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A Study on Micromachining And Effects of Cryogenic Treatment on Micro End Mill Cutters.

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Abstract: *The research in micromachining has been started from last decade. The demand of microcomponent and microproduct is increasing progressively in electronics, optics, medical and automobile sectors. As machining dimensions diminishes from macro to micro, machining conditions varies which affect tool life, cutting forces and surface machined. Numerous efforts are in progress which attempts to enhance the tool performance. Cryotretment of cutting tools gives improved hardness, strength and wear resistance due to the precipitation of η (eta) carbide in metal matrix. In macromachining cryotreated tools performed well and ample of literature is available while the applications of cryotreatment for micro cutting tools, its characterization and performance are emerging area. In present paper the effects of cryotreatment on micro end mill cutters have been investigated.*

Keywords : *Micromachining, Cryotreatment, Tungsten Carbide, Size Effects*

I. Introduction

The demand of micro component is increasing in aerospace, biomedical and automobile industry. It has been found that, photolithography base micromanufacturing techniques have some limitation regarding use of material as it is applicable only for silicon, copper and Ni alloys. Micro cutting have some solution to overcome the limitation of photolithography process. Improving the life of micro cutting tool is the requirement of micro machining. [6]

Size effect, material homogeneity, minimum chip thickness these are the some concepts which differentiate micromachining from macromachining. In the study it has been found that, in micromachining the rapid tool wear generates higher cutting forces and this deteriorates surfaces. It is expected by improving tool life, the performance of micromachining can be improved. A few approaches have been proposed to overcome the tool failure and to make micromachining (preferably cutting) more suitable. The first approach involves the use of cutting fluids to provide cooling and lubrication. However, it is very difficult to transport the cutting fluid to the cutting zone and tool-workpiece interfaces due to the high cutting speeds and the small size of the contact zone. This limitation is also true to a great extent in macroscale machining.

The second approach involves the application of coatings on the micro tool surfaces to reduce wear. This approach is routinely adopted at the macroscale to enhance tool life. Although a few researchers have demonstrated that coatings prolong micro tool life to an extent but coatings become futile once it gets removed from the substrate. In the third approach; hybrid machining, for e.g. laser assisted micromachining, some researcher reported that poor surfaces while machining along with high set up cost. While considering the above issue the fourth approach is there i.e. Cryogenic treatment of cutting tools.

Cryogenic treatment, which is also known as sub-zero heat treatment, has made significant contributions to the improvement of wear resistance, tool life and dimensional integrity. Moreover, in cryogenic treatment the formation of martensite and precipitation of η- phase is body phenomena so gives better hardness and wear resistance than coating on cutting tool.

In contrast to macromachining, de-burring, size effects, minimum chip thickness due to grain size, hardness, impurities, homogeneities, defects in workpiece affects micromachining processes dominantly. When complicated parts are machined, cutting tool radius immediately chip-off due to tool wear, so tool life improvement is essential to make micro cutting easier [9]. This paper thus aimed at critical review of cryogenic treatment of specifically micromachining tools. It has been observed that that, the applications of cryogenic treatment for micro cutting tool, its characterization and performance analysis is nascent area for micromachining. Further, a very little work of cryotreated cutting tool has been found in micro cutting.

II. Tool Material

Tungsten carbide cutting tools is composite of very hard tungsten carbide grains in binder matrix of tough cobalt metal made by liquid phase sintering method. Figure 1 shows the tungsten carbide (WC) hard phase which forms a continuous structure throughout the bulk of material, called the ceramic skeleton. Also the soft cobalt binder phase (Co) forms a continuous network structure [4].

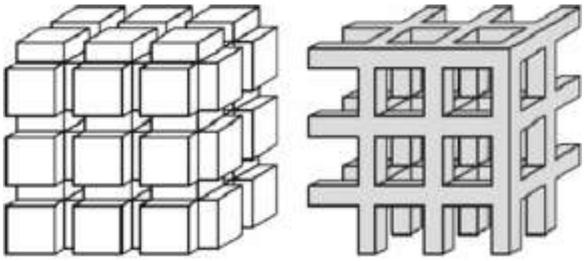


Figure 1: Hard tungsten carbide skeleton and soft cobalt binder form a composite of WC-Co [4].

The following phases are generally present in metallographic microstructure of cemented tungsten carbides:

Table 1: Phases in WC-Co [4]

Phase	**Definition of phase**
α- Alpha	(Tungsten carbide- WC)
B- Beta	Cobalt binder
γ - Gamma	Carbide of a cubic lattice (TaC ,TiC, , NbC) that may contain other carbides
η- Eta	Multiple complex carbides Co6W6C (M12C), Co3W3C (M6C),

The formation of η phase while cryogenic treatment gives the improved tool life and better abrasive wear resistance to tungsten carbide tool. It has been found that the proportion of η phase increases while cryo treatment and it act as filler in the larger carbide. As η phase is harder than the rest of the material, it enhances the fracture toughness of the cutting tool. The growth of η phase depends on the selection of cryogenic parameter so it will give optimum hardness [3].

According to Gill *et. al.* (2012) hard phase particles of tungsten carbide are refined into their most stable form via the phenomenon of spherodization. It also aligns the hard phase carbide particulate structure into a durable, stress-free crystallographic configuration. This reduces the risk of stress-induced fractures. The fine eta (η) carbide particles precipitate during the cryogenic treatment. These are in addition to the larger carbide particles present before cryogenic treatment. These fine particles act as fillers along with the larger particles to form a denser, more coherent, and much tougher matrix in the material. At the same time cryogenic treatment relieve the residual micro stresses in the tools while sintering process which is main cause for tool failure [1, 4, 8].

III. Experimental Details

Carbide tools has wide use in industrial applications, Micro end mills and drills are generally made from tungsten carbide has high hardness and strength [19]. In the present work, tungsten carbide with 10% of cobalt, axis made micro end mills (E9661) have been used. The geometry of tools shown in figure 2.

d-0.8, l- 2.4, D- 3, L- 38 (All Dimensions are in mm.)

Figure 2: Geometry of micro end mill cutters (Axis catalogue)

Cryogenic treatment applied at temperature -80˚C to -140 ˚C is termed as shallow treatment while, temperature between -140˚C to -196˚C is termed as deep cryogenic treatment. To study the effects of both, i.e. Shallow (SCT) and deep (DCT), both temperatures taken for study 8 hr soaking period. Applied cryo-cycles on micro end mills is as shown in Table 2.

Sr No	Soaking temperature	Soaking period	Tempering temp and period	Quantity of tools
1	untreated	-	-	1
2	-100˚C	8, hr	150˚C for 2 hr	1
3	-180˚C	8, hr	150˚C for 2 hr	1

Table 2: Applied cryogenic treatment parameters

Liquid nitrogen is used for cryotreatment of cutting tools followed by tempering treatment at 150˚C for 2 hr. The purpose of tempering is to relieve the internal stresses of tools. Figure 3 shows the set-up of cryogenic treatment and tempering furnace respectively.

Figure 3 : (a) Cryogenic treatment set up **(b) Tempering furnace**

IV. Results And Discussion

3.1 Microhardness Test

To examine the effects of cryotreatment on micro end mill carbide tools Vickers micro hardness test is conducted at the load of 0.5 kg according to ASTM E384-09. Wire cut EDM is used to cut the tools and 3 readings are taken from core to surface with equal distance of 500 µm and average of three values is used to plot the graph. The effects of shallow and deep cryotreatment at different soaking period on micro end mill is as shown in figure 4.

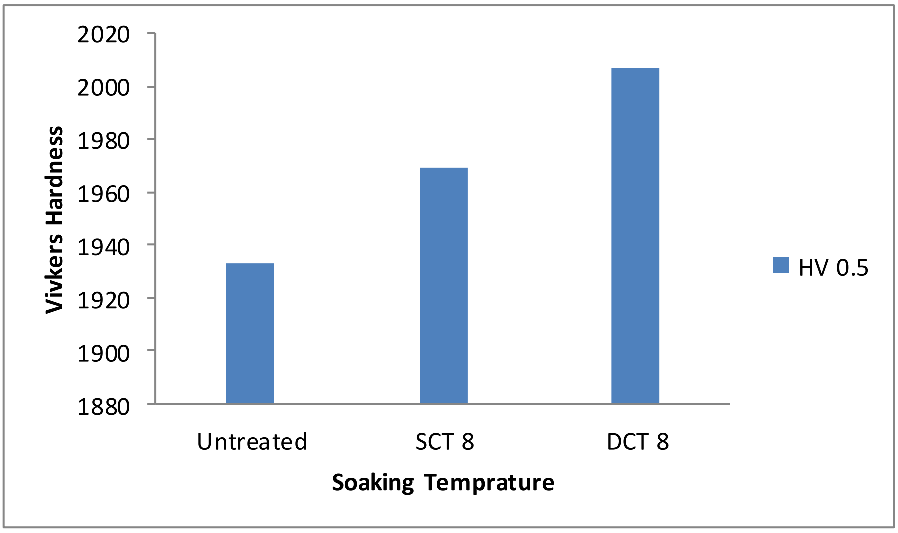
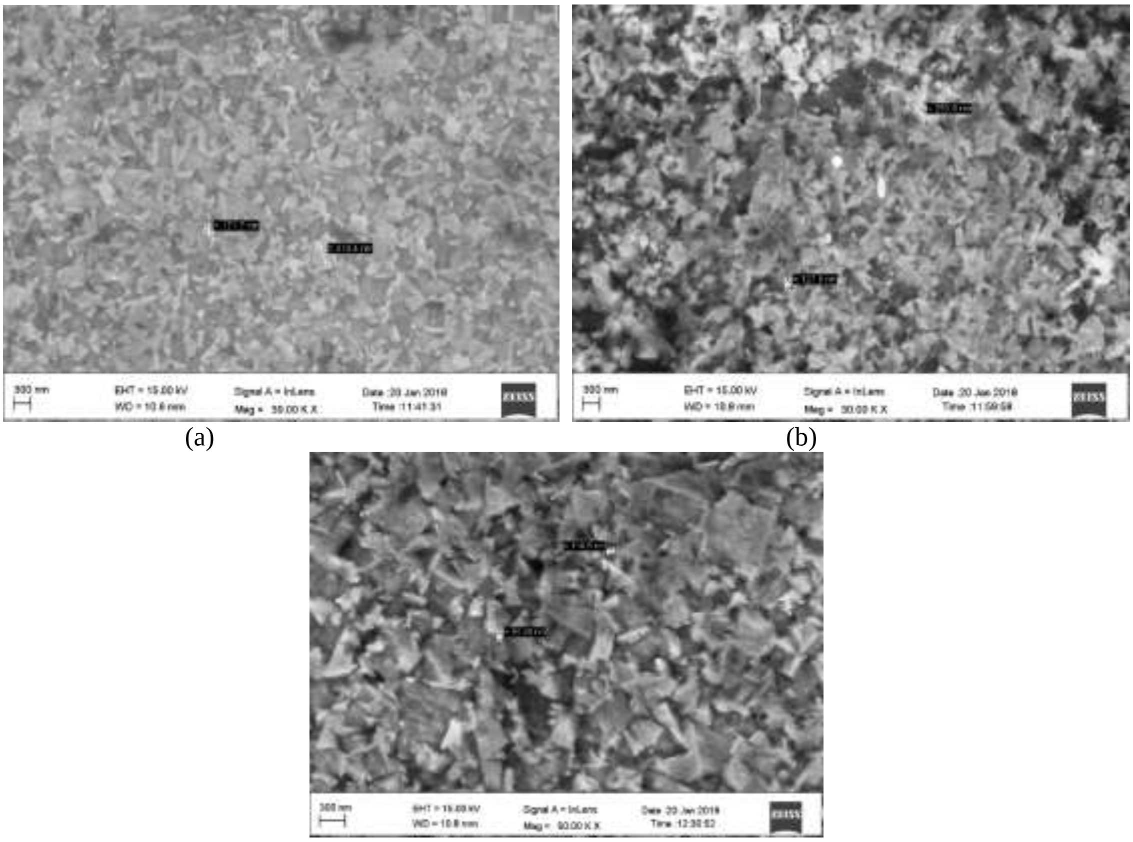


Figure 4: Microhardness value of untreated and cryotreated tools

It has been found that, the microhardness value increased for both shallow and deep cryotreatment as compare to untreated tool. This might be attributed to formation of new η carbide in metal matrix and refinement of grain structure. The highest microhardness valueis obtained for deep cryotreated for 8 hour (-180ºC). This shows that as temperature reduces the rate of precipitation increases.

3.2 Scanning electron microscopy (SEM)

Scanning electron microscope images are taken to observe the microstructure of micro tungsten carbide end mill cutters. Figure 4 (a-c) shows the SEM images of untreated shallow cryotreated for 8 hour and deep cryotreated for 8 hr.



(a) (b)

(c)

Figure 4: SEM images of (a) untreated (b) SCT 8 (c) DCT 8

From figure 4 (b) (c) it is clear that the size of α phase (tungsten carbide) particle increased after cryogenic treatment , this might be attributed to increase the hardness of micro end mills after cryogenic treatment.

V. Conclusions

From the experimental work following conclusion can be drawn:

1) Cryogenic treatment improves the mechanical properties of conventional tools.

2) Size effects, material homogeneity and minimum chip thickness are phenomenon which differentiate micromachining from macromachining

3) The hardness of micro tungsten carbide tools increased after cryotreatment.

4) It is found that, the size of α phase particle increased after cryotreatment, this might be reason to increase the hardness of microtools.

References

[1]. Nursel Altan Özbek, Adem Çiçek,, Mahmut Gülesin, Onur Özbek, "Investigation of the effects of cryogenic treatment applied at different holding times to cemented carbide inserts on tool wear ", International Journal of MachineTools & Manufacture86(2014)34–43, (2014).

[2]. Simranpreet Singh Gill, Harpreet Singh , Rupinder Singh &,Jagdev Singh, "Cryoprocessing of cutting tool materials—a review", International Journal Advance Manufacturing Technology, (2010) 48:175–192, , (2010).

[3]. Sıtkı Akincioğlu and Hasan Gökkaya and İlyas Uygur, "A review of cryogenic treatment on cutting tools", International Journal Advance Manufacturing Technology, January 2015 .

[4]. Simranpreet Singh Gill , Jagdev Singh , Rupinder Singh and Harpreet Singh, "Metallurgical principles of cryogenically treated tool steels—a review on the current state of science", International Journal Advance Manufacturing Technology ,(2011) 54:59–82, (2011).

[5]. A. Y. L. Yong. K. H. W. Seah . M. Rahman, "Performance of cryogenically treated tungsten carbide tools in milling operations", Int. Journal Advance Manufacturing Technology (2007) 32: 638–643, (2007).

[6]. Petar Piljek, Zdenka Keran and Miljenko Math" micromachining – review of literature from 1980 to 2010", Interdisciplinary Description of Complex Systems 12(1), 1-27, 2014.

[7]. Shreyas T. Dhande, Vijay A. Kane, Chandrashekhar L. Gogte, " Cryogenic Treatment of Tungsten Carbide Tools: Review ", International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064, (2014).

[8]. Swamini A. Chopra and V. G. Sargade, "Metallurgy behind the Cryogenic Treatment of Cutting Tools: An Overview", 4th International Conference on Materials Processing and Characterization, Materials Today: Proceedings 2 (2015) 1814 – 1824, (2015).
[9]. Ajish T.N, Dr. Govindan P , "Effects and challenges of tool wears in micro milling by using different tool coated materials". IJRMET Vol. 4, Issue 2, May - October 2014
[10]. Ajit Behera, "Comparative study of cryo-treated steel", Indian Institute of Technology, Kharagpur.
[11]. http://www.heat-treat-doctor.com/ A discussion of Retained Austenite. *The Heat Treat Doctor*, date of access 10 may2017.
[12]. https://www.quora.com/Why-cant-cast-iron-be-welded, date of access, 10 May 2017.
[13]. D.Dornfeld, S.Min and Y Takeuchi, "Recent advances in mechanical micromachining", CIRP Annals, 55, 2, pp,. 01-01-2006.
[14]. M. Pratheek and Anil Kumar Jain, "Micromachining of borosilicate glass wafers using rotary ultrasonic machine- experiment and analysis", 3rd International Conference on Materials for the Future - Innovative Materials, Processes, Products and Applications, Paper ID: icmf154, November 2013.
[15]. Patel piljek, Zdenka keran, and Miljenko Math, "Micromachining- review of literature from1980 to 2010", interdisciplinary description of complex system, 12(1), 1-27. 2014.
[16]. Aamer Jalil Mian, "Size effects in micromachining", thesis *submitted to the* university of manchester *for the degree of* Doctor of Philosophy in the faculty of Engineering and Physical Sciences, (2011).
[17]. Samad Nadimi Bavil Oliaei1 & Yiğit Karpat," Influence of tool wear on machining forces and tool deflections during micro milling", Int. Journal Advance Manufacturing Technology DOI 10.1007/s00170-015-7744-4,(2015).
[18]. F. Ducobu , E. Filippi, E. Rivière-Lorphèvre , "Chip formation and minimum chip thickness in micro-milling", Faculté Polytechnique de Mons, Service de Génie Mécanique, Rue du Joncquois 53, B-7000 Mons (Belgium).
[19]. J.Chae, S.S. Park, T.Freiheit, "Investigation of Micro-Cutting Operations", Intwenational journal of Machine Tools & Manufacture 46(2006) 313-332