EFFECT OF CRYOGENIC TREATMENT OF CEMENTED CARBIDE INSERTS ON PROPERTIES AND PERFORMANCE IN MACHINING OF ALUMINUM

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Abstract :

In this research paper, the influence of cryogenic treatment on different characteristics of CNMG 120408 MT TT8125 CEMENTED CARBIDE INSERT is presented. Further the performance in dry turning of Aluminum using untreated and cryo treated carbide inserts were evaluated. Microstructural characterisation and crystallographic orientation were studied with the help of scanning electron microscopy (SEM) and X-ray diffraction (XRD) respectively. The results indicated that cryo treatment resulted in formation of hard and wear resistant η phase. At the same time, the concentration of binder phase i.e. cobalt on the top surface region increased. The turning tests were conducted at three different cutting speeds (500, 600, and 700 rpm.) while feed rate and depth of cut were kept constant at 0.2 mm/rev and 0.5 mm, respectively. The influences of cryogenic treatment were investigated on the flank wear and chip characteristics. Both the worn parts of the cutting tools as well as the chips were also examined using SEM. The results showed that cryogenic treatment significantly improved the surface finish. The cryogenically treated demonstrated superior resistance to tool wear compared to its untreated counterpart in the entire range of cutting speeds. The chip thickness along with chip reduction coeffiecient was found to decrease for cryogenically treated insert compared to those for untreated insert during dry turning of Aluminum.

Keywords: Cryogenic treatment, cemented carbide, microstructure, dry turning, tool wear.

I. INTRODUCTION

Machining is a versatile technique of producing a wide variety of components from a wide range of materials with acceptable levels of dimensional accuracy and surface integrity. The advances in the field of materials Science and Technology have lead to development of new materials with improved engineering properties even for commonly used materials.

Even the strength and hardness of a variety of conventional engineering materials has increased many fold to keep pace with development of new materials.

Sintered carbides are extensively used as cutting tool material, a material in machining a wide variety of work materials in present day machining industry with proven machining abilities compared to HSS tool and cast alloy

Cryogenic treatment is carried out at low temperatures to convert the retained assistance to martensite phase, there by benefitting the improvements in tool life significally. The cryogenically treated tool inserts become so hard that brittleness also creeps in. To reduce the brittleness by retaining hardness post treatment becomes necessary in terms of tempering.

The tool inserts when subjected to low temperature tempering for predetermined time show the beneficial improvements. The process can be made more effective by subjecting the inserts to both air and furnace cooling.

"The combined effect of cryogenic treatment and tempering would benefit the inserts by the removal of residual stresses and proper segregation of carbide particles that will increase the hardness significally".

II. LITERATURE SURVEY

Cemented carbide is a modern cutting tool manufactured by mixing, compacting and sintering primarily tungsten carbide (WC) and cobalt (CO) powders. Co acts as a binder for the hard WC grains. The carbide tools have strong metallic characteristics having good electrical and thermal conductivity. They are chemically more stable, have high stiffness and exhibit lower friction, and operate at higher cutting velocities than HSS tools. But carbide tools are more brittle and more expensive than HSS. They are generally recommended for machining steel, K grade carbides and straight tungsten carbide grades with no alloying carbides. They are used for machining grey cost iron, non ferroy metals, and non metallic materials. M grade carbides re alloyed WC grades generally with less amount of Tic than the corresponding P Sires, and have wider application in machining austentic stainless steel, manganese steel as well as steel casting. Each grade within a group is assigned a number to represent its position from maximum hardness to maximum toughness (higher the number, tougher the tool).

Cryogenic treatment refers to the treatment of materials at very low temperatures generally around -183^{0}c which is much lower than cold treatment where temperatures are around -96^{0}c. The appreciable changes include the changes in the mechanical properties and in crystal structures of materials. However survey of literature shows that large part of the research work has been limited to cryogenic treatment on ferrous metals. Barron [3] performed abrasive wear tests on a wide variety of steel and concluded that metals which can exhibit retained austenite at room temperature can have the wear resistance significantly increased by subjecting them to cryogenic treatment. Collins [4] has explained in detail the process of austenite to martensite transformations and also explains how cryogenic treatment process can be used in combination with austeniting treatment to achieve either increase or decrease in hardness and increase or decrease in wear resistance for tool steels. Other related works show that both hardness and wear resistance of toll steels can improve simultaneously through cryogenic treatment. This was supported by Molinari [5]. Mohanlal [6] who also justified the simultaneous improvement of hardness and wear resistance of tool steels upon cryogenic treatment. Microstructure analysis on cryogenically treated tool steels indicate that treatment has increased the carbide population and also distributed the carbides evenly throughout the structure, resulting in improved wear resistance. [7]C. Maranhao, J.Paul Davim predicted, in machining of AISI 316 steel, the frictional drag encounters in the tool rake (between the tool and the work piece).

Techniques for improving performance of cutting tools:

Various cooling methods have been adopted for extending the tool life. Some of the technique involves conventional Flat cooling, Jet cooling, Mixed cooling in machining was found significant interest in research. Recently cryogenic cooling in machining was found significant interest in research. Alternating to enhance tool life is application of suitable coating materials on the surface of the cutting tools (PVD and CVD) was widely used technique for tool coating some of the famously used tool coating used Tic, TicN, TiN, Al2O3, Zin etc, This coating in general posses high wear resistance, hot hardness chemical in hardness, and antifriction properties that help the cutting tool to be operated under hostile cutting condition. Cryogenic treatment of cutting tools is the newest addition to the existing techniques for improving the cutting tool performance.

Cryogenic cooling approaches in metal cutting are classified in four groups according to application of researches:

Cryogenic pre cooling the work piece by repulsing or an enclosed both and cryogenic tool back cooling or conductive remote cooling, cryogenic Jet cooling by injection of cryogen to the cutting zone by general flooding or to the cutting tool edges or faces, tool-chip and tool – work interfaces by micro nozzles.

III. METHODOLOGY

1. Cryogenic Treatment:

In the present work, uncoated cemented Carbide cutting tool inserts of geometry CNMG 120408 MT TT8125 have been used.

The cryogenic treatment is as follows:

- Descend: A gradual lowering of temperature from room temperature to -196^{0}C.
- Soak:

  Case 1: Holding the temperature at -196^{0}C for 24 hours.

  Case 2: Holding the temperature at -196^{0}C for 12 hours.

  Case 3: Holding the temperature at -196^{0}C for 6 hours.
- Ascend: Subsequently raising the temperature back to room temperature.

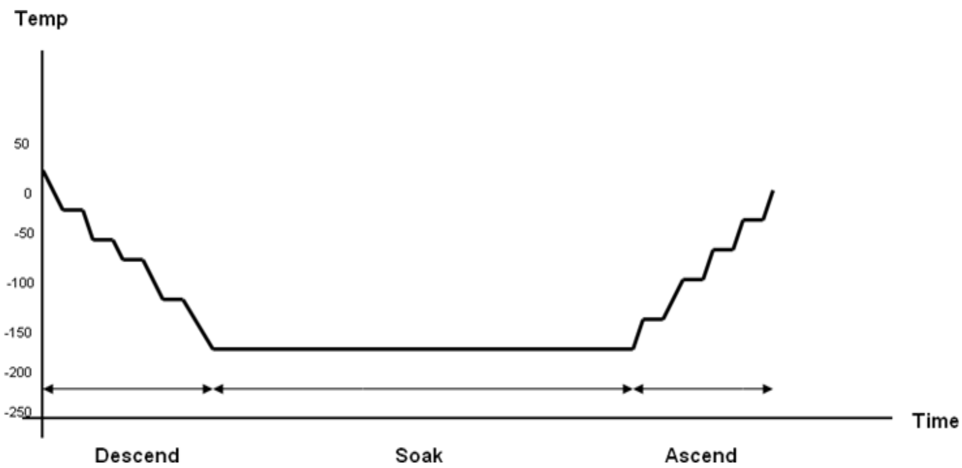


Fig.1: Cryogenic Treatment Cycle

Fig.2: Liquid Nitrogen container with gadget

2. Tempering:

For Cryo-Treated samples Tempering was done in electrical furnace at +196°C for 60 minutes, followed by air and furnace cooling

Fig.3: Electrical Furnace

3. Machining:

Machining was done by CNC Lathe Machine

Fig.4: CNC Turning Machine

4. Micro structure study:

The microstructures of both as received and treated inserts where studied under an scanning electron microscope for analyzing the phase distribution.

Fig.5: SEM Experimental Setup

5. Surface finish measurement:

Surface finish measurement was done by using Talysurf surface profile measuring machine.

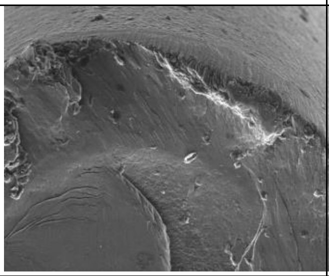
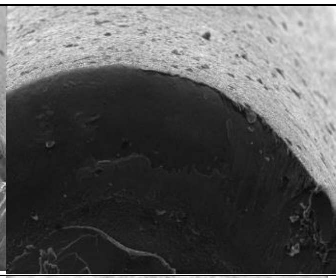
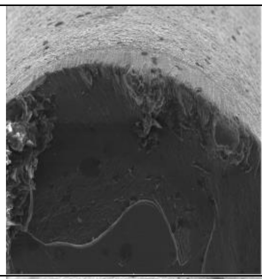
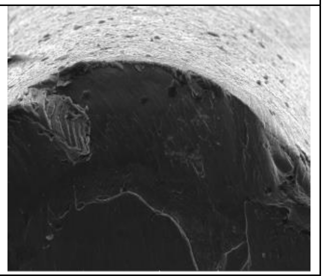
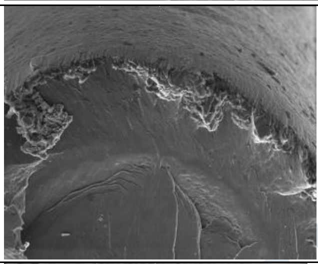
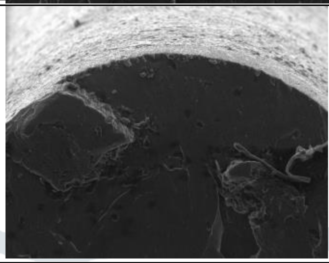
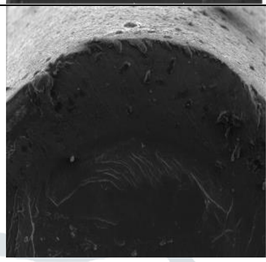
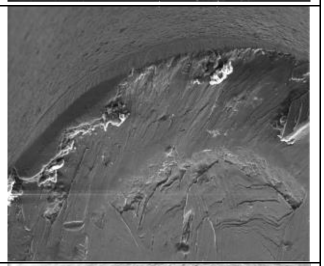
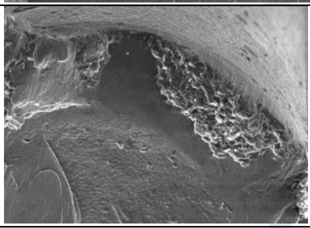
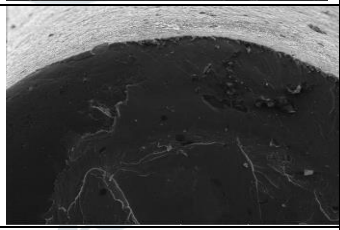
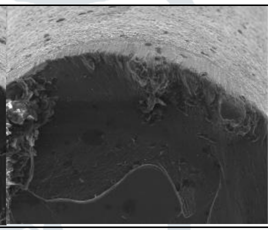
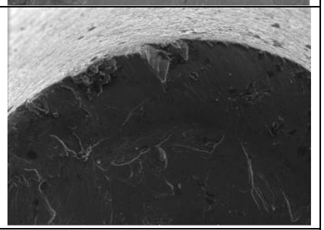
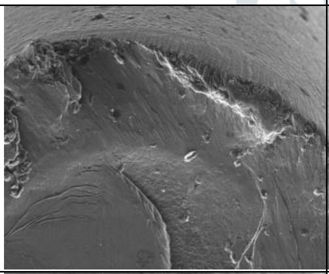
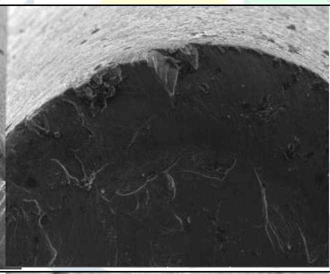
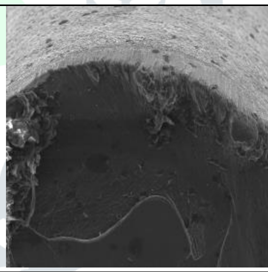
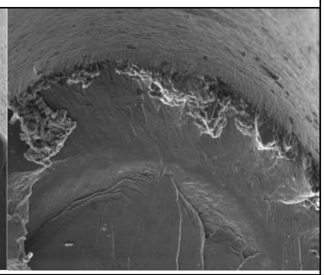
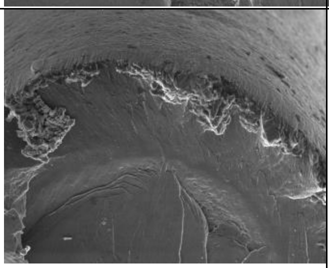
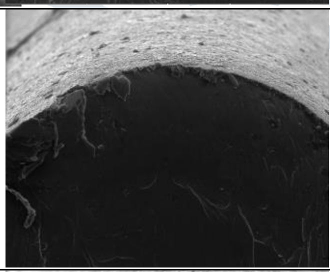
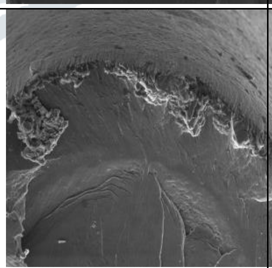
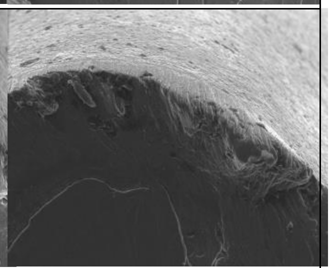
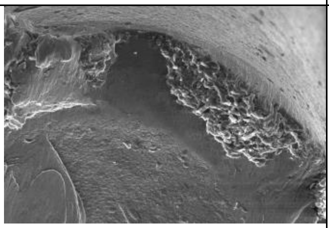
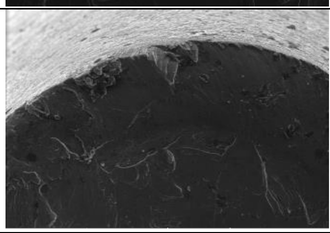
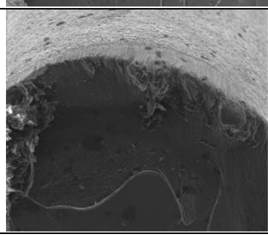
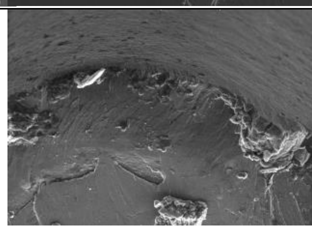
Fig.5: Talysurf surface profile measuring machine.

IV. EXPERIMENTS CONDUCTED:

S. no	CRYO - TREATMENT SOAKING TIME (in hrs)	AFTER HEAT TREATMENT TYPE OF COOLING	SPEED (rpm)	FEED (mm/rev)	DEPTH OF CUT (mm)
1	24	AIR	500	0.2	0.5
2	24	AIR	600	0.2	0.5
3	24	AIR	700	0.2	0.5
4	24	FURNACE	500	0.2	*0.5*
5	24	FURNACE	600	0.2	*0.5*
6	24	FURNACE	700	0.2	0.5
7	24	SUDDEN	500	0.2	0.5
8	24	SUDDEN	600	0.2	0.5
9	24	SUDDEN	700	0.2	0.5
10	12	AIR	500	0.2	0.5
11	12	AIR	600	0.2	0.5
12	12	AIR	700	0.2	0.5
13	12	FURNACE	500	0.2	0.5
14	12	FURNACE	600	0.2	0.5
15	12	FURNACE	700	0.2	0.5
16	12	SUDDEN	500	0.2	0.5
17	12	SUDDEN	600	0.2	0.5
18	12	SUDDEN	700	0.2	0.5
19	6	AIR	500	0.2	0.5
20	6	AIR	600	0.2	0.5
21	6	AIR	700	0.2	0.5
22	6	FURNACE	500	0.2	0.5
23	6	FURNACE	600	0.2	0.5
24	6	FURNACE	700	0.2	0.5
25	6	SUDDEN	500	0.2	0.5
26	6	SUDDEN	600	0.2	0.5
27	6	SUDDEN	700	0.2	0.5
28	Un treated	-	500	0.2	0.5
29	Un treated	-	600	0.2	0.5
30	Un treated	-	700	0.2	0.5

Table.1: Experiments conducted

V. RESULTS AND DISCUSSIONS:

	Un treated	Cryo treated – 24hrs soaking – Air cooling	Cryo treated – 12hrs soaking – Air cooling	Cryo treated – 6hrs soaking – Air cooli90ng
Speed(rpm)				
700				
600				
500				
	Un treated	Cryo treated – 24hrs soaking – Furnace cooling	Cryo treated – 12hrs soaking – Furnace cooling	Cryo treated – 6hrs soaking – Furnace cooling
Speed (rpm)				
700				
600				
500				
	Un treated	Cryo treated – 24hrs soaking – Sudden Cooling	Cryo treated – 12hrs soaking – Sudden Cooling	Cryo treated – 6hrs soaking – Sudden Cooling
Speed(rpm)				

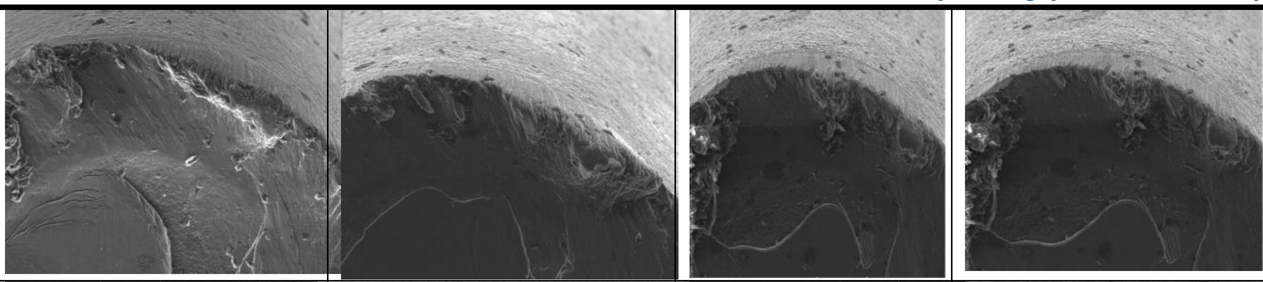
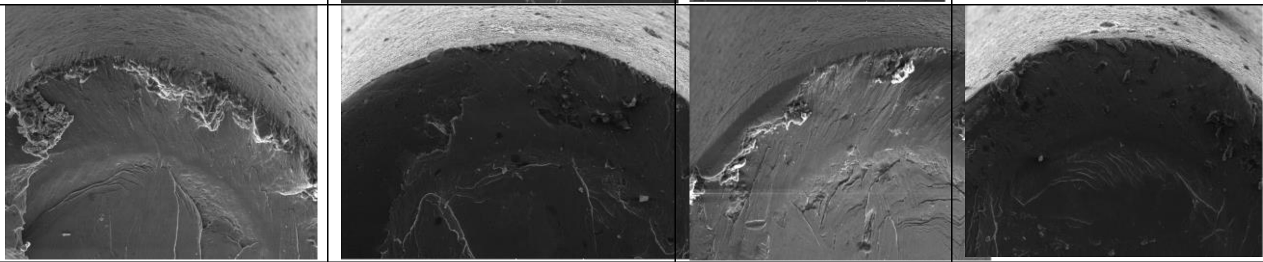
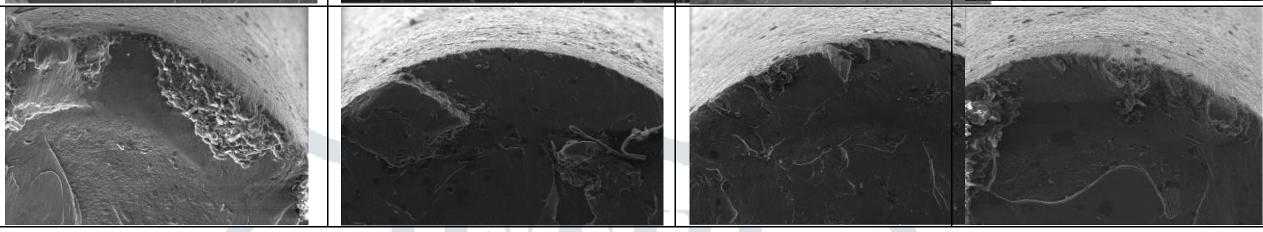
700	
600	
500	

Table.2: After Machining SEM Images of Treated and Un Treated Inserts.

It is clearly observed from the experiment that in all the machining trials the growth of flank wear more or less showed the established pattern (Table2). Under all cutting velocities, Cryo-treated and tempered inserts provided the highest tool life followed by Cryo-treated tool inserts. Initially flank wear of both types of inserts is same but with consequent machining, cryogenically treated inserts showed less flank wear compared to untreated inserts. Also the tool life is reduced at high cutting speed. There was a gradual improvement in tool life observed in samples after treatment. The maximum tool life was shown by Cryo-treated and tempered at 196^{0}C followed by air cooling. Higher wear rate of untreated inserts during the machining can be attributed to coarse carbide structure.

MICROSTRUCTURE ANALYSIS: SEM MICROGRAPHS

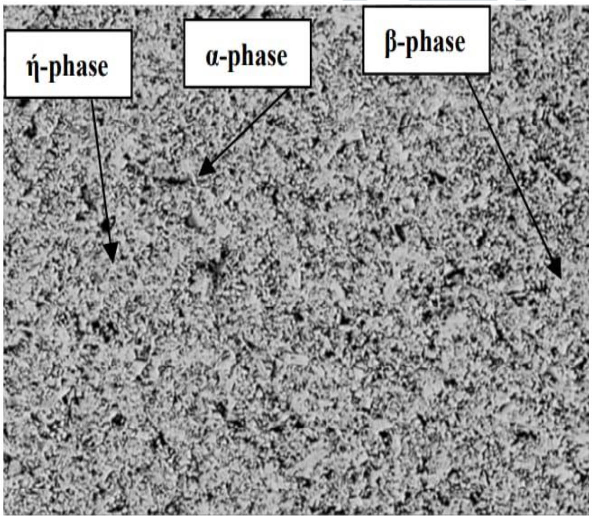


Fig.6: Untreated Insert.

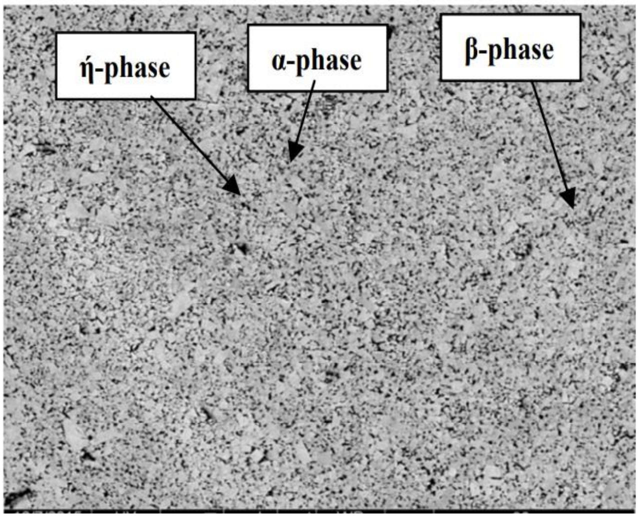


Fig.7: Cryo Treated Insert.

In the Fig.6 & Fig.7 the grey phase represent tungsten carbide (α-phase), White region specify cobalt binder (β-phase), Dark field (ή-phase).

- Compared to untreated samples, treated samples shown better segregation of carbide particles.
- Treated samples shown increased population of carbide phase which would have been the result of cryogenic treatment.
- This justifies the conversion of retained austenite to martensite and hence the hardness of material increased which results in improvement of wear resistance.

EXPERIMENTAL RESULTS OF SURFACE FINISH:

S. no	CRYO - TREATMENT SOAKING TIME (in hrs)	AFTER HEAT TREATMENT TYPE OF COOLING	SPEED (rpm)	Ra VALUE (MICRO METER)	SURFACE FINISH
1	24	AIR	500	0.480	Ground finish
2	24	AIR	600	0.575	Ground finish
3	24	AIR	700	0.027	Super finish
4	24	FURNACE	500	0.947	Ground finish
5	24	FURNACE	600	1.050	Smooth turned
6	24	FURNACE	700	1.567	Smooth turned
7	24	SUDDEN	500	1.998	Smooth turned
8	24	SUDDEN	600	1.388	Smooth turned
9	24	SUDDEN	700	1.253	Smooth turned
10	12	AIR	500	0.758	Ground finish
11	12	AIR	600	0.853	Ground finish
12	12	AIR	700	0.540	Ground finish
13	12	FURNACE	500	1.491	Smooth turned
14	12	FURNACE	600	1.866	Smooth turned
15	12	FURNACE	700	1.132	Smooth turned
16	12	SUDDEN	500	2.441	Smooth turned
17	12	SUDDEN	600	2.050	Smooth turned
18	12	SUDDEN	700	1.576	Smooth turned
19	6	AIR	500	0.895	Ground finish
20	6	AIR	600	0.570	Ground finish
21	6	AIR	700	1.565	Ground finish
22	6	FURNACE	500	0.903	Ground finish
23	6	FURNACE	600	0.974	Ground finish
24	6	FURNACE	700	1.678	Smooth turned
25	6	SUDDEN	500	1.119	Smooth turned
26	6	SUDDEN	600	1.831	Smooth turned
27	6	SUDDEN	700	1.061	Smooth turned
28	Un treated	-	500	2.461	Smooth turned
29	Un treated	-	600	2.982	Smooth turned
30	Un treated	-	700	1.981	Smooth turned

It is clearly observed from the experiment that in all the machining trials the cryo treated and tempered inserts provide better surface finish than the untreated inserts. The best surface finish was shown by cryo treated (24 hrs soaking) and tempered at 196^0C followed by air cooling.

VI. CONCLUSIONS:

- Cryogenic Treatment and tempered Cemented Carbide tool insert converts the retained austenite to martensite phase and hence the hardness of material increased which results in improvement of wear resistance.
- Cryogenic Treatment of Cemented Carbide tool inserts result in improved surface finish.
- The observed wear patterns in treated samples show regular and well established trend.
- Since Tungsten is hard material, the densification of binder Cobalt phase takes place improving tool life.

VII. REFERENCES:

1. R.G.Deshpande 1, K.A. Venugopal, Machining with cryogenically treated carbide cutting tool inserts.
2. Nirmal S Kalsia1, Rakesh Sehgalb, Vishal S Sharma C, Effect of tempering after cryogenic treatment of tungsten carbide-cobalt bounded inserts.
3. Barron RF Cryogenic treatment of metal to improve wear resistance, Cryogenics 22(5) (1982) 409-413.
4. Collins D.N. Cryogenic treatment of tool steels advanced material process, 154 (6):H23-H29 (1998).
5. Molinari A, Pelizerzi S, Straffelini G, Stiansy KH Effect of deep cryogenic treatment on the mechanical properties of tool steels and material process technology 118(3): (2001), 350-355.
6. Mohanlal D, Rangnarayanum S Kalanidi A cryogenic treatment to augment wear resistance of tll and die steels. Cryogenics 41 (3): (2001), 149-155.
7. Huang JY, Zhu TY, Liao XZ, Beyerien IJ, Bourke MA, Mitchel TE. Microstructure of cryogenically treated M2 tool steels. Matter SciEngg. A; 339: 2003, 241-4.