CRYOGENIC TREATMENT OF SHAPER CUTTERS AND HOBS FOR TOOL LIFE IMPROVEMENT

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Abstract— **Cryogenic treatment has been acknowledged by some as means of extending tool life of many cutting tool materials, thus improving productivity significantly. However real mechanisms which guarantee better tool performance are still dubious. This implies the need of further investigations in order to control the technique more significantly. Studies on cryogenically treated HSS tools show microstructural changes in material that can influence tool lives. However little research has been done on other cutting tool materials. Metal cutting process forms the basis of the engineering industry and is involved either directly or indirectly in the manufacture of nearly every product of our modern civilization. The cutting tool is one of the important elements in realizing the full potential out of any metal cutting operation. Over the years the demands of economic competition have motivated a lot of research in the field of metal cutting leading to the evolution of new tool materials of remarkable performance and vast potential for an impressive increase in productivity. Changes in work piece materials, manufacturing processes and even government regulations catalyze parallel advances in metal cutting tooling technology. As manufacturers continually seek and apply new manufacturing materials that are lighter and stronger and therefore more fuel efficient it follows that cutting tools must be so developed that can machine new materials at the highest possible productivity. Developmental activities in the area of cutting tool materials are guided by the knowledge of the extreme conditions of stress and temperature produced at the tool-work piece interface. In the given study, cryogenic treatment have been done on different cutters and hob and its effect on tool life, cost, microstructure and hardness is observed and analyzed . Due to cryogenic treatment, cost can be saved without affecting properties of tools/cutters.**

***Keywords*— Cutting tool technology, Cryogenic Treatment, Cost saving.**

I. INTRODUCTION

Tool materials have improved rapidly during the last sixty years and in many instances, the development of new tool materials has necessitated a change in the design trend of machine tools to make full use of the potentialities of tool materials for high productivity. Progress from carbon tool steels, high speed steels and cast alloys to carbides and ceramics has facilitated the application of higher speeds at each stage of development. With the advent of carbides and ceramics radical changes have taken place in the design of tool holders and cutters and the concept of the throw away tipped tool where the insert is held mechanically and is discarded after use represents a major advance in the metal removing technology of modern times.

Till 1900 machining was performed by plain carbon tool steel, shortly after 1900 high speed steel was introduced which has undergone many modifications giving rise to several types of HSS. The next notable improvement came with the introduction of cobalt bonded sintered tungsten carbide. However, shortage of tungsten has led to the development of many non-tungsten cutting tool materials. Ceramic tools exhibit very high hardness and wear resistance facilitating the use of higher cutting speeds. UCON a new tool material consisting of columbium, tungsten, titanium permits 60% increase in the cutting speed when compared with tungsten carbide. Cubic Boron Nitride with hardness next to diamond which is claimed to give speed 5 to 8 times that of carbide can be used to cut hardened materials. Polycrystalline diamond bonded to tungsten carbide substrate has been successfully employed for machining non-ferrous materials. But no single tool material has all the desired properties to withstand wide range of stresses, temperatures, abrasion and thermal shock to which a cutting tool is subjected during metal cutting. Each cutting tool has a unique combination of properties that are important to its performance. Hence by fine tuning combinations of tool material compositions, coatings and geometries tool makers enable users to make more parts faster and at reduced cost. Traditional tool materials such as HSS continue to undergo substantial improvement in their properties through suitable modifications in their composition by optimizing the processing technique as well as incorporating various surface treatments.

As a result of these technological advances HSS are still in use having surviving competition from carbides and ceramics. Carbide because of the ability to retain its strength and hardness at very high temperatures, to withstand cutting speeds 6 or more than 6 times higher than tools of HSS and the economical price has become a logical choice of many cutting industries. However, with the incorporation of suitable surface treatments, its service life as well as its properties can be enhanced even more.This document is a template. For questions on paper guidelines, please contact us via e-mail.

II. Literature Survey

Barron after cryogenically treating several materials including the M2 high speed steel at −84 °C (maintaining it at this temperature for 24 h) observed a significant improvement on the wear resistance in sliding abrasion tests. when compared to conventionally heat treated steel (quenched and tempered). When the temperature of the cryogenic treatment was reduced further to −196 °C, the wear resistance was increased even more. He has attributed the improvement of the wear resistance of these tools to another mechanism besides the transformation of the retained austenite into martensite.

Dong et al. did a detailed study on the effects of varying the deep freezing and tempering cycles on high speed steel and confirmed that in tool steels, this treatment affects the material in two ways. Firstly, it eliminates retained austenite, and hence increases the hardness of the material. Secondly, this treatment initiates nucleation sites for precipitation of large numbers of very fine carbide particles, resulting in an increase in wear resistance.

Popandopulo and Zhukova carried out dilatometry studies and microstructure analysis during cryogenic treatment. They observed volume reduction of the specimen at the temperature range of −90 to +20 °C. This behaviour was attributed to partial decomposition of the martensite and precipitation of carbon atoms at dislocation lines and formation of ultramicroscopic carbides.

Paulin also verified the presence of fine precipitated carbide particles and their importance to the material properties. The precipitated carbides reduce internal tension of the martensite and minimize micro cracks susceptibility, while the uniform distribution of fine carbides of high hardness enhances the wear resistance. Huang et al. confirmed that cryogenic treatment not only facilitate the carbide formation but can also make the carbide distribution more homogeneous.

Yun et al. verified changes in the microstructure of M2 high speed steel when this material was submitted to different cycles of cryogenic treatment at −196 °C. Comparing the conventional quenching cycle with other cryogenic cycles it was observed increases of 11.5% in the bending strength, 43% in the toughness and changes in the room temperature and hot hardness. The results were again attributed to transformation of the retained austenite into martensite and precipitation of ultra-fine carbides, with this latter being considered the key point for the changes in the properties.

Mohan Lal et al., made a comparative study on wear resistance improvement of cryogenically treated samples with standard heat-treated samples through flank wear test and sliding wear test. Untempered samples when cryogenically treated yield 3%, 10% and 10.6% extra life over tempered and cryogenically treated T1, M2 and D3 samples, respectively. Hence it is suggested to cryogenically treat without tempering. Tempered samples when cryogenically treated at 133 K for 24 h yielded negative results, but when cryogenically treated at 93 K for 24 h the results were favourable. Hence tempered samples if treated at still lower temperatures may yield still better results on par with untempered cryotreated samples. This also suggested to conclude that the stabilization of phases that would take place during tempering requires sufficient degree of undercooling and time to get transformed to stable harder/tougher phases that offer better wear resistance. Cryogenic treatment done at 93 K as per the prescribed cycle yields 20% extra life as compared to the maximum life achieved through cold treatment. Cryogenic treatment at 93K for 24 hours is superior to TiN coatings also. The effect of cryotreatment on TiN coating is not favourable which may be because of uneven contraction of the coating material and the substrate leading to incipient cracks at the interface. Hence cryotreatment should not follow TiN coating.

It was found that wear resistance has been improved by 85% for shallow cryogenic treatment and 372% for deep cryogenic treatment over conventional heat treatment and also the wear resistance improvement of deep cryogenic treatment is 152% over shallow cryogenic treatment. Wear is found to increase linearly with load at constant sliding speeds and with sliding speed at constant loads. Studies show that the wear improvement of samples treated at 83 K (close to DCT) was approximately 2.6 times higher than the wear resistance of sample treated at 188 K (close to SCT). Also it was found that the improvement of wear resistance for the above alloys when treated at 188 K ranges by factors from 1.2 to 2.0 whereas the same alloys when treated at 83 K improves the wear resistance by factors ranging from 2.0 to 6.6.

In a more recent work it was verified that cryogenic treatment no doubt improves the resistance to chipping of tools and to a less significant extent, improves flank wear resistance but however, under certain conditions, such as prolonged exposure to high temperatures during long continuous cutting operations, cryogenically treated tools can lose their superior properties. In light of the fact that cryogenically treated tools perform best when the tool temperature is kept low, their effectiveness can be extended if coolants or suitable methods of cooling are used to keep the tool temperatures low. Hence, the validity of claims that cryogenic treatment can improve the lifespan of cutting tools would depend a lot on the cutting conditions.

Tools under mild cutting conditions stand to gain from cryogenic treatment, but heavy-duty cutting operations with long periods of heating of the cutting tool will not benefit from it.

The real mechanisms which guarantee better tool performance after cryogenic treatment are still dubious. This implies in the need of further investigation in order to control the technique more scientifically.

PROBLEM IDENTIFICATION

1.) To make a detailed study of basics of cryogenic treatment through research papers.
2.) To implement cryogenic treatment for special cutting tools like shaper cutters, hobs.
3.) To study and evaluate the effects of cryogenic treatment on tool life.
4.) To evaluate cost reduction through implementation of cryogenic treatment.

III. METHODOLOGY

A. *MAKING OF LIQUID NITROGEN*

A common method for production of liquid nitrogen is the liquefaction of air. Liquefaction is the phase change of a substance from the gaseous phase to the liquid phase. In the liquid nitrogen compressors or generators, air is compressed, expanded and cooled via the Joule-Thompson's effect as depicted in Figure 3.1 and Figure 3.2. Figure3.1 shows the set up for making nitrogen. Since nitrogen boils at a different temperature than oxygen, the nitrogen can be distilled out of the liquid air, recompressed and re-liquefied. Once liquid nitrogen is removed from the distillation chamber it is stored in a pressurized tank or a well-insulated deewar flask. Liquid nitrogen is converted to a gas before it enters the chamber so that at no time does liquid nitrogen come in to contact with the parts assuring that the dangers of cracking from too rapid cooling are eliminated.

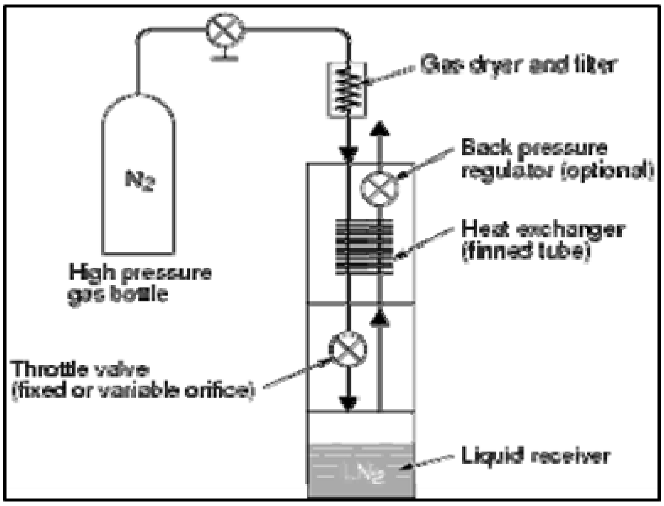

Figure. 1 Making of liquefied nitrogen

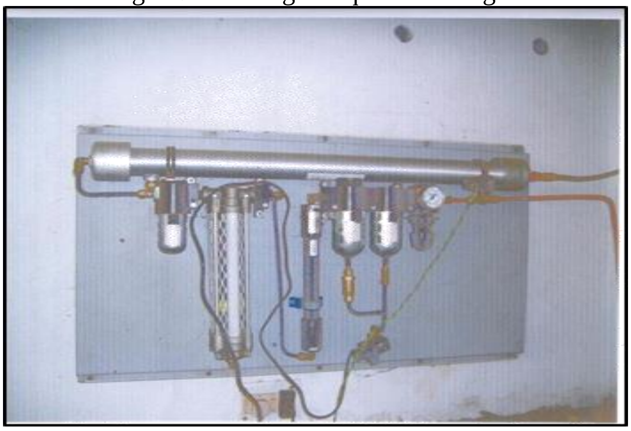

Figure 3.2. Set up for making of Nitrogen

B. *CRYOGENIC TREATMENT PROCEDURE*

The liquid nitrogen as generated from the nitogen 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 wherein they are are stored for 24 hours with continuous supply of liquid nitrogen. Figure 3.3 illustrates the entire set up for cryogenic treatment. The entire process is schematically shown in Figure 3.3.

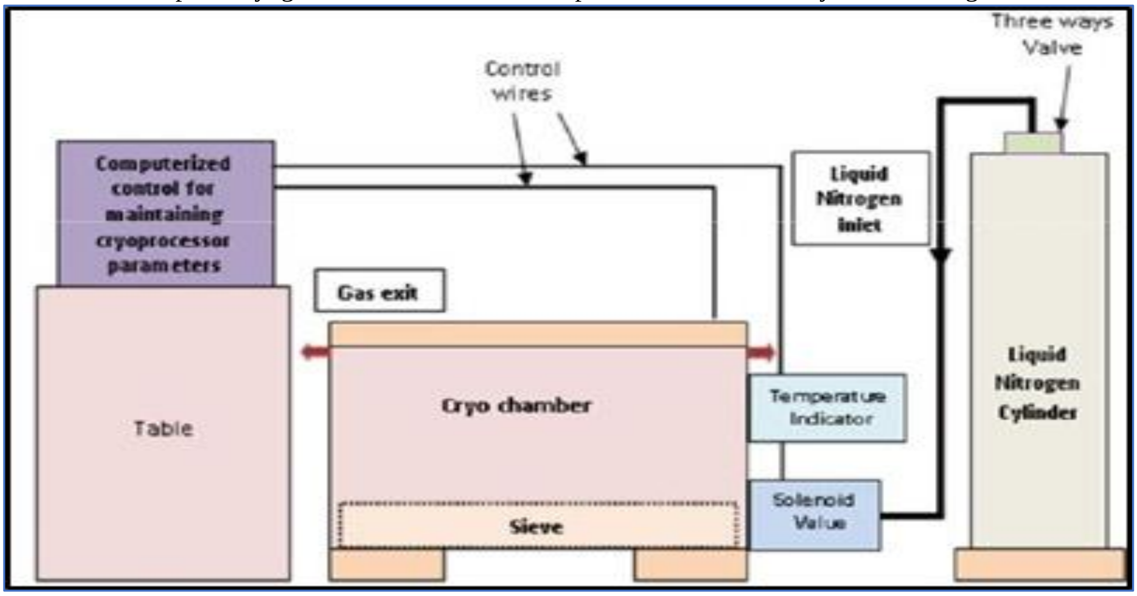

Figure 3 Cryogenic Treatment Setup

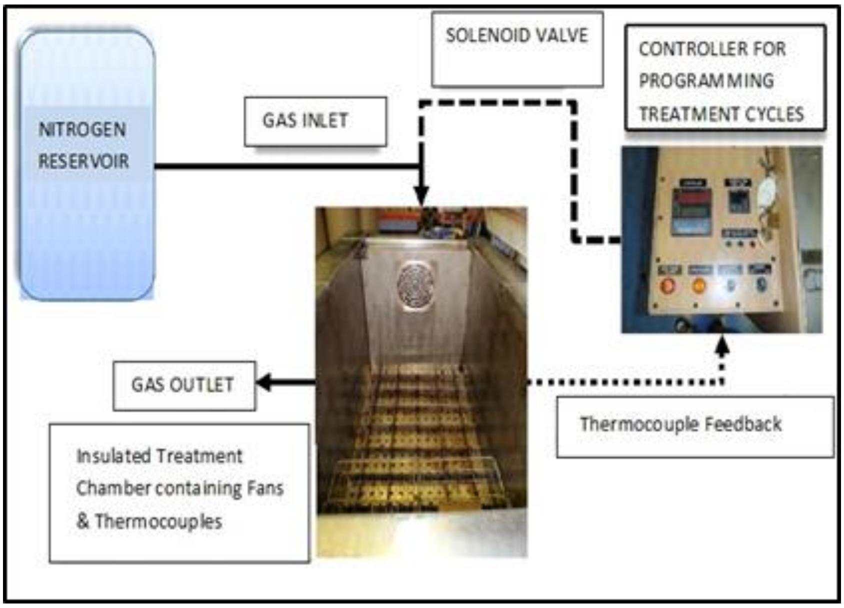

Figure . 4 Cryogenic Treatment Actual Setup

C. *ADVANTAGES*

1. Improvement in mechanical properties.
2. Increased Tool & Die Life.
3. Reduction in premature failure of the components.
4. Reduction in the cost of replacement of tools & dies.
5. Process could be carried out after chemical heat treatment such as nitriding.
6. Reduces vibration of the system.
7. Significantly enhances abrasive wear resistance.
8. Improves corrosion resistance.
9. This process is irreversible, with beneficial properties retained even after resurfacing.
10. Transforms retained austenite into the harder, more desirable martensite.

D. *APPLICATIONS*

1. Cutting tools: cutters, knives, blades, drill bits, end mills, turning or milling inserts. There are two main types of cryogenic treatments of cutting tools.
2. Forming tools: roll form dies, progressive dies, stamping dies.
3. Mechanical industry: pumps, motors, nuts, bolts, washers.
4. Medical: tooling, scalpels.
5. Motorsports and Fleet Vehicles: brake rotors and other automotive components.
6. Musical: Vacuum tubes, brass instruments, guitar strings and fret wire, piano wire, amplifiers, cables, connectors.
7. Aerospace & Defence: communication, optical housings, weapons platforms, guidance systems, landing systems.
8. Automotive: brake rotors, transmissions, clutches, brake parts, rods, crank shafts, camshafts axles, bearings, ring and pinion, heads, valve trains, differentials, springs, nuts, bolts, washers.

IV RESULTS & CONCLUSIONS

A. *PIECE GEAR COST SAVING*

Cost Saving Workout Sheet

Part Name:- PIECE GEAR 4

INTRODUCED CRYOGENIC TREATMENT FOR SHAPER CUTTER FOR TOOL LIFE IMPROVEMENT

	PIECE GEAR 4	
	BEFORE CRYOGENIC	AFTER CRYOGENIC
SHAPER CUTTER PRICE	27683	27683
CRYOGENIC TREATMENT PRICE	0	400
Coating (Alcrona)	39540	39540
Total Shaper Cutter cost including Coating.	67223.00	67623.00
Tool life / Re-Sharpening	300	800
Total Tool life (Considering 30 no's Re-sharpening)	9000	24000
Tool cost / piece	7.47	2.82
No of reshrpening (Considering 12,000 no's / month)	40.0	15.0
Resharpening cost / Month (Considering per setting cost - 30 min X 2.0 Rs/min = 60 RS.)	2400.00	900.00
No of tool setting per month	40.0	15.0
Tool Setting Cost / month (Considering per setting cost - 10 min X 2.5 Rs/min. = 25 Rs.)	1000	375
Setting cost / piece	0.08	0.03
Re sharpening Cost / Piece	0.27	0.04
Tool cost / piece	7.82	2.89
Savings / Piece	INR\ 4.93	

Cost Savings	Monthly:-	12,000 qty X Rs.4.86/piece = Rs 58,320
	Yearly :-	Rs 58,320 X 12month = Rs 6,99,840

Additional Benefits :-
1) 25 no's Re-sharpening reduced. 25 No's X 30 min/re-sharp = 750 min. / Month, 9000 min. / Year. (6.25 Days)
No. of Shaper Cutter Re-sharpening Saved/Year - 300 nos.
2) Savings in capacity. 25 settings X 10 min/setting = 250 min. / month, 3000 min. / Year. (2.08 Days)
No. of Shaper Cuttering settings Saved / year - 300 nos.

Table 1 Piece gear cost saving

Cryogenic treatment resulted in cost saving of 45.14 Lakhs per annum.

Summary of Cryogenic Treatement Cost Saving					
Sr. No.	**Part Name**	**Cutter Type**	**Cost Saving Per Piece (in Rs.)**	**Cost saving Per Month (in Lakhs Rs.)**	**Cost saving Per Year (in Lakhs Rs.)**
1	Ring Gear (40T)	Shaper Cutter	9.47	1.89	22.73
2	Ring Gear (50T)	Shaper Cutter	15.13	1.06	12.8
3	Piece Gear 4	Shaper Cutter	4.86	0.58	7
4	Sproket Driven Tundra	Hob	2.18	0.21	2.61
			Total	**3.74**	**45.14**

Table 2 Summary of Cost Saving

B. METALLURGICAL PROPERTIES COMPARISON

Surface Hardness and Core hardness are found be almost same.

Metallurgical Properties Comparison		
	Non Cryogenic	**Cryogenic**
Surface Hardness	64 HRC	63.67 HRC
Core Hardness	69 HRC	69.33 HRC

Table 3 Hardness comparison

Microstructure studies shows the absence of retained austenite in cryogenic treated tools.

Microstucture	
Non- Cryogenic	The core microstructure shows finely distributed carbides in the matrix of fine tempered martensite. There is slight presence of retained austenite.
Cryogenic	The core microstructure shows finely distributed carbides in the matrix of fine tempered martensite.There is no presence of retained austenite due to cryogenic treatment.

Table 4 Microstructure results

V FUTURE SCOPE

1) This process can be implemented for the similar cutter.
2) Also, it can be implemented for special cutting tools such as deburring blade, shaving cutter, gun drills.
3) Also, with the help of Scanning electron microscope analysis can be done on actual percentage of retained austenite converted into martensite.

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