Cryogenic Treatment of Carbon Boron Nitride (CBN) Tools: Review

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Abstract: In this review paper, the information is presented mainly on cryogenic treatment technology on cutting tools, the cryogenic treatment is a process complementary to conventional heat treatment, involves the deep freezing of materials at cryogenic temperatures to improve the physical and mechanical properties. The execution of the cryoprocessing on cutting tools materials increases the resistance to wear, hardness and reduces the consumption of tools and the downtime for the configuration of the machine tool, which entails a reduction of costs. The objective of this review paper is the comparison between the cryogenic treated tool (CBN) and the untreated tool (CBN) and also shows a new development in the prediction of the tool life of the tool wear. The present paper summarizes the state of art about CT of CBN material, cryogenic treatment method, parameters, and results.

***Keywords*: Cryogenic treatment, CBN Tool, Tool life, Tool wear, Liquid nitrogen**

1. Introduction

The cutting tool material commonly used in conventional the machine tools are made of high speed steel. As the technology has been advancing more quickly, cutting tool materials such as Cemented carbides and ceramics are needed to machine many materials that are difficult to machine at higher cutting speeds and material removal rates (MRR) with performance reliability [3]. In industrial application most of the hard material is machined by carbon boron nitride (CBN) tool. Out of, we selected the OHNS material, because it is used for manufacturing of die. In die manufacturing process, milling operation is required. In milling process, there is lots of problem face by the industry regarding life of tool. In recent years, increased interest in the effects of low temperature on tool and die materials, particularly CBN tools has been tested. Over the past few years, there has been an increase in the application of cryogenic treatment to different types of materials. Research has shown that cryogenically treated tool increases tool life, and in most cases provides additional qualities to the tool, such as stress relief, hardness, toughness, etc. This method consists of cooling the material at low temperature (165 K to 88 K). These materials are kept at that temperature (soaking) for some time and then heated gradually to room temperature. The present study focused on the cryogenic treatment of CBN tool.

2. LITERATURE REVIEW

2005 A. Y. L. Yong . K. H. W. Seah . M. Rahman 'Performance of cryogenically treated tungsten carbide tools in milling operations' Cryogenic treatment has been acknowledged by some as a means of extending the tool life of many cutting tool materials, cryogenically treated tools exhibit better tool wear resistance than untreated ones.
2006 A.Y.L. Yong, K.H.W. Seah, M. Rahman had worked on wear resistance 'Performance evaluation of cryogenically treated tungsten carbide tools in turning' in result they got extended the tool life wear resistance better.
2008 Dinesh Thakur , B. Ramamoorthy, L. Vijayaraghavan 'Influence of different post treatments on tungsten carbide–cobalt inserts'. Help to improvement of tool wear resistance of inserts.
2009 Simranpreet Singh Gilla, Rupinder Singhb, Harpreet Singhc, Jagdev Singha 'Wear behaviour of cryogenically treated tungsten carbideinserts under dry and wet turning conditions' results The commercially available uncoated square-shaped tungstencarbideinserts use for machining.cryogenically treated at −196 °C . improvement in flank wear .The criterion selected for determining the tool life was based on the maximum flank wear (0.6 mm) .A considerable increase in tool life was also recorded.
2010 B.R. Ramji H. N. Narasimha murthy m. Krishna 'Analysis of forces, roughness, wear and temperature in turning cast iron using cryotreated carbide inserts',The cryogenic treatment cycle consisted of cooling the test samples from room temperature to cryogenic temperature of -178.9 C in three hours, soaking at cryogenic temperature around 24 hours and warming to room temperature in about five hours.Scanning Electron Microscopy for studying the flank wear mechanism.

2011 Alan K.T. Lau, T. S. Srivatsan, Debes Bhattacharyya, Ming Qiu Zhang and Mabel M. P. Ho 'Comparative Study to Analyze the Effect of Tempering during Cryogenic Treatment of Tungsten Carbide Tools in Turning' improvement in properties of the materials. Better result evaluated in terms of tool wear, power consumption and surface roughness achieved.
2012 Shivdev Singh , Dilbag Singh , Nirmal S Kalsi 'Experimental analysis of cryogenic treatment on coated tungsten carbide inserts in turning' experimental investigation of cryogenically treated, coated and uncoated tungsten carbide cutting tool inserts in turning of AISI 1040 steel, treated tools have lower tool wear and cutting forces then untreated tool
2015 S Thamizhmanii , R Mohideen , A M A Zaidi and S Hasan 'Surface Roughness and Tool Wear on Cryogenic Treated CBN Insert on Titanium and Inconel 718 Alloy Steel' The execution of cryo processing on cutting tool materials increases wear resistance, hardness, and dimensional stability and reduces tool consumption and down time for the machine tool set up, thus leading to cost reductions.
2017 Swamini Chopra , D. R. Peshwe, Kavita A. Deshmukh 'Cryogenic Treatment of Cubic Boron Nitride (CBN) Cutting Inserts' Help to improvement of tool wear resistance of inserts

3. CARBON BORON NITRIDE

Cubic Boron Nitride (CBN) is a super-hard material which, in contrast to diamond, can be used for machining iron-based alloys and steels and in many other important applications where diamond cannot be used. Cubic boron nitride (CBN) is an allotropic crystalline form of boron nitride almost matching the hardness of diamond. Cubic boron nitride was first synthesized in 1957. The hexagonal crystals are obtained at 2,800°F− 3,700°F and pressures of 3.45 to 6.2 MPa (0.5 to 0.9 × 106psi), in the presence of catalyzers such as alkali metals, antimony, lead or tin, lithium, magnesium, and nitrides.

3.1 IMPORTANCE PROPERTIES OF CBN

The popularity of CBN is due to its hardness, thermal resistance which is higher than diamond's, allowing work at 1,900°C (3,500°F), and the good chemical resistance of CBN to ferrous alloys. Cubic boron nitride is used mainly for grinding high-quality tool steels. Because of its chemical nature, CBN has no affinity for low carbon steels, being widely employed for grinding high-speed steels. Cubic boron nitride has an excellent thermal stability, oxidation starts above 1,000°C (1,800°F) and becomes complete around 1,500°C (2,700°F).

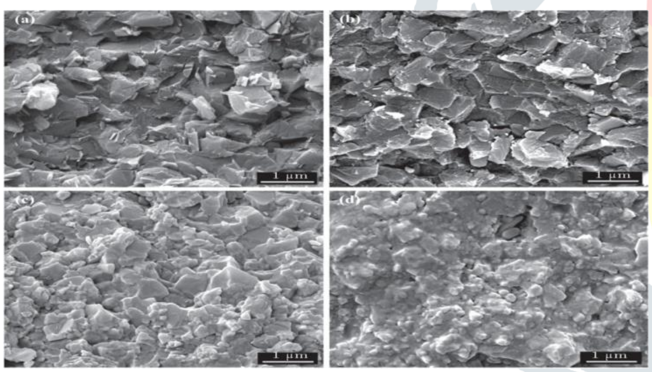

Fig.1. Microstructure of CBN material

4. TOOL LIFE

The life of tool is affected by many factors such as: cutting speed, depth of cut, chip thickness, tool geometry, material or the cutting fluid and rigidity of machine. Physical and chemical properties of work material influence tool life by affecting form stability and rate of wear of tools. The nose radius tends to affect tool life.

1. Cutting speed: Cutting speed has the greatest influence on tool life. As the cutting speed increases the temperature also rises. The heat is more concentrated on the tool than on the work and the hardness of the tool matrix changes so the relative increase in the hardness of the work accelerates the abrasive action. The criterion of the wear is dependent on the cutting speed because the predominant wear may be wear for flank or crater if cutting speed is increased.

2. Feed and depth of cut: The tool life is influenced by the feed rate also. With a fine feed the area of chip passing over the tool face is greater than that of coarse feed for a given volume of swarf removal, but to offset this chip will be greater hence the resultant pressure will nullify the advantage.

3. Tool Geometry: The tool life is also affected by tool geometry. A tool with large rake angle becomes weak as a large rake reduces the tool cross-section and the amount of metal to absorb the heat.

4. Tool material: Physical and chemical properties of work material influence tool life by affecting form stability and rate of wear of tool.

5. Cutting fluid: It reduces the coefficient of friction at the chip tool interface and increases tool life.

5. CRYO TREATMENT

5.1 INTRODUCTION TO CRYOGENIC TREATMENT

Cryogenic treatment (CT) is one of the techniques that improve the wear characteristics of different materials. The method of processing the material at low temperature was introduced after the observation in which the metal parts were transported through the train [5]. During transport, the metal came into contact with the dry ice of the temperature of 194 K, which improved the wear resistance. After this observation, it was confirmed that the cooling of the material at low temperature improves the properties of the material. In the 1930s and 1940s these treatments were found to improve the performance of cutting tool CBN. Cryogenic treatment is one of the cooling techniques. Cryogenics is the combination of two Greek words "Kryos" means freezing and "Genics" means generated [4]. Professor Kamerlingh Onnes from the University of the Netherlands first used word CT in 1894 to describe the science of producing lower temperatures. These low temperature treatments use different gases such as oxygen, nitrogen, hydrogen and helium. [3, 7]

5.2 CONCEPT OF CRYOGENIC TREATMENT

Cryogenics is defined as the branches of physics and engineering that study very low temperatures, how to produce them and how the materials behave at those temperatures. Instead of the known temperature scales of Fahrenheit and Celsius, cryogenics use the scales of Kelvin and Rankine. The word cryogenics literally means "the production of freezing cold"; however the term is used today as a synonym for the low temperature state. It is not well defined at what point on the temperature scale the refrigeration ends and Cryogenics begins. The NIST workers in Boulder, Colorado, have decided to consider the field of cryogenics as the one that contains temperatures below -180 ° C (93.15 K).

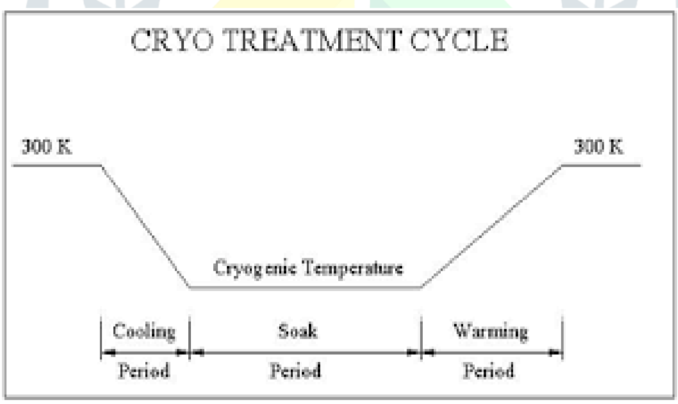

Fig.2. Cryogenic treatment cycle

5.3 CRYOGENIC TREATMENT PROCEDURE

The liquid nitrogen as generated from the nitrogen plant is stored in storage vessels. With help of transfer lines, it is directed to a closed vacuum evacuated chamber called cryogenic freezer through a nozzle. The supply of liquid nitrogen into the cryo-freezer is operated with the help of solenoid valves. Inside the chamber gradual cooling occurs at a rate of 2º C /min from the room temperature to a temperature of-196º C. Once the sub zero temperature is reached, specimens are transferred to the nitrogen chamber or soaking chamber where in they are stored for 24 hours with continuous supply of liquid nitrogen.

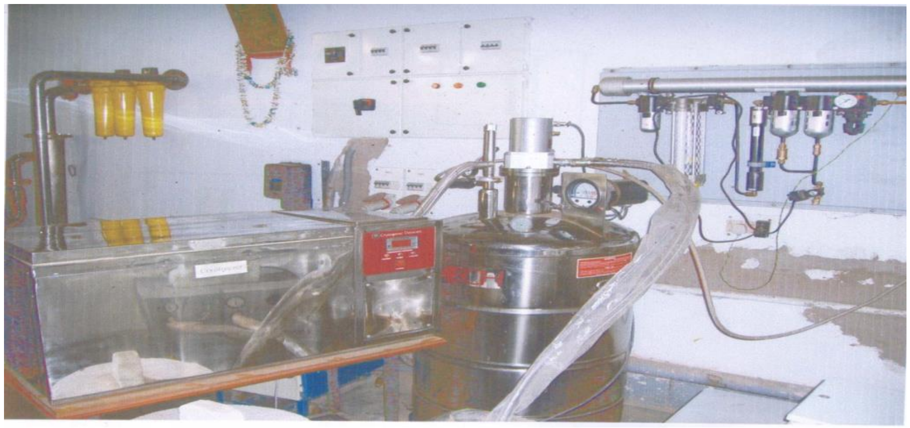

Fig.3. Photograph of the cryogenic treatment set up

5.4. PARAMETERS OF CRYOGENIC TREATMENT

Darwin identified the main process parameter during his work with CT. These parameters are cooling rate, soaking temperature, soaking period and warming rate. These parameters also have a contribution in improvement in wear characteristics. The parameters for improving mechanical properties of CBN are as follow.

1. Soaking temperature (72%)

2. Soaking period (23%)

3. Rate of cooling (10%)

4. Tempering temperature (2%)

5.4.1 COOLING RATE AND WARMING RATE

Cooling rate is rate at which the sample is slowly cooled down to soaking temperature. Warming rate is the rate at which sample is warmed slowly up to room temperature. It was observed that slow cooling and heating rate of approximately 1-3 ° C / min were used to avoid thermal micro-cracking of the material.

5.4.2 SOAKING TEMPERATURE

The soaking temperature is the temperature at which the sample is maintained during a given soaking period. The first CT users applied the soaking temperature in the range between 193 to 173 K. Now, the recent application known as deep cryogenic treatment uses the temperature in the range of 103 K to 77 K.

5.4.3 SOAKING PERIOD

The soaking period is the period in which the sample is kept at a low temperature for some time. From previous studies it was found that the soaking period varies from 8 hours to 40 hours. Many researchers studied the effect of CT on CBN tools and found interesting results such as improved tool life, improved mechanical properties, etc.

6. CONCLUSIONS

From this study, the following conclusions can be drawn:

1. The deep cryogenic treatment plays a vital role in improving the mechanical properties such as hardness, wear resistance, toughness of different materials.

2. It was found that there was an improvement in wear resistance and hardness.

3. From this study, it can be said that the cryogenic treatment if applied correctly can significantly reduce the useful life of the tool, which reduces the machining process.

4. Cryogenic treatment is an effective heat treatment that can be widely applied to cutting tool. This method can help to reduce production costs by increasing cutting tool performance.

5. In order to achieve maximum benefits from cryogenic treatment on cutting tools, cryogenic treatment parameters (holding temperature, holding time, identification of heat treatment to be applied before or after, etc.) should be applied under optimum conditions according to the tool material and operational settings.

6. The treatment on cutting tools applied between −80 and −140 °C is termed shallow cryogenic, while the treatment applied between −140 and -196 0c is termed deep cryogenic treatment. Both treatments offer different contributions according to cutting tool type and material. It is important to determine appropriate temperatures in order to obtain maximum performance.

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