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CRYOGENIC TREATMENT OF CUTTING TOOLS

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Abstract

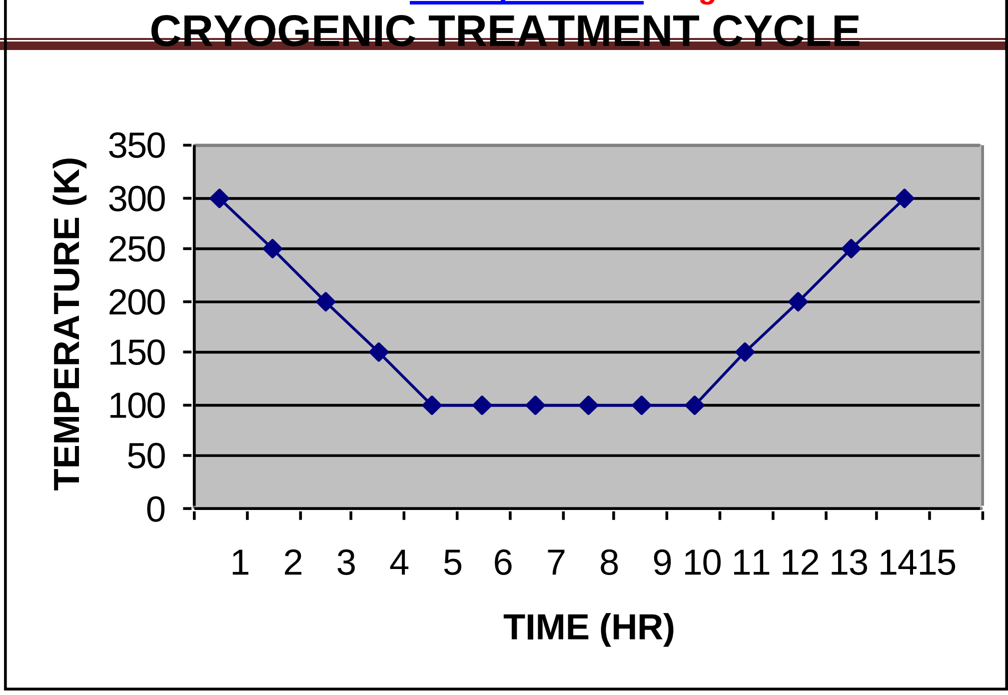
Cryogenic treatment of cutting tools changes the metallurgical properties which in turn, improves mechanical properties of the treated tools. Cryogenic treatment is a supplementary process to conventional heat treatment process. It is an inexpensive one time permanent treatment affecting the entire section of the cutting tools unlike coatings. Though the benefits have been reported widely, there are issues debated upon, in respect of the treatment parameters, extent of benefits experienced in different materials, underlying mechanism and pretreatment conditions. A study on the improvement in wear resistance in different cutting tool inserts has been made. Cryogenic treatment imparts, increased wear resistance leading to extended life of the cutting tool inserts, good dimensional stability and surface finish. The improvement in the characteristics of cutting tool inserts after cryogenic treatment can be attributed to the transformation of retained austensite to martensite, precipitation of fine carbide particles fully dispersed in the matrix. It is found that cryogenic treatment imparts nearly 100% improvements in tool life. Cryogenic treatment costs less than wear resistance coatings. It adds only 10-15% of tool cost. It is even superior to TiN coatings.

Keywords: Cryogenic treatment, HSS tool, Carbide inserts, Ceramic inserts, Tool life.

1. INTRODUCTION

In the field of cryogenic engineering, one is concerned with developing and improving low-temperature techniques, processes, and equipment. As contrasted to low- temperature physics, cryogenic engineering primarily involves the practical utilization of low-temperature phenomena, rather than basic research, although the dividing line between the two fields is not always clear-cut.

The freezing of metals has been acknowledged for many decades as an effective method for increasing wear life and decreasing residual stress in cutting tools. It is believed that the life of cutting tools get extended substantially due to cryogenic treatment. The treatment is an add-on process over conventional heat treatment in which the cutting tools are cooled down to prescribed cryogenic temperature level around (93k) at a slow rate, maintained at this temperature for a long time and then heated back to room temperature. Cryogenic treatment is an inexpensive one time permanent treatment affecting the entire section of the cutting tool sunlike coatings. In the heat treatment of cutting tools the problem of retained austenite after heat treatment has prevailed since the development of tool steels. This retained austenite is soft and unstable at lower temperatures that it is likely to transform into martensite under certain conductiv econditions.



“Figure 1 “cryogenic treatment cycle.

It should be noted that freshly formed martensite is also brittle and only tempered martensite is acceptable. To further aggravate this problem the transformation of austenitetomartensiteyieldsa4%volumeexpansioncausingdistortionwhichcannot be ignored. This cryogenic treatment being add-on process to convectional heat treatment is recommended by many researchers to be done before high temperature tempering. Cryogenic treatment creates denser molecular structure of cutting tools in a large contact surface are that reduces friction, heat and wear.Cryogenic treatment converts almost all the soft retained austenite into hard martensite and the martensite is tampered as the metal returns to room temperature. It forms micro-fine carbide fillers, that the dispersed in martensite structure between the larger carbide particles present in steel. This structural matrix resists penetration of foreign particles and so improves abrasion resistance. It decreases the residual stresses in tool steel. It improves the entire structure of the cutting tool, not just the surface. Subsequent refinishing operations or regrinds do not affect permanent improvements. Cryogenic treatment is one permanent process and does not need repeated treatments. It does not lead to changes in dimensions or surface finish. Cryogenic treatment is expected to enhance abrasive wear resistance, toughness, tensile strength and reduce the brittleness.

Cryogenic treatment is expensive and hence, it is employed for expensive machine parts and in cases where the reliability of the whole machine is crucial. Examples reported are race cars/bikes, tools and dies and gun barrels. Cryogenic treatment is alsobeingemployedfornon-ferrousturbineblades,brassmusicalinstruments,knives, blades and some selected nylon machine parts. There are interesting differences in the temperature dependence of the mechanical properties of f.c.c. (face centered cubic) and b.c.c. (body centered cubic) metals. The flow stress of f.c.c. metals increases moderately as the temperature is lowered, but the rate of work hardening is much greater atlowtemperaturesthanatnormaltemperatures.Inb.c.c.metals,thereis a very marked increase in yield stress with decreasing temperature but the work- hardening is not very temperature sensitive. According to present ideas, the temperaturedependenceofthemechanicalpropertiesmayariseintwodifferentways

The tire cord and metal components in the original tire can be separated easily from the robber, and the rubber particles can be used again for other items. Researchers have been skeptical about the process because it imports no apparent visible change in the material and the mechanism is also unpredicted. However, a number of aerospace, automotive and

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electronic industries in USA, China and other developed countries have adopted this process in their regular treatment/production line to improve wear resistance and dimensional stability of cutting tools. Tools get worn out due to long term usage there are two types of wear found in tools. They are (1) Crater wear: the crater wear is on to rake face and more or less circular. The crater does not always the extended to the tool tip. It increases the cutting forces, modifies the tool geometry and softens the tool tip. (2) Flank wear: flank wear or wear landisintheclearancesurfaceofthetool.Thewearlandcanbecharacterizedbythe engthofwearland.Itmodifiesthetoolgeometryandchangesthecuttingparameters.

Tool life represents the useful life of the tool, expressed generally in time units from the start of a cut to some end point defined by a failure criterion. A tool that no longer performs the desired function is said to have failed and hence reached the end of its usefullife.Thetoollifecanbespecifiedbyanyofthefollowingmeasurablequantities:

(1) Actual cutting time to failure
(2) Length of work cut to failure
(3) Volume of metal removed to failure
(4) Number of components produced
(5) Cutting speed for a given time to failure.

The present work is a comparative study on the wear resistance improvement of cryogenicallytreatedcuttingtoolinsertswithnormalcuttingtoolinsertsthrough“Flank wear test”. The CNC turning centre is used to perform the machining operation. The flank wear is measured in the toolmaker’s microscope. And the tool life is found out.

2. CRYOGENICTREATMENT

Cryogenic treatment of cutting tools consists of cooling-down these tools at a predeterminedrate,uptoagivencryogenictemperature,maintainingthepartsatthat lowesttemperatureforagivendurationoftimeandthenallowingthesetoolstowarm- up at a given warming-uprate.

Therefore, the main variables of the cryogenic treatment are:

1. The rate of cooling (degrees Kelvin per minute).
2. The lowest temperature that the specimens attain at which these are maintained or soaked for a given duration (degrees Kelvin).
3. Thedurationforwhichthespecimensaremaintainedatthelowesttemperature i.e. soaking time (Number of hours).
4. The rate of warming-up (degrees Kelvin per minute).

Thevaluesofthesevariableswilldependupon,thedesiredpropertiesexpectedinthe treated cutting tools, costs affordable for the cryogenic treatment, cryogenic facilities available and also upon the shape and size of the cutting ools.

2.1 Set-up and method used for cryogenic treatment

2.1.1 Lowest process temperature

We had access to liquid nitrogen as the coolant and hence the lowest temperature at whichthecuttingtoolscouldbemaintainedorsoakedwasassured-77degreesKelvin.

2.1.2 Process chamber

The process needed an insulated chamber that could hold liquid nitrogen and cutting tools for an adequate duration without refilling. We used 100 liters capacity container insulated on all sides by 75 mm thick, molded polyurethane foam. This chamber retained liquid nitrogen for 12 hours in static conditions and was sturdy enough to handle cutting tools. A suitable vacuum insulated cryostat will economize on the consumption of liquid nitrogen but that will be expensive and can be cost effective only in case of regular usage.

2.1.3 Soaking

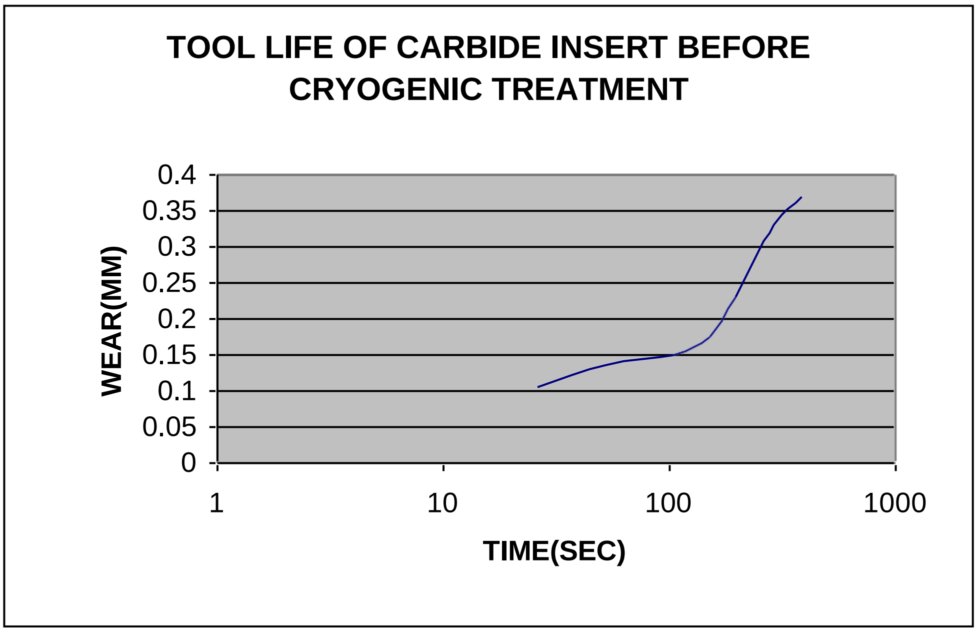
The chamber was filled-up with liquid nitrogen so that the cutting tools were submerged. The chamber was topped-up at 4 hour intervals so that the specimens retained at -77 degrees Kelvin. We soaked all the cutting tools in the present set of experiments for 12hours.

3. EXPERIMENTATION

This experimentation was carried out for HSS tools, cemented carbide inserts and ceramic inserts.

We have chosen the Mild steel rod as a work piece material of 250mm length and 50mm diameter. Initially assuming the tool life like 10s, 50s, and 100s etc and depending upon that the length of machining was calculated. The cemented carbide insert was fixed in the tool holder of the CNC turning centre and tool life of cemented carbide insert was found out. The CNC lathe was programmed to cut the calculated length of cut. And in every run of the cut the insert was removed from the tool holder and the flank wear was measured in the tool maker's microscope. This same procedurewasrepeateduntiltheflankwearexceeded0.4mm.TheCNCturningcentre was used for machining the work piece and to find out the tool life of the cutting tools. The graph was drawn correlating tool life and the wear.

The same procedure was repeated for HSS tools and ceramic inserts.



"Figure 1" Tool life of cemented carbide insert before cryogenic treatment.

Table 1
Tool signature for flank wear test

Back rake angle	0^0
Side clearance angle	6^0
Clearance angle	0^0
Side cutting angle	93^0
Nose radius	0 mm.

Table 2
Machining specifications for flank wear test

Cutting velocity	200m/min
Feed	0.1mm/rev
Depth of cut	0.5 mm
Cutting method	Dry (without coolant)
Work piecematerial	Mild steel rod.

"Figure 2" Tool life of carbide insert after cryogenic treatment.

4. CONCLUSIONS

All attempts made in this research were towards investigation of the effects of cryogenic treatment to augment wear resistance. This work was carried out with the background of diverse claims and reports in terms of property improvement towards enhanced tool life and possible reasons suggested for the same by previous researchers.

Cryogenic treatment creates denser molecular structure of cutting tools resulting in a larger contact surface area that reduces friction, heat and wear. Cryogenic treatment nearlyincreasesthetoollife98%.Itdoesnotleadtochangesindimensionsorsurface finish. It decreases the residual stresses in cutting tools.

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