Effect of Cryogenic Treatment on Tool Life of HSS Single Point Cutting Tool

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Abstract—The cryogenic treatment of cutting tool material is widely being accepted in order to enhance the physical and material properties of the HSS tool. This cryogenic treatment is normally worked out at -196 degree Celsius in order to get the microstructure homogeneity resulting into increasing tool life. The aim of this paper is toexplores the effect of cryogenic treatment on a single point cutting tool made up of HSS which shows the micro structural charges in the tool material that can influence the tool life significantly. The result shows that the HSS cutting tool undergoing cryogenic treatment exhibit better performance based on tool wears toughness, hardness, rigidity, fatigue, resistance by transformation of retained austenite to martensite.

Keywords*- cryogenic treatment,HSS tool,microstructure,tool life,wear,fatigue,rigidity,hardness,martensite*

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I. INTRODUCTION

The commonly used cutting tool material in the conventional machining process is high speed steel (HSS). The HSS tools treated by cryogenic treatment have greater tool life as compared to the tool treated by conventional treatment. The cryogenic word derived from two Greek words 'Cryos' which means cold and 'gen' means generate or to produce or to born. This cryogenic treatment is carried out in two different ways such as hallow cryogenic treatment and deep cryogenic treatment. The SCT also called cryogenic treatment performed at -80 degree Celsius (i.e. dry ice temp). Whereas DCT is carried out at -196 degree Celsius (i.e. liquid nitrogen temperature). Unlike coatings that are superficial treatment the core of tool. This ensures the maintenance of tool properties after regrinding and resharpening as well. One off the most important advantages of this type of treatment is that there is not deterioration off metallurgical of metallurgical properties of HSS after subsequent resharpening and regrinding. Apart from this, the cryogenic treatment improves the machinability off cutting tool, having high wear resistance, better strength, and dimension stability. It should be noticed that the cooling and heating rates must be kept at 0.5degree per min in order to avoid thermal micro cracking formation. Therefore the cryogenic treatment is carried out of very low temperature that it itself relieves the brittleness and internal residual stresses. It has been reported that the cryogenic treatment transform the retained austenite formed after conventional heat treatment into 100% martensite in addition of forming fine microstructure homogenization.

II. LITERATURE SURVEY

1) Rahul Chopra found that the tool wear rate attained using cryogenically treated HSS toll is less as compared to the non treated tool. Also he had found that the material removed rate increases with increase in a cutting speed. Thus it is observed that performance of cryogenically treated cutting tools was improved 3 times more than that of hardened and tempered tools.
2) Indra Reddy has proposed that the process hardness number of untreated tool is 66 while cryo treated tool is 68. During the performance evaluation in machining tool life test is conducted for different values of speed, viz. 88, 150, 250, 420 and 710 rpm with feeds of 0.06, 0.07 and 0.1 mm per revolution at constant depth of cut 1mm. It is formed that the tool life of untreated HSS cutting tool is 102.68 minutes and that of cryo treated tool is 105 min.
3) Simranpreet Singh Gill has proposed the deep cryogenic treatment on M2 HSSS turning tool in terms of tool flank wear. The recorded maximum tool life enhancement ever traditionally heat treated tool is approximately 35% for shallow cryogenic treated tools and 50% for deep cryogenic treated tools. Thus deep deep cryogenically treated tools of M2 HSS perform more consistently as compared to shallow cryogenically treated as well as traditionally heat treated tools
4) Lakh winder Pal Singh has carried out the experimental on HSS tool by Taguchi method. Turning operation was carried out on the work specimen with cryogenically treated and untreated HSS tools. In order to calculate the nose radius of HSS tool by optimizing the machining parameters such as cutting speed, feed rate and depth of cut from the analysis is has been observed that the microstructure of HSS gets homogenisation after cryogenic treated.
5) Flavio J. Da Silva et.al has found that the high speed steel tools undergoing cryogenic treatment shows microstructural changes which improves the tool life from 92% to 817% in industry where the sample

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showed a fraction very closed to 0% of retained austenite.

6) According to V. Firouzdor the tool life of M2 HSS drill is indicated 77% and 126% improvement in cryogenic treated and cryogenic and temper-treated respectively. Through the SEM analysis observation and chemical analysis data of the chips, diffusion wear was found as the dominated wear mechanism.
7) Dr. I. Satyanarayana has proposed the experiment to find the optimum working condition to reduce the tool wear rate in HSS drill bit. As per the experiment it was observed that the flank wear of cryogenically treated drill bit is less as compared to untreated drill bit. Which shows the hardness value of untreated drill is 49.5 HRB whereas of treated drill is 53 HRB.

III. MEHODOLOGY

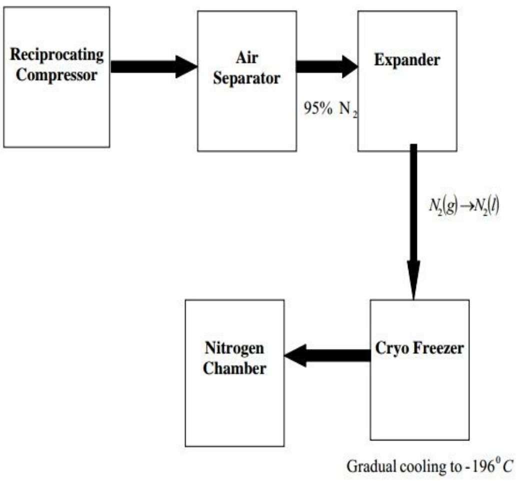

fig.1: schematic representation of cryogenic Treatment procedure

The liquid nitrogen as generated from the nitrogen plant is stored 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 at a rate of 2 degree celsius per min from the room temperature to a temperature of -196 degree celsius. One the subzero temperature is reached, specimens are transferred to the nitrogen chamber or soaking chamber or soaking chamberwherein they are are stored for 24 hours with continuous supply of nitrogen. Fig. illustrated the entire set up for cryogenic treatment. The entire process is schematically shown in fig.

Fig.2 Procedure of cryotreatment

Fig.3cryogenic treatment set up

IV. PROCESS OF CRYOGENIC

1) Austenitizing
Austenitization means to heat the iron, iron based metal on steel to a temperature at which at charges crystal structure from ferrite t austenite. The tool steel is held at 1100 degree Celsius temperature to transform ferrite to austenite.

2) Quenching
After austenitizing temperature the steel is cooled to ambient temperature rapidly in suitable quenching media lie water, oil, air. Once the austenite is cooled below its critical temperature .It become unstable it starts to transform to martenite.

3) Cryoprocessing
4) Fig.3 Typical cryogenic steel treating cycle Cry processing is the supplementary process t the conventional heat treatment which is carried out at -196 degree Celsius. This process is used to enhance the overall cross sectional area of the HSS tool.
The cutting tool is placed at cryogenic temperature for about 8 to 40 hours this is called as soaking period. The long soaking period is necessary to

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allow transformation of retained austenite to martenite. After removing the tool from cryo chamber the tool get heated at room temperature to harden.

5) Tempering
Tempering is the process of reheating the tool steel at predetermined temperature which is lower than that of transformational temperature. The tempering temperature for tool steel varies from 100 to 200 degree Celsius where the tool is plaud at this temp for about 1 hour. This process is worked out after cryoprocess in order t reduce extra hardness ad ensures dimensional stability.

V EFFECT OF CRYOGENIC TREATMENT ON HSS

HSS tools are so named because they were developed to cut at higher speeds. Developed around 1900 HSS are the most highly alloyed tool steels. The tungsten (T series) were developed first and typically contain 12 - 18% tungsten, plus about 4% chromium and 1 - 5% vanadium. Most grades contain about 0.5% molybdenum and most grades contain 4 - 12% cobalt.

It was soon discovered that molybdenum (smaller proportions)could be substituted for most of the tungsten resulting in a more economical formulation which had better abrasion resistance than the T series and undergoes less distortion during heat treatment. Consequently about 95% of all HSS tools are made from M series grades. These contain 5 - 10% molybdenum, 1.5 - 10% tungsten, 1 - 4% vanadium, 4% Chromium and many grades contain 5 - 10% cobalt.

HSS tools are tough and suitable for interrupted cutting and are used to manufacture tools of complex shape such as drills, reamers, taps, dies and gear cutters. Tools may also be coated to improve wear resistance. HSS accounts for the largest tonnage of tool materials currently used. Typical cutting speeds: 10 - 60 m/min.

Comparison of conventional Heat Treatment and cryogenic Treatment

Sr. No	Cryogenic treatment on tool	Conventional heat treatment on tool
1	Changes overall microstructure of tool material.	Changes only surface properties of tool material.
2	Austenite is completely converted into martensite.	In microstructure retained austenite is present.
3	Gives more tool life, low wear rate and high hardness	Results in Less tool life, high wear rate and less hardness.
4	Built up edge formation do not take place	Tools have tendency to form built up edge during machining
5	Increases ability to withstand high cutting forces.	Cannot withstand high cutting forces.

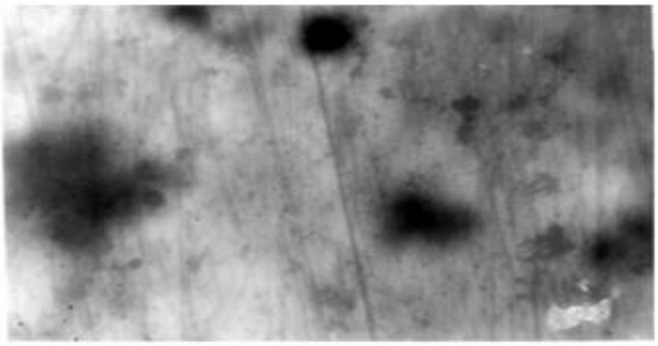
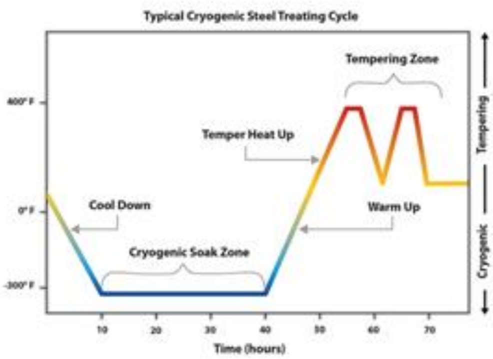


Fig.4 a Microstructure before Cryogenic Treatment

Fig.4 b Microstructure after Cryogenic Treatment

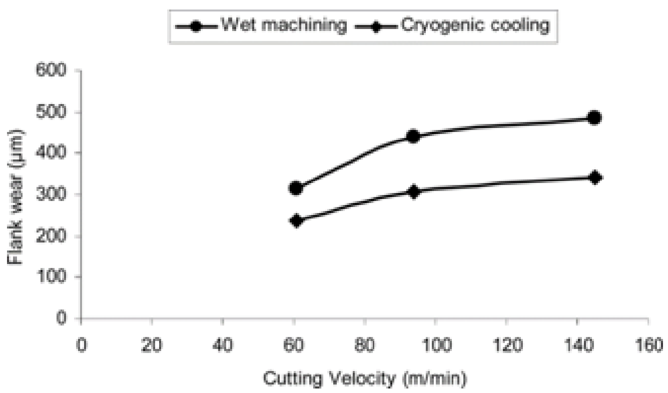
VI RESULTS AND DISCUSSION:

It can be observed that tool life at a higher depth of cut is substantially low compared to that at a low depth of cut. It is said that tool life at a lower feed rate is much higher than he at a higher feed rate. At a higher feed rate the chip thickness is increased and more heat is generated, which reduces the hardness of the tool material resulting rapid tool wear. The application of cryogenic coolant is seen to be more effective at a higher cutting speed. Percentage increase in tool life for all cutting speeds and at a feed rate of 0.1mm/min is higher than that at a feed rate of 0.05mm/min.

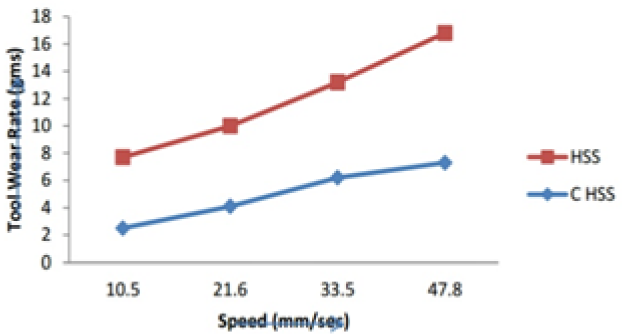


The graph given below illustrate the the tool wear rate of conventionally treatedand cryogenically treated HSS at different speed.

Graph 1 Effect of cutting velocity on flank wear



Graph 2 TWR attain using treated using treated and non treated HSS tool Tool



From the above figure it can be observed that the tool treated by cryogenic treatment has gone carbide precipitation and homogenization as compared to untreated tool.

VII Conclusion:

Cryogenic treatment is the permanent one time heat treatment process. This cryogenic treatment is non-destructive, non damaging process which reduces abrasive wear, relieves internal stress, and minimizes the mirocracking due to cutting forces. Toughness, tensile strength and stability with release of internal stresses .One of the major aspect of this cryogenic treatment is that it transform 100% retained austenite to martenite which is harder than retained austenite. Cryogenic treatment also creates the denser molecules structure area in accordance with rigidity that reduces friction, heat and wear.

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