



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJIRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**

# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 11, Issue 9, September 2022

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

Impact Factor: 8.118

9940 572 462

6381 907 438

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# Investigation on the Effect of Cryo Treated & Performance of Cutting Tool Inserts

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**ABSTRACT:** In this investigation, 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 characterization 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  $\eta$  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 (600, 700, and 800 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 coefficient 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 led 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 austenite to martensite phase, thereby benefiting the improvements in tool life significantly. 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 significantly.

## 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 cast iron, non ferrous metals, and non metallic materials. M grade carbides are alloyed WC grades generally with less amount of TiC than the corresponding P grades, and have wider application in machining austenitic 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  $-183^{\circ}\text{C}$  which is much lower than cold treatment where temperatures are around  $-96^{\circ}\text{C}$ . 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 austenitizing 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 tool 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).

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, Al<sub>2</sub>O<sub>3</sub>, 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 toolperformance.

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  $-196^{\circ}\text{C}$ .
- Soak:
  - Case 1: Holding the temperature at  $-196^{\circ}\text{C}$  for 48 hours.
  - Case 2: Holding the temperature at  $-196^{\circ}\text{C}$  for 24 hours.
  - Case 3: Holding the temperature at  $-196^{\circ}\text{C}$  for 12 hours.
- Ascend: Subsequently raising the temperature back to room temperature.

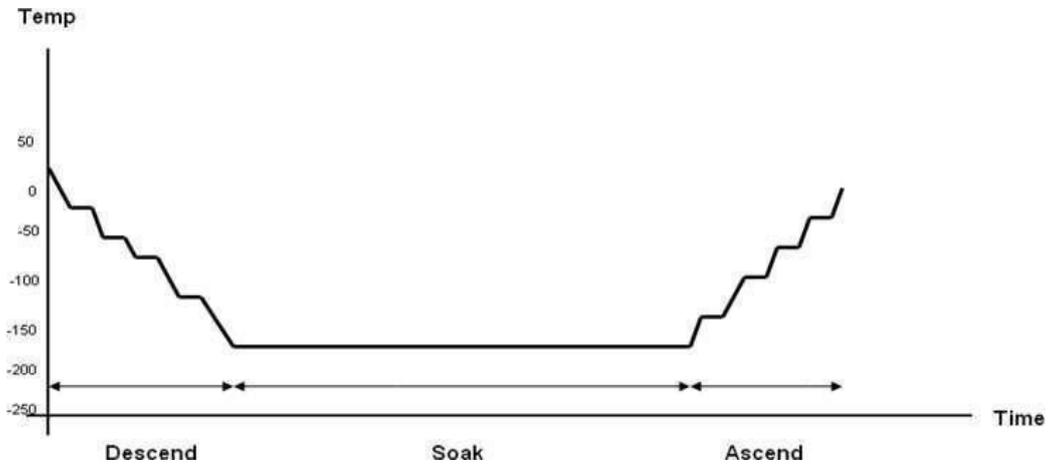


Fig.1: Cryogenic Treatment Cycle



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. Micro structure study:

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



Fig.5: SEM Experimental Setup Fig.6: Talysurf surface profile measuring machine.

4. Surface finish measurement:

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



**IV. EXPERIMENTS CONDUCTED**

Table.1: Experiments Values

S. no	CRYO - TREATMENT SOAKING TIME ( in hrs )	AFTER HEAT TREATMENT TYPE OF COOLING	SPEED ( rpm )	FEED ( mm/rev )	DEPTH OF CUT ( mm )
1	48	AIR	600	0.2	0.5
2	48	AIR	700	0.2	0.5
3	48	AIR	800	0.2	0.5
4	48	FURNACE	600	0.2	0.5
5	48	FURNACE	700	0.2	0.5
6	48	FURNACE	800	0.2	0.5
7	48	SUDDEN	600	0.2	0.5
8	48	SUDDEN	700	0.2	0.5
9	48	SUDDEN	800	0.2	0.5
10	24	AIR	600	0.2	0.5
11	24	AIR	700	0.2	0.5
12	24	AIR	800	0.2	0.5
13	24	FURNACE	600	0.2	0.5
14	24	FURNACE	700	0.2	0.5
15	24	FURNACE	800	0.2	0.5
16	24	SUDDEN	600	0.2	0.5
17	24	SUDDEN	700	0.2	0.5
18	24	SUDDEN	800	0.2	0.5
19	12	AIR	600	0.2	0.5
20	12	AIR	700	0.2	0.5
21	12	AIR	800	0.2	0.5
22	12	FURNACE	600	0.2	0.5
23	12	FURNACE	700	0.2	0.5
24	12	FURNACE	800	0.2	0.5
25	12	SUDDEN	600	0.2	0.5
26	12	SUDDEN	700	0.2	0.5
27	12	SUDDEN	800	0.2	0.5
28	Un treated	-	600	0.2	0.5



29	Un treated	-	700	0.2	0.5
30	Un treated	-	800	0.2	0.5

V. RESULTS AND DISCUSSIONS

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

	Un treated	Cryo treated – 24hrs soaking – Air cooling	Cryo treated – 12hrs soaking – Air cooling	Cryo treated – 6hrs soaking – Air cooling
Speed (rpm)				
800				
700				
600				
	Un treated	Cryo treated – 24hrs soaking – Furnace cooling	Cryo treated – 12hrs soaking – Furnace cooling	Cryo treated – 6hrs soaking – Furnace cooling
Speed (rpm)				
800				



700				
600				
	Un treated	Cryo treated – 24hrs soaking – Sudden Cooling	Cryo treated – 12hrs soaking – Sudden Cooling	Cryo treated – 6hrs soaking – Sudden Cooling
Speed (rpm)				

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<sup>o</sup>C followed by air cooling. Higher wear rate of untreated inserts during the machining can be attributed to coarse carbide structure.

**Microstructure Analysis**

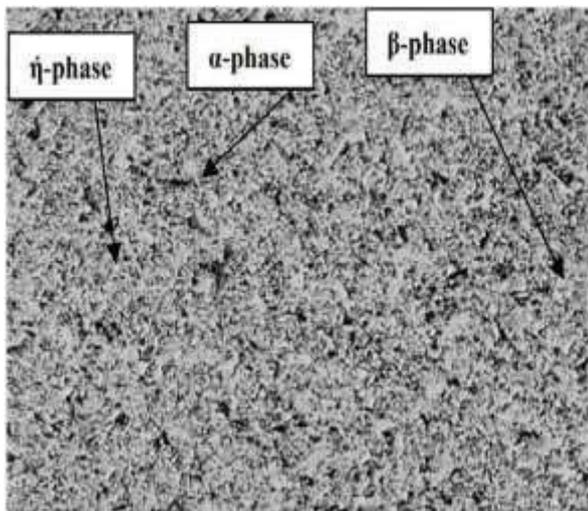


Fig.6: Untreated Insert.

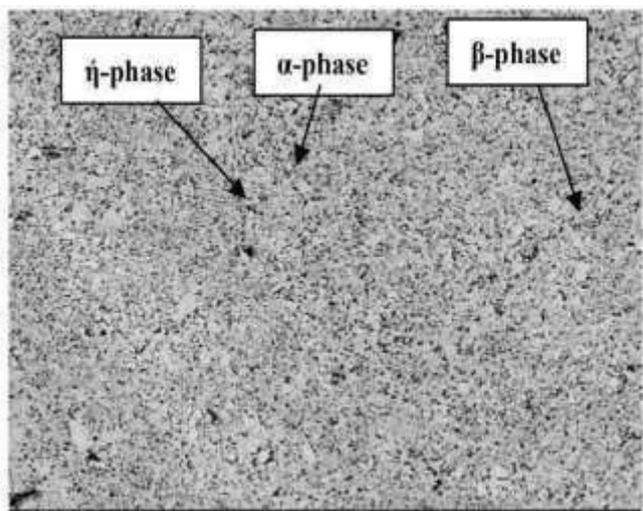


Fig.7: Cryo Treated Insert.



In the Fig.6 & Fig.7 the grey phase represent tungsten carbide ( $\alpha$ -phase), White region specify cobalt binder ( $\beta$ -phase), Dark field ( $\eta$ -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.

Table 3. 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	48	AIR	600	0.480	Ground finish
2	48	AIR	700	0.575	Ground finish
3	48	AIR	800	0.027	Super finish
4	48	FURNACE	600	0.947	Ground finish
5	48	FURNACE	700	1.050	Smooth turned
6	48	FURNACE	800	1.567	Smooth turned
7	48	SUDDEN	600	1.998	Smooth turned
8	48	SUDDEN	700	1.388	Smooth turned
9	48	SUDDEN	800	1.253	Smooth turned
10	24	AIR	600	0.758	Ground finish
11	24	AIR	700	0.853	Ground finish
12	24	AIR	800	0.540	Ground finish
13	24	FURNACE	600	1.491	Smooth turned
14	24	FURNACE	700	1.866	Smooth turned
15	24	FURNACE	800	1.132	Smooth turned
16	24	SUDDEN	600	2.441	Smooth turned
17	24	SUDDEN	700	2.050	Smooth turned



18	24	SUDDEN	800	1.576	Smooth turned
19	12	AIR	600	0.895	Ground finish
20	12	AIR	700	0.570	Ground finish
21	12	AIR	800	1.565	Ground finish
22	12	FURNACE	600	0.903	Ground finish
23	12	FURNACE	700	0.974	Ground finish
24	12	FURNACE	800	1.678	Smooth turned
25	12	SUDDEN	600	1.119	Smooth turned
26	12	SUDDEN	700	1.831	Smooth turned
27	12	SUDDEN	800	1.061	Smooth turned
28	Un treated	-	600	2.461	Smooth turned
29	Un treated	-	700	2.982	Smooth turned
30	Un treated	-	800	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 (48 hrs soaking) and tempered at 196<sup>0</sup>C followed by air cooling.

**EDS Analysis:**

The composition of the top surface of both the untreated and cryo treated were examined using energy dispersive spectroscopy (EDS) through X-ray. EDS spectra along with chemical composition demonstrated that some change in composition took place on the surface of the inserts after cryo treatment. Notable changes include increase in concentration of Co and C on the top surface of cryo treated inserts. This shows that redistribution and densification of Co took place on the top surface of cryo treated inserts. Increase in C percentage may be attributed to the formation of η phase carbides which were also revealed from SEM images. The increase in binder phase might be helpful in enhancing the bonding strength of WC particles.

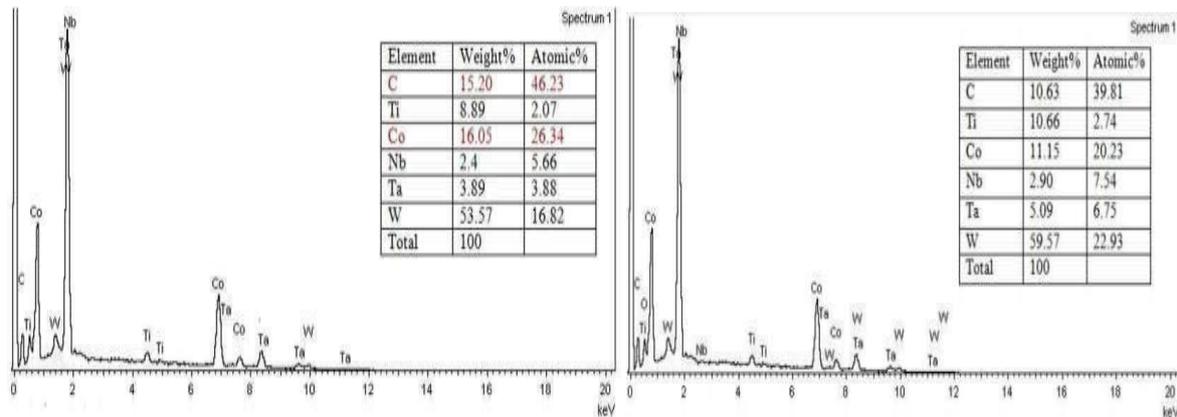


Fig. 6. X-RD Analysis

### VI. CONCLUSIONS

- Cryogenic treatment of CNMG 120408 MT TT8125 cemented carbide inserts results in change in microstructure, formation of  $\eta$  phase carbides and redistribution or densification of Co which automatically increase wear resistance.
- Smooth and more regular wear pattern were observed for cryogenically treated inserts
- Cryogenic treatment also improved resistance to chipping.
- 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.

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