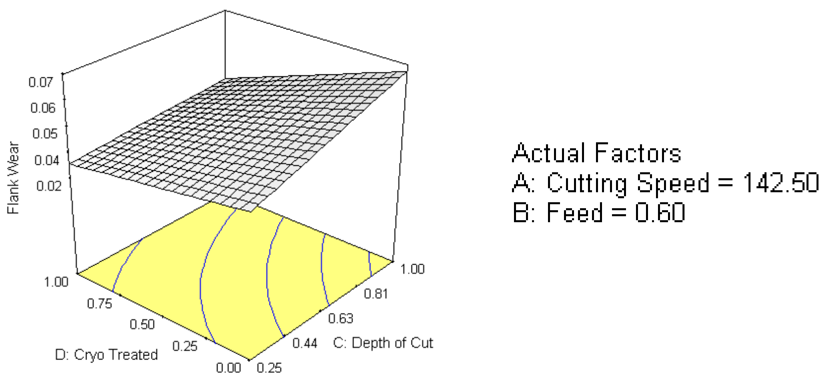


Figure 15: Flank wear v/s deep cryogenic treatment and Depth of Cut

The Figure 15 labels the impact of deep cryogenic treatment and depth of cut parameters. Other parameters cutting speed and feed are kept constant. It is evident that depth of cut has the least effect on flank wear. The graph shows the comparison between cryogenically treated inserts and the untreated on and between low depth of cut and high level depth of cut with respect to flank wear. Generally the cryogenically treated inserts face lesser flank wear than the untreated cutting tool inserts and similarly flank wear is less at small depth of cut. So, in nutshell these 3D surface plots give better understanding of the effect of various factors and their interactions etc.

Optimization

The optimization examines the amalgamation of factor levels that concurrently fulfill the requirement spaces on every responses and factor optimization of sole response or the concurrent optimization of numerous responses which can perform graphically or statistically. The ideal cutting parameters for turning C45 steel with uncoated tungsten carbide cutting tool inserts is to discover the optimal cutting parameters so as to minimize the flank wear. Numerical optimization has been used to optimize the goal. A maximum and minimum level has been provided for each parameter included in optimization. The optimized data is shown in Table 4 and 5.

Table 4: Range of cutting parameters

		Lower	Upper
Name	**Goal**	Limit	Limit
Cutting Speed	**is in range**	60	225
Feed	**is in range**	0.2	1
Depth of Cut	**is in range**	0.25	1
Cryo Treated	**is in range**	0	1
Flank Wear	**minimize**	0.01	0.13

Table 5: Optimized values of cutting parameters

Number	Cutting Speed	Feed	Depth of Cut	Cryo Treated	Flank Wear	Desirability
1	**61.48**	**0.20**	**0.25**	**1.00**	**0.01**	**0.998659**
2	60.00	0.20	0.26	0.26	0.01	0.989593
3	60.00	0.20	0.47	1.00	0.01	0.981251
4	60.00	0.20	0.49	0.99	0.01	0.979069
5	60.04	0.24	0.25	0.00	0.01	0.976217
6	61.29	0.26	0.25	0.17	0.01	0.96959
7	60.00	0.20	0.64	1.00	0.01	0.967433
8	60.00	0.31	1.00	1.00	0.02	0.910873
9	60.00	0.74	0.25	0.00	0.03	0.814698
10	**217.93**	**0.20**	**1.00**	**0.99**	**0.03**	**0.796191**

Validation of plots

For validation of plots the results were verified by taking the three sets of value of cutting parameters. Three separate work pieces of C-45 material were turned with cryo-treated and untreated cutting tool inserts and found that the results are attained with good accuracy. The validation parameters are shown in Table 6.

Table 6: Validation of experimental results

Number	Cutting Speed	Feed	Depth of Cut	Cryo Treated	Flank Wear
1	60.00	0.31	1.00	1.00	0.03
2	60.00	0.74	0.25	0.00	0.03
3	215	0.20	1.00	0.99	0.03

Results and Discussions

Flank wear: Flank wear is very important tool wear occurring during turning operation. The Flank wear is mainly credited to rubbing of the tool with the machine surface triggering scratchy wear and also high heat, which influence the tool material and results in plastic distortion of the cutting edge. The flank wear of deep cryogenically treated cutting tool bits is lesser than that of unprocessed bits.

The Table 7 gives the comparative data of cryo-treated as well as cutting inserts under various cutting conditions

Table 7: Improvement of tool life at various cutting parameters

Sr. No.	**Cutting Speed mtr/min**	**Feed mm/rev.**	**Depth of cut in Mm**	**Flank Wear**		**% improvement in tool life (Flank wear reduction)**
				Untreated	**Cryo treated**	
1.	60	0.2	0.25	0.03, 0.03 χ=0.03	0.01,0.01 χ=0.01	66.66
2.	60	0.2	1	0.05, 0.05 χ=0.05	0.02, 0.03 χ=0.025	50.00
3.	60	1	0.25	0.04, 0.04	0.02, 0.02	50

				χ=0.04	χ=0.02	
4.	60	1	1	0.05, 0.08 χ=0.065	0.02, 0.02 χ=0.02	69.23
		Mean of above		**58.97%**		
5.	225	0.2	0.25	0.04, 0.05 χ=0.045	0.01, 0.02 χ=0.015	66.66
6.	225	0.2	1	0.06, 0.07 χ=0.065	0.04, 0.04 χ=0.04	38.46
7.	225	1	0.25	0.06, 0.05 χ=0.055	0.01, 0.02 χ=0.015	72.79
8.	225	1	1	0.12, 0.13 χ=0.125	0.06, 0.06 χ=0.06	52.00
		Mean of above		**57.48%**		

From the above Table 7 it is observed that the cryogenically treated bits show longer life than unprocessed bits hence better wear resistance during dry cutting situations. The percentage improvements of the treated inserts at various cutting conditions like cutting speed, feed, and depth of cut are tabulated in Table 7. It can be observed the cryogenically treated inserts yielded better tool life both at low and high speed. From the table it can be seen that the improvement of the tool life after deep cryogenic treatment were by an amount by 58% app. The above gain in tool life is due to the structural variations in tool material.

The cryogenic treatment is the extension process to conservative heat treatment processes. Cryogenic treatment is not a substitute for good heat treatment process, but it is an additional process which is done before tempering. The tool insert are cooled at excessively low temperature (-196°C) in the atmosphere of liquid Nitrogen in order to enhance the service life the tool through morphological changes occurring during this treatment. These days the carbide tipped tools are getting significant improvement on their tool wear residence due to cryogenic treatment. This treatment is neither a coating, nor a substitute for heat treatment and also not a remedy for bad heat treatment. Cryogenic treating creates changes to the inanimate structure of materials. The chief changes are to improve the scratch resistance and fatigue resistance. These changes include:

1. Retained Austenite to Martensite in hard Steels
2. Decrease Residual stress
3. Precipitates Fine Eta Carbides in Steel

Transformation of Austenite to Martensite include

- Lessening of Vacancies in Crystal Lattice
- Improvement of the Atom to Atom Spacing
- Re-Ordering of the Alloying Elements

This treatment improves the crystal construction of metals by reducing the millions of voids per cubic crystal lattice which makes a structure extra flawless. This labels the shifting of atoms in a crystal lattice subsequently austenite and martensite have dissimilar size crystal construction so there will be stresses produces in to the crystal structure where the two co-occur. Cryogenic process removes these stresses by shifting most of the retained austenite to martensite.

The process also boosts the precipitation of tiny carbide particles in tool steels to convert it into an alloying metal. These small carbides act as solid area there by increasing the coefficient of friction in the steel which adds to its wear resistance. The treatment also releases remaining stresses in metals and plastics.

The cryogenic treatment affects the entire volume of the material. It works remarkably with most coatings.

Speed, Feed and depth of cut

Feed, cutting Speed and depth of cut in both cases i.e. cryogenically treated as well as untreated influence flank wear. Speed and feed affect more than the depth of cut. Results under various cutting parameters have been obtained and it is very interesting to know that cryogenic treatment reduces the flank wear to great extent.

Discussion

In this study the investigations have been carried out by using C-45 work material along with uncoated tungsten carbide cutting tools. In this study flank wear of cutting tool is measured by using mitutoyo tool maker's microscope during orthogonal dry turning on C-45 rods. The influence of cryogenic treatment of cutting tools together with other cutting parameters (C. Speed, Feed, and Depth of cut) has been assessed. The readings were tabulated for various experiments to find the impact of cryogenic treatment. The results have shown that this treatment certainly improves tool life by reducing flank wear.

Conclusions and scope for future work

It is concluded that the wear of the flank of the cryogenically treated tool bits is less than the untreated ones. The tool life of these treated cutting tool bits is also better than raw bits. Hence, subjecting tool to cryogenic treatment results in better resistance to tool wear. Extra cutting parameters such as cutting speed, feed, and depth of cut also affect the flank wear. Speed and feed influence more than depth of cut. It is also in accordance with the previous work done.

The optimized parameters for increasing tool life for treated tools are cutting speed (61.48 mtr/min), feed (0.20 mm / rev) and depth of cut (0.25 mm). These improved results were authenticated with great accuracy.

Scope for Future Work:

It is recommended that the work of this study may be further extended by considering the following:

- The present work was on ferrous material similar investigations may be done for ferrous material using cubic born nitride (CBN) and diamond tools.
- The study may also be done using wet turning all machining using suitable conditions.
- The investigation may also be done on interrupted turning/machining rather than continuous. Thus, allowing the cutting tool to cool down and to its effect on tool life.
- Research may be done on multi point cutting tool instead of single point cutting tool.

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