Proc. of Int. Conf. on Current Trends in Eng., Science and Technology, ICCTEST

Performance of Deep Cryogenically Treated Molybdenum Based M-35 Tool Steel

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***Abstract*—Tool life of a cutting tool is dependent on many parameters such as tool material, machining conditions and work material. The main aim of this study is to analyze the differences in tool performance between deep cryogenically treated and untreated tool steel during orthogonal turning of C-45 steel. The Deep Cryogenic treatment has been carried out on M-35 tool steel at -193^{0}C. An improvement in tool life has been found on Deep Cryogenically treated M-35 tool steel due to morphological changes that takes place in the tool material, which helps in decreasing the amount of force and power required for turning operation at the cost of friction. Also helps in improving surface finish of work material. This paper describes a study on the effect of Deep Cryogenic treatment of M-35 tool steel.**

***Index Terms*— Cryogenic treatment, M-35 tool steel, Tool life, C-45 steel, Morphology, Surface finish.**

I. INTRODUCTION

Cryogenically treated materials find a lot of usage in industries. Over the past few years, there has been an increase in interest in the use of Cryogenic treatment to different materials. Research has shown that Cryogenic treatment increases product life, and in most cases provides additional qualities to the product, such has stress relieving. In the area of cutting tools, extensive study has been done on tool steels, which include high speed steel and medium carbon steel. It has been reported that Cryogenic treatment can double the service life of high speed steel tools, and also increase hardness and wear resistance [1].
Cryogenic treatment of cutting tool materials such has Molybdenum based tool steel, have yet to be extensively studied. If Cryogenic treatments can double the service life of high speed steel [2], it could probably same for Molybdenum based M-35tool steel. The main objective of this study is to analyze the effects of Cryogenic treatment on M-35 tool steel.

II. CRYOGENIC TREATMENT

Cryogenic treatment refers to subjecting material to very low temperature. This process is not limited in application to metals, but can also be applied to wide range of materials. Several different cryogenic processes have been tested by researchers. These involve a combination of deep freezing and tempering cycles. Generally, they can be described as a controlled lowering of temperature from room temperature to -193^{0}c, maintenance of the temperature for about 24 hours followed by a controlled rising of temperature back

Grenze ID: 02.ICCTEST.2017.1.40

to the room temperature. 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 site for precipitation of large number of very fine carbide particles, resulting in an increase in wear resistance [3].

III. EXPERIMENTAL DETAILS

A. Work Material and Tool Material

The work material used in this study is C-45 steel. The tool material used in this study is M-35 tool steel.

B. Cryogenic Process

The tool samples in this work were subjected to cryogenic treatment with the following parameters
Cooling time: 6 hours at the rate of 2^{o}C/min, Soaking time: 24 hours at -193^{o}C,Medium used: Liquid Nitrogen, Warming time: 6 hours at the rate of 2^{o}C/min.

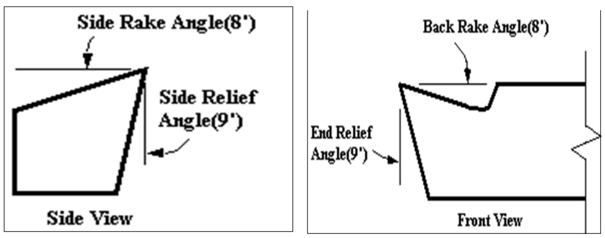

Fig.1: Turning tool

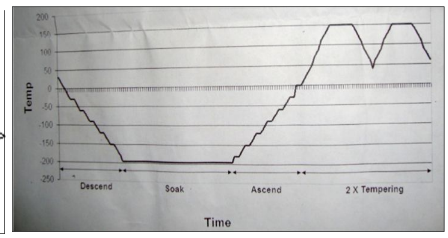

Fig.1:cryogenic treatment

IV. TESTING

A. Lathe tool dynamometer

A lathe tool dynamometer was used to measure radial and thrust force involved in machining operation. The cutting parameters are shown in tableI.

TABLE I

SL. NO.	PARAMETERS	VALUES
1.	Speed	310 – 760 rpm
2.	Feed	0.84 – 0.112 mm/rev
3.	Depth of cut	0. 5 mm

B. Microstructure

The microstructure of both treated and untreated samples of tool were examined under NIKON optical microscope

C. Surface finish

Measurements of surface finish of the machined work pieces were carried out by perthometer.

V. RESULTS AND DISCUSSION

A. Microstructure

Photo micrographs of untreated and treated samples are shown in figure 3 & 4. The following are the salient observations:

1. The figure reveals the structure after cryogenic treatment shows larger number of alloy carbides.
2. The alloy carbides are more uniform and slightly denser.
3. Martensite matrix appears to be more homogenous.
4. Formation of secondary carbides after cryogenic treatment.

5. No Retained austenite is visible.
6. The carbides are of fine Spheroidal and slightly elongated .

Thus in summary the matrix microstructure changes that occur due to Cryogenic treatment have contributed for the improved wear resistance of M-35tool steel.

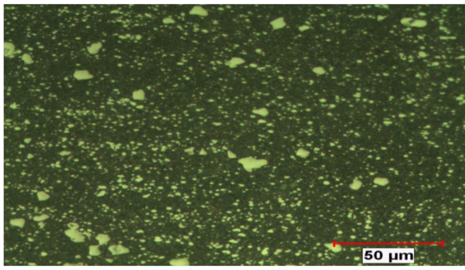

Fig.3: Microstructure of Untreated M-35 Tool Steel

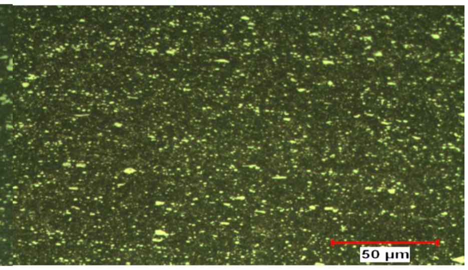

Fig.4:Microstructure of Treated M-35 Tool Steel

B. Effect of Deep Cryogenic Treatment on Thrust Force and Radial Force

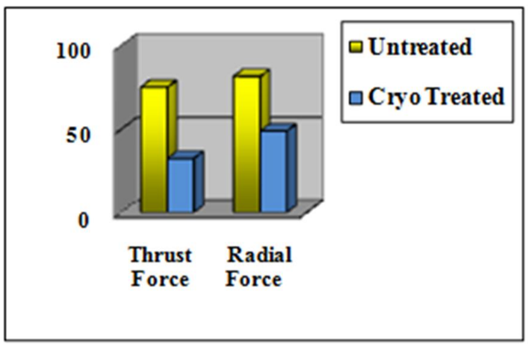

Fig. 5:Histogram indicating the Thrust Force(N) and Radial Force(N) at Speed=310 rpm, Feed=0.112mm/rev. and Depth of Cut=0.5mm.

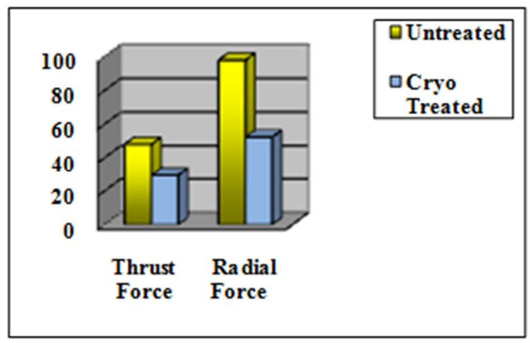

Fig. 6:Histogram indicating the Thrust Force(N) and Radial Force(N) at Speed=760 rpm, Feed=0.112 mm/rev. and Depth of Cut=0.5 mm

Effect of Speed and Feed

It has been observed from histograms that as the speed increases from 310 rpm to 760 rpm and feed rate increases from 0.084 to 0.112 mm/rev, there is a decrease in thrust force and radial force for cryo treated M-35tool steel

Effect of Cryo Treatment

From the results obtained it is observed that in case of low speed, low feed and constant depth of cut, the decrease in thrust force and radial force is by an amount of 14.28% and 46.6%in in comparison with untreated tool has been estimated with the help of Merchant's Circle Diagram. Also, it is observed that in case of high speed, high feed, and constant depth of cut, the decrease in thrust force and radial force is by an amount of 38.6% and 46.6% in comparison with untreated tool has been estimated with the help of Merchant's Circle Diagram.

C. Effect of Deep Cryogenic Treatment on Shear Force and Normal Force

i.Effect of Speed and Feed

It has been observed from histograms that as the speed increases from 310 rpm to 760 rpm and feed rate increases from 0.084 to 0.112 mm/rev, there is a decrease in shear force and normal force for cryogenic treated M-35tool steel.

iii.Effect of Cryogenic Treatment

From results it is observed that in case of low speed and low feed and constant depth of cut the decrease in shear force and normal force is by an amount 56.78% and 44.3% in comparison with untreated tool has been

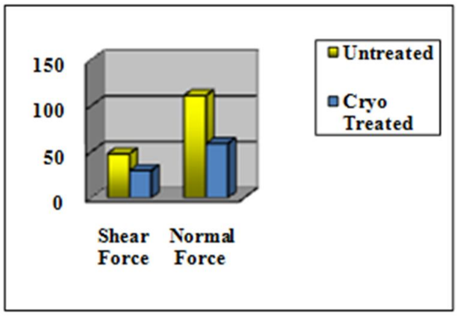

Fig.7:Histogram indicating the Shear force(N) and Normal force(N) at Speed=310 rpm, Feed=0.112 mm/rev. and Depth of Cut=0.5 mm

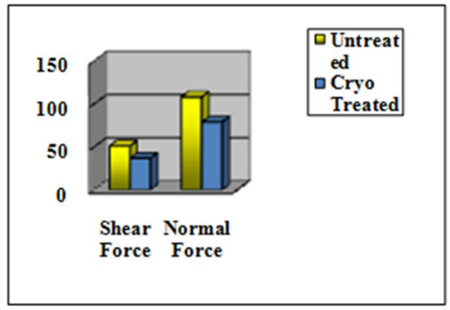

Fig.8:Histogram indicating the Shear Force(N) and Normal Force(N) at Speed=480 rpm, Feed=0.112 mm/rev. and Depth of Cut=0.5 mm

estimated with the help of Merchant's Circle Diagram. Also, it is observed that in case of high speed and high feed and constant depth of cut the decrease in shear force and normal force is by an amount 50.33% and 47.8% in comparison with untreated tool has been estimated with the help of Merchant's Circle Diagram.

D. Effect of Deep Cryogenic Treatment on Power

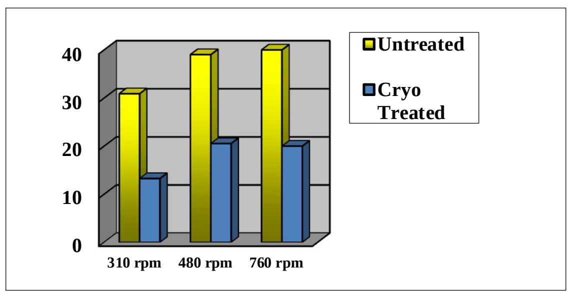

Fig.9: Histogram indicating the Power(W) required for turning at Feed=0.112 mm/rev. and Depth of Cut =0.5 mm

Effect of Speed and Feed

It has been observed from histograms that as the speed increases from 310 rpm to 760 rpm and feed rate increases from 0.084 to 0.112 mm/rev, there is a decrease in power required for turning by cryo treated M-35tool steel.

Effect of Cryogenic Treatment

From results it can be observed that in case of low speed, low feed and constant depth of cut the decrease in power required for turning by M-35 tool steel is by an amount 37.4% in comparison with untreated tool has been estimated with the help of Merchant's Circle Diagram. Also, it can be observed that in case of high speed, high feed and constant depth of cut the decrease in power required for turning by M-35 tool steel is by an amount 50 %in comparison with untreated tool has been estimated with the help of Merchant's Circle Diagram.

E. Effect of Deep Cryogenic Treatment on Surface Finish

Effect of Speed and Feed

It has been observed from graphs that as the speed increases from 310 rpm to 760 rpm feed rate decreases from 0.112 to 0.084 mm/rev, there is an increase in surface finish obtained for turning by cryogenic treated M-35 tool steel.

Effect of Cryogenic Treatment

From results it is observed that in case of low speed, low feed and constant depth of cut the increase in surface finish obtained for turning by M-35 tool steel is by an amount 22.7 % in comparison with untreated tool has been estimated with the help of Merchant's Circle Diagram. Also, it is observed that in case of high

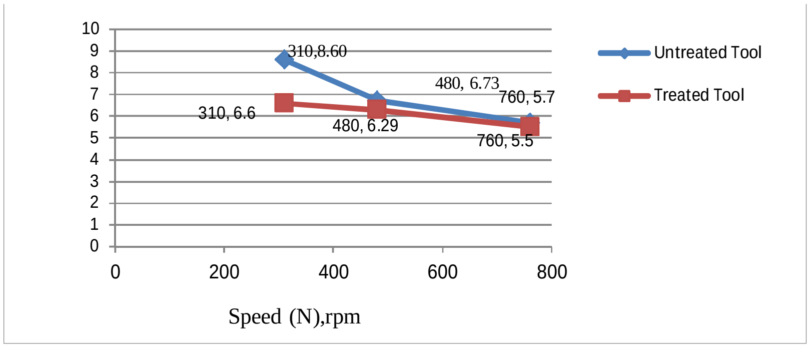

Fig.10:Graph indicating the effect of Treated and Untreated M35 Tool on Surface Finish(μm) for Feed=0.112 mm/rev. and Depth of Cut=0.5 mm

speed, high feed and constant depth of cut the increase in surface finish obtained for turning by M-35 tool steel is by an amount 3.5% in comparison with untreated tool has been estimated with the help of Merchant's Circle Diagram.

VI. CONCLUSIONS

The significant conclusions of the study carried out on performance of deep cryogenically treated Molybdenum based M-35 tool steel is as follows:

- Deep Cryogenic treatment on M-35 tool steel improves the structure by enhancing carbides in place of retained Austenite.
- Improvement in microstructure is responsible for decreasing the radial force, thrust force, shear force and normal force on shear plane.
- It has been found that Deep Cryogenic treatment on M-35 tool steel has helped in decreasing the power required for turning operation by decreasing the coefficient of friction to a larger extent at high cutting speed which is responsible for increasing productivity at the cost of tool wear.
- Deep Cryogenic treatment on M-35 tool steel improves the surface finish.

Hence it can be concluded that Deep Cryogenic treatment is more effective on performance of M-35 tool steel with comparison to the untreated M-35tool steel.

AKNOWLEDGEMENT

The authors express their thanks to staff of Mechanical Engineering Department, to the Principal of DBIT and to the Management of Wayanamac Education Trust, Bangalore, for the support and facilities given for the successful completion of the Research work.

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