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EXPERIMENTAL INVESTIGATION ON CRYOGENIC TREATED HSS TOOL

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1. Introduction

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.

2. Literature Survey

In recent decades, there has been an increase in interest in the application 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 as stress relieving. In the area of cutting tools, extensive study has been done on tool steels, which include high-speed steel (HSS) and medium carbon steels. It has been reported that cryogenic treatment can double the service life of HSS tools, and also increase hardness and toughness simultaneously. In recent decades, there has been an increase in interest in the application 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 as stress relieving. 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. Molinari found out that the deep cryogenic treatment (−196°C) of quenched and tempered high speed steel tools improves their properties; in particular, it increases the hardness and improves the hardness homogeneity, reduces the tool consumption and the down time for the equipments set up, thus leading to about 50% cost reduction. The greatest improvement in properties is obtained by carrying out the deep cryogenic treatment between quenching and tempering. However, a significant improvement can be obtained even by treating the tools at the end of the usual heat treatment cycle, i.e. the finished tools. This last solution is more flexible than the other one and can extend the use of the treatment to many practical applications.

3. Materials and methods

HSS TOOL (High speed cutting tool)

HIGH-SPEED TOOL STEELS and their requirements are defined by The American Society for Testing and Materials in Specification A600-79 as follows: High-speed tool steels are so named primarily because of their ability to machine materials at high cutting speeds. They are complex iron-base alloys of carbon, chromium, vanadium, molybdenum, or tungsten, or combinations thereof, and in some cases substantial amounts of cobalt.

The carbon and alloy contents are balanced at levels to give high attainable hardening response, high wear resistance, high resistance to the softening effect of heat, and good toughness for effective use in industrial cutting operations.

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 soleniod valves. Inside the chamber gradual cooling occurs at a rate of 2º C /min from the room temperature to a temperature of -80º C.

Once the sub zero temperature is reached, specimens are transferred to the nitrogen chamber or soaking chamber where in they are are stored for 24 hours with continiuos supply of liquid nitrogen. This figure illustrates the entire set up for cryogenic treatment. The entire process is schematically.

FIGURE 1 CRYOGENIC TREATMENT

4. EXPERIMENTAL TESTING

HARDNESS TEST

This gives the metals ability to show resistance to indentation which show it's resistance to wear and abrasion. Hardness testing of welds and their Heat Affected Zones (HAZs) usually requires testing on a microscopic scale using a diamond indenter.

TABLE 1 HARDNESS TEST

Material	Hardness
HSS Tool	64
Cryogenic HSS Tool	76

Scanning Electron Microscopy (SEM), also known as SEM analysis or SEM microscopy, is used very effectively in microanalysis and failure analysis of solid inorganic materials. Electron microscopy is performed at high magnifications, generates high-resolution images and precisely measures very small features and objects. Laboratory Testing Inc. near Philadelphia, PA (USA) offers scanning electron microscope services, using a complete system which also offers Energy Dispersive X-ray Spectroscopy (EDS) capabilities.

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Microstructure

Normal HSS Tool

Cryogenic HSS Tool

Figure 2 MICRO STRUCTURE

TABLE 2 MATERIAL REMOVAL RATE ON NORMAL HSS

Spindle Speed	Feed Rate	Depth of cut mm	Cutting Speed	MRR mm^3/min
300	0.1	0.5	23.09	1.15
	0.2	1	22.15	4.43
	0.3	1.5	20.73	9.33
	0.4	2	18.84	15.07
	0.5	2.5	16.49	20.62

400	0.1	0.8	30.41	2.43
	0.2	1.6	28.40	9.09
	0.3	2.4	25.64	18.45
	0.4	3.2	21.36	27.34
	0.5	4	16.33	32.67

TABLE 3 MATERIAL REMOVAL RATE ON CRYOGENIC HSS

Spindle Speed	Feed Rate	Depth of Cut	CuttingSpeed	MRR mm^3/min
300	0.1	0.68	22.92	1.56
	0.2	1.35	21.64	5.85
	0.3	2.05	19.71	12.12
	0.4	2.7	17.17	18.54
	0.5	3.3	14.06	23.20
400	0.1	0.92	30.26	2.78
	0.2	1.8	27.99	10.07
	0.3	2.75	24.54	20.25
	0.4	3.6	20.02	28.83
	0.5	4.51	15.50	34.97

CONCLUSION

Cryogenic treatments accelerate the decomposition of martensite which modifies the precipitation behavior of secondary carbides. Comparative study on the hardness and toughness of cryogenically treated HSS samples and carbide inserts with that of untreated tools. In the sliding wear test, the weight loss of cryogenically treated tools is more as compared to that of untreated tools. This can be attributed to the fact that tool becomes brittle after cryogenic treatment. By this technique specially hardness, wear resistance, corrosion resistance, toughness increases. Cryogenics materials will be part of the dynamic future. We must not only continue to make incremental improvements in present materials but develop whole new technologies of manufacturing and processing for to achieve the highest performance in cryogenics materials field. Cryogenics-based technologies have applications in wide variety of areas as metallurgy, chemistry, power industry, medicine, rocket propulsion and space simulation, food process

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