Performance Parameter of Cryogenically Treated and Detonation Coated HSS

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Abstract: Metal cutting process forms the basics of the engineering industry. The cutting tool is one of the important elements in realizing the full potential out of any metal cutting operation. 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. The incorporation of suitable surface treatments, its service life as well as its properties can be enhanced even more. Cryogenic treatment is an inexpensive one time permanent treatment affecting the entire section or bulk of the component unlike coatings. The treatment is an add on process over conventional heat treatment in which the samples are cooled down to prescribed cryogenic temperature for a long time and then heated back to room temperature. It is believed that life of cutting tool get substantially extended due to cryogenic treatment. To make a comparative study on hardness and wear resistance of cryogenically treated HSS samples and Tungsten carbide coating with that of untreated tools and study the effect of shear and stress of WC coated and uncoated HSS by using ANSYS and SOLIDWORKS software and find the microstructure changes. By this we can suggest that the tool life will be increased through the cryogenic treatment.

Keywords: cryogenic treatment, hardness test, optical microscope analysis, sem analysis, solid works and Ansys software

INTRODUCTION

1.1 BACKGROUND

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 for an impressive increase in productivity. Changes in work piece materials, manufacturing processes and even government regulations catalyse parallel advances in metal cutting tooling technology. (18)

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 developed that can machine new materials at the highest productivity. The properties that a tool material must process are as follows:

- Capacity to retain form stability at elevated temperatures during high cutting speeds.
- Cost and ease of fabrication
- High resistance to brittle fracture
- Resistance to diffusion
- Resistance to thermal and mechanical shock

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. Tool wear occurs by one or more complex mechanisms which includes abrasive wear, chipping at the cutting edge, thermal cracking etc. Since most of these processes are greatly accelerated by increased temperatures, the more obvious requirements for tool materials are improvements in physical, mechanical and chemical properties at elevated temperature. (18)

1.2 TECHNOLOGICAL DEVELOPMENT

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. (18)

Till 1900 machining was performed by plain carbon tool steel, shortly after 1900 high speed steel was introduced this 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. (18)
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. (18)

Cryogenic treatment is an inexpensive one time permanent treatment affecting the entire section or bulk of the component unlike coatings. The treatment is an add on process over conventional heat treatment in which the samples are cooled down to prescribed cryogenic temperature for a long time and then heated back to room temperature. It is believed that life of cutting tool get substantially extended due to cryogenic treatment. However, researchers have been skeptical about the process because it imparts no apparent visible change. Moreover mechanism is also unpredictable and research articles are also not sufficient to support the treatment. So in general cryogenic treatment is still in the dormant level. Over the past few years there has been an interest in the application of cryogenic temperature to different materials. Some literature says that the cryogenic treatment can improve the life span would depend a lot on the cutting conditions. (18)

I. LITERATURE REVIEW

Studies on cryogenically treated high speed steel tools by Amin et al. [1] stated that the common methods to eliminate retained austenite is the deep cryogenic treatment. Besides the elimination or reduction of retained austenite at low temperatures the carbide percentage increases and shows a more homogenous distribution as compared with the conventionally heat treated samples. The wear resistance and hardness of the samples are improved significantly after the deep cryogenic treatment. At low temperatures, the martensite unit cells endure a high degree of contraction which forces the carbon atoms to jump to the nearby defects to decrease the structure internal stresses. These carbon atoms act as preferential sites for carbide nucleation during tempering. This phenomenon leads to an increase in the carbide percentage and improves its distribution.

Candane et al. [3] stated that high speed steel is the most ideal tool material for operations such as drilling, tapping and reamining where the economic cutting speed is too low for its competitors. In case of deep drilling operations high speed steel is the most ideal and extremely unique in performance due to its ability to absorb shocks and vibrations during drilling.

Daniel [3] stated that most recent studies the surface integrity resulting from cryogenic machining regarding residual stress and hardness are analysed the influence of the combination of process integrated cryogenic treatment and mechanical processes on the grain size. They revealed a significant grain refinement and thus increase corrosion resistance.

Firozdzor et al. [4] concluded from experimental studies that wear resistance improvement was mainly attributable to the resistance of cryogenically treated drills against diffusion wear mechanism, mainly due to the formation of fine and homogeneous carbide particles during cryogenic treatment. During cryogenic treatment, the secondary carbides precipitate in the austenite matrix, promote the transformation of the retained austenite to martensite and consequently enhance hardness and wear resistance of the alloy. It was also concluded that cooling and heating rates must be kept constant at about 0.5 ºC/min to avoid any thermal micro cracking formation.

Cryogenic treatment of M2 HSS can facilitate carbon clustering formation and increase in the carbide density in subsequent treatment. Cryogenic treatment promotes the complete transformation of retained austenite into martensite at cryogenic temperature that is attributed to improved wear resistance. This transformation is responsible for hardness increasing of steel as well as the increase in wear resistance.

Flavio et al. [5] have shown micro structural changes in the material that can influence tool lives and productivity significantly. Published results also show that tool life improves from 92% to 817% when using the cryogenically treated HSS tools in the industry.

The cryogenic treatment is applied to the whole volume of the material, reaching the core of the tools. This guarantees retention of their properties even after regrinding or sharpening. The treatment was applied using temperatures in the range of -80 ºC to -100 ºC for periods of about 30min to 1h, and the improvement on tool life was credited to the transformation of retained austenite (softer) into martensite (harder) and the production of a more stable structure. The conventional heat treatment normally uses cooling conditions only until room temperature, which may leave some retained austenite on the microstructure. This fact must be considered during heat treatment of tool steels. For the eutectoid steel the Mf (final transformation temperature) temperature is of approximately of -50 ºC, therefore after quenching some percentage of retained austenite will be present. Lately this structure can be transformed into martensite if the material is submitted to reheating or to a stress field, causing distortion on its body. This non tempered martensite may cause cracks, particularly in complex shape tools made of highly alloyed steels. The subzero treatment will transform a great deal of this retained austenite by reaching the Mf line, giving more dimensional stability in the tool microstructure.

Murthy et al. [6] stated that the erosion resistance of the detonation spray coating is higher. This is possibly due to the
slightly higher micro hardness, lower porosity and possibly higher residual compressive stresses of the detonation spray coating. **Paulin [7]** verified the presence of fine precipitated carbide particles and their importance to the material properties. It was concluded that 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. **Pusavec et al.[8]** mention that by simply avoiding cooling lubrication fluids usage and applying dry machining alternatives, with new high performance coated cutting tools, there would be a huge process gain from a sustainability. **Spigarelli et al.[9]** stated that deep cryogenic treatment transforms the retain austenite into martensite and causes the precipitation of finally dispersed carbides. During deep cryogenic treatment primary martensite decomposes through a time dependent transformation, leading to the nucleation of numerous coherent nanocarbides, which are considered to be the precursors of the nano sized carbides formed during subsequent tempering. These nanoparticles, which should thus form only in primary martensite are considered to be responsible for the significant increase in wear resistance observed in tool steels after deep cryogenic treatment.

II. OBJECTIVE OF THE STUDY

- To make a comparative study on the hardness and wear resistance of cryogenically treated HSS samples and Tungsten carbide coating with that of untreated tools.
- To study the effect of shear and stress of WC coated and uncoated HSS by using ANSYS and SOLIDWORKS software.
- To study the micro structural changes.

III. SCOPE OF THE STUDY

The study provides a better understanding of cryogenic treatment and the tool life will increase after the treatment of the cryogenic by through the analysis method.

IV. CRYOGENIC TREATMENT

Cryogenics is defined as the branches of physics and engineering that study very low temperatures, how to produce them, and how materials behave at those temperatures. Rather than the familiar temperature scales of Fahrenheit and Celsius, cryogenists use the Kelvin and Rankin scales. (16)

The word cryogenics literally means "the production of icy cold"; however the term is used today as a synonym for the low-temperature state. It is not well-defined at what point on the temperature scale refrigeration ends and cryogenics begins. The workers at the National Institute of Standards and Technology at Boulder, Colorado have chosen to consider the field of cryogenics as that involving temperatures below −180 °C (93.15 K). This is a logical dividing line, since the normal boiling points of the so-called permanent gases (such as helium, hydrogen, neon, nitrogen, oxygen, and normal air) lie below -180 °C while the Freon refrigerants, hydrogen sulphide, and other common refrigerants have boiling points above -180 °C. Cryogenic temperatures are achieved either by the rapid evaporation of volatile liquids or by the expansion of gases confined initially at pressures of 150 to 200 atmospheres. The expansion may be simple, that is, through a valve to a region of lower pressure, or it may occur in the cylinder of a reciprocating engine, with the gas driving the piston of the engine. The second method is more efficient but is also more difficult to apply. (16)

Cryogenic treatment is a one-time permanent treatment process and it affects the entire cross-section of the material usually done at the end of conventional heat treatment process but before tempering. Also it is not a substitute process but rather a supplement to conventional heat treatment process. It is believed to improve wear resistance as well the surface hardness and thermal stability of various materials.

This treatment is done to make sure there is no retained austenite during quenching. When steel is at the hardening temperature, there is a solid solution of Carbon and Iron, known as Austenite. The amount of martensite formed at quenching is a function of the lowest temperature encountered. At any given temperature of quenching there is a certain amount of martensite and the balance is untransformed austenite. This untransformed austenite is very brittle and can cause loss of strength or hardness, dimensional instability, or cracking. Quenches are usually done to room temperature. Most medium carbon steels and low alloy steels undergo transformation to 100 % martensite at room temperature. However, high carbon and high alloy steels have retained Austenite at room temperature. To eliminate retained Austenite, the temperature has to be lowered. (16)

Liquefed gases, such as liquid nitrogen and liquid helium, are used in many cryogenic applications. Liquid nitrogen is the most commonly used element in cryogenics and is legally purchasable around the world. Liquid helium is also commonly used and allows for the lowest attainable temperatures to be reached. These gases are held in either special containers known as Dewar flasks, which are generally about six feet tall (1.8 m) and three feet (91.5 cm) in diameter, or giant tanks in larger commercial operations. Cryogenic transfer pumps are the pumps used on LNG piers to transfer Liquefied Natural Gas from LNG Carriers to LNG storage tanks.

THE 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 fig3.2 and fig. 3.3. Fig.3.4 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 dewar 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 ensuring that the dangers of cracking from too rapid cooling are eliminated.

V. SURFACE TREATMENT

Advances in manufacturing technologies (increased cutting speeds, dry machining, etc.) triggered the fast commercial growth of various surface treatments for cutting tools; on the other hand these surface coating technologies enabled these advances in manufacturing technologies. No single treatment will solve every problem and their use should be restricted to those operations where extra expense of the treatment can be justified by a substantial performance gain. (18) The process of surface treatment helps the surfaces of engineering materials to:

- Wear and friction controlling
- Corrosion resistance improving
- Changes the physical property
- Reduce cost

Ultimately the functions on service lines of the materials can be improved. Common surface treatments can be divided into two major categories:

a. Treatments that cover surfaces
b. Treatments that alter surfaces

Treatments covering surfaces:

- Organic coatings as paints, cements, laminates, fused powders, lubricants, or floor toppings on the surfaces of the materials.
- Inorganic coating such as electroplating, autocatalytic plating’s, conversion coatings, thermal sprayings, furnace fusing, or coat thin films on the surfaces of the materials (PVD and CVD). (18)

Treatments altering surfaces:

- High energy treatments such as ion implantation, laser glazing/fusion, and electron beam treatment.
- Hardenings such as flame, induction, laser or electron beam
- Heavy diffusion treatments include carburizing, nitriding, and carbonitriding
- Special treatments such as cryogenic, magnetic and sonic treatment. (15)

VI. THERMAL SPRAY COATING

Thermal spray coating is a group of processes in which metals, alloys, ceramics, plastics and composite materials in the form of powder, wire, or rod are fed to a torch or gun with which they are heated to near to above their melting point. Combustion or electrical arc discharge is usually used as the source of energy for thermal spraying. The resulting molten droplets of material are accelerated in a gas stream and projected against the surface to be coated (i.e., the substrate). On impact, the droplets flow into thin lamellar particles adhering to the surface, overlapping and interlocking as they solidify. Thermal spraying can provide thick coatings (approx. thickness range 20 micrometers to several mm, depending on the process and feedstock), over a large area at high deposition rate as compared to other coating processes such as electroplating, physical and chemical vapour deposition.

Several variations of thermal spraying are distinguished:

- Flame spraying
- Electric-arc (wire-arc) Spraying
- Plasma spraying
- High-velocity oxygen fuel spraying (HVOF)
- Detonation spraying
- Cold spraying

DETONATION GUN PROCESS

In the detonation gun process, shown schematically in Fig 4.2, a mixture of oxygen and acetylene, along with a pulse of powder, is introduced into a barrel and detonated using a spark.

Fig 4.2 Schematic Diagram of the Detonation thermal Spray process.

The high-temperature, high-pressure detonation wave moving down the barrel heats the powder particles to their melting points or above and accelerates them to a velocity of about 750 m/s. By changing the fuel gas and some other parameters, the Super D-Gun process achieves velocities of about 1000 m/s. This is a cyclic process, and after each detonation the barrel is purged with nitrogen and the process is repeated at up to about 10 times per second. Instead of a continuous swath of coating as in the other thermal spray processes, a circle of coating about 25 mm in diameter and a few micrometers thick is deposited with each detonation. A uniform coating thickness on the part is achieved by precisely overlapping the circles of coating in many layer Typical coating thicknesses are in the range of 0.05 to 0.50 mm, but thinner and much thicker coatings can be used. The detonation gun coatings have some of the highest bond strengths and lowest porosities of the thermal spray coatings. Careful control of the gases used generally results in little oxidation of metallic or carbides. Virtually all metallic, ceramic, and cermets materials can be deposited using detonation gun deposition. Detonation gun coatings are used extensively for wear and corrosion resistance as well as for many other types of applications.
They are frequently specified for the most demanding applications, but often can be also the most economical choice because of their long life.

<table>
<thead>
<tr>
<th>RPM</th>
<th>600</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>10 min</td>
</tr>
<tr>
<td>Type of abrasive paper</td>
<td>Emery</td>
</tr>
</tbody>
</table>

High speed steels owe their name to the fact that they were originally developed for high speed metal cutting. The properties of high resistance to wear and heat high initial hardness of about 25 to 30 RC at annealed condition and the economical price of HSS have made them a logical choice of many cutting industries. This finds applications as turning tools, twist drills, counter bores, taps and dies, reamers, broaches, milling cutters, hobs, saws, etc. The perfect combination of alloying elements and the domain of heat treatment processes confers excellent hardness and wear resistance properties allied to good toughness. The HSS samples considered in this work are M2 and M35 metals and alloys with dimensions 10x50 mm.

VII. TUNGSTEN CARBIDE POWDER

Tungsten carbide (WC) is an inorganic chemical compound containing equal parts of tungsten and carbon atoms. In its most basic form, tungsten carbide is a fine gray powder. There are two well-characterized compounds of tungsten and carbon, WC and tungsten semi carbide, W\textsubscript{C}. Both compounds may be present in coatings and the proportions can depend on the coating method. At high temperatures WC decomposes to tungsten and carbon and this can occur during high-temperature thermal spray.

VIII. LABORATORY TEST

a) SLIDING WEAR TEST

The materials considered for this were the cryogenically treated and untreated as well as tungsten carbide coated M35 and M2 grade HSS samples with dimensions 10 x 50 mm. The test was conducted on a machine called disc and pinion as shown in fig 5.1. The sample was mounted perpendicularly on a stationary vice such that it’s one of the face is forced against the abrasive that is fixed on the revolving disc. Hence it is the abrasive paper that tends to wear the surface of the samples. When the disc rotates for a particular period of time the sample can be loaded at the top to press against the disc with the help of a lever mechanism. In the present experimental work, speed and time were kept constant while the load was varied from 20 and 40 N. Parameters that remained constant throughout all the experiments are given in table

Table 5.1 Parameters taken constant in sliding wear test

<table>
<thead>
<tr>
<th>RPM</th>
<th>600</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>10 min</td>
</tr>
<tr>
<td>Type of abrasive paper</td>
<td>Emery</td>
</tr>
</tbody>
</table>

b) HARDNESS TEST

Rockwell hardness testing (the apparatus being shown in fig. 5.2) is a general method for measuring the bulk hardness of metallic and polymer materials. Although hardness testing does not give a direct measurement of any performance properties, hardness correlates with strength, wear resistance, and other properties. Hardness testing is widely used for material evaluation due to its simplicity and low cost relative to direct measurement of many properties. This method consists of indenting the test material with a diamond cone or hardened steel ball indenter. The indenter is forced into the test material under a preliminary minor load $F_0$ (Fig. 5.3 A) usually 100 kgf. When equilibrium has been reached, an indicating device, which follows the movements of the indenter and so responds to changes in depth of penetration of the indenter, is set to a datum position. While the preliminary minor load is still applied an additional major load is applied with resulting increase in penetration (Fig. 5.3 B). When equilibrium has again been reached, additional major load is removed but the preliminary minor load is still maintained. Removal of the additional major load allows a partial recovery, so reducing the depth of penetration (Fig. 5.3 C). The permanent increase in depth of penetration, resulting from the application and removal of the additional major load is used to calculate the Rockwell hardness number.

In the present experimental work Rockwell Hardness was measured on cryogenically treated and untreated M2 and M35 grade HSS as well as WC coated M2 and M35 HSS samples with a minimum of three indentations in each. The average of these measurements was considered for comparison.

IX. RESULTS AND DISCUSSION

METALLOGRAPHIC EXAMINATION

This part of the work had the objective of analysing the changes that occurred in the micro structure of the M2 and M35 high speed steel after the cryogenic treatments well as Tungsten Carbide coating. Metallographic study basically includes the following:

OPTICAL MICRO-EXAMINATION

This is defined as the method of studying microstructure constituents (grains, phases, micro pores, etc) by means of a metallurgical microscope. In order to carry the analysis first the samples were polished using emery paper of four different grits. This was followed by mirror finishing by polishing the samples on velvet cloth which is mounted on a rotating disc. After this these samples were etched with 2% nital and dried in air. Microstructure examination was carried out using an optical microscope.(17)

SCANNING ELECTRO MICROSCOPE

Scanning electron microscope creates images by using electrons instead of light waves while conventional
Microscopes use a series of lenses to bend light waves and create magnified images. The SEM shows very detailed three-dimensional images at much higher magnification. The images obtained from this are black and white only as this does not work on the principles of light waves.\(^{(17)}\)

**IMPLEMENTATION OF ANSYS AND SOLID WORKS ANALYSIS OF SHEAR AND STRESS BEFORE AND AFTER CRYOGENIC TREATMENT**

ANSYS is general-purpose Finite Element Analysis (FEA) software package. Finite element analysis is a numerical method of deconstructing a complex system into very small pieces (of user designed size) called elements. The software implements equations that govern the behavior of these elements and solves them all creating a comprehensive explanation of how the system acts as a whole. In this paper includes overview of twist drill analysis using Ansys. The objective is to acquire basic understanding and skill in the usage of Ansys software. Solid works is a software package. Solid modelling can easily predict the behavior of real model under specified load and displacement conditions.

**X. RESULT AND DISCUSSION**

**XI. LABORATORY TEST**

**Sliding wear test**

M2 and M35 grade HSS as well as WC coated M2 and M35 HSS samples were subjected to sliding wear test to evaluate the effect of cryogenic treatment on the wear resistance. The tests were conducted on HSS samples by the load of 20N, time is set at 10 minutes and the rotary speed of emery is set at 600 RPM are being constant. Table 6.1 shows the results of friction according to the wear. From the table we can conclude that after cryogenic treatment loss of material is less compared to the untreated material. Hence the tool life of the tool steel will increase after cryogenic treatment.

Table 6.1 Effect of friction and wear of M2 and M35 HSS before and after cryogenic treatment

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Specimen(HSS coated with WC)</th>
<th>Friction (N)</th>
<th>Wear (Micrometer)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M2 coated/untreated</td>
<td>7.5</td>
<td>60</td>
</tr>
<tr>
<td>2</td>
<td>M2 coated/treated</td>
<td>6</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>M2 treated/coated</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>4</td>
<td>M35 coated/untreated</td>
<td>7</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>M35 coated/treated</td>
<td>7.5</td>
<td>45</td>
</tr>
<tr>
<td>6</td>
<td>M35 treated/coated</td>
<td>6</td>
<td>35</td>
</tr>
</tbody>
</table>

The graphical representation of wear of M2 and M35 HSS before and after cryogenic treatment is shown in fig 6.1. In this graph after cryogenic treatment WC coating is applied material shows very less wear both M2 and M35 grade HSS compare to untreated and treated WC coated material. The M2 HSS coating is applied on untreated tool steel shows higher wear rate. After coating cryogenically treated M2 and M35 HSS shows median removal of material. The main drawback

**Table 6.2 Effect of friction and wear of M2 and M35 coated HSS**

<table>
<thead>
<tr>
<th>Sl No</th>
<th>Specimen (HSS)</th>
<th>Friction (N)</th>
<th>Wear (Micrometers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M2 untreated</td>
<td>10</td>
<td>150</td>
</tr>
<tr>
<td>2</td>
<td>M2 treated</td>
<td>10</td>
<td>70</td>
</tr>
<tr>
<td>3</td>
<td>M35 untreated</td>
<td>12</td>
<td>225</td>
</tr>
<tr>
<td>4</td>
<td>M35 treated</td>
<td>11.5</td>
<td>160</td>
</tr>
</tbody>
</table>
of coated material is the erosion of the coated material when testing is done.

Fig 6.2 Wear of M2 and M35 coated HSS before and after cryogenic treatment

HARDNESS TEST
Table 6.3 shows the hardness of both cryogenically treated and untreated M2 and M35 grade HSS samples. They are practically the same thus indicating that the cryogenic treatments had no influence on this property of this tool steel. The hardness results did not show conspicuous difference between the treated and untreated tool steel.

Table 6.3 hardness of M2 and M35 HSS before and after treatment

Table 6.4 shows the hardness of both cryogenically treated and untreated WC coated M2 and M35 grade HSS samples. The coated material shows more hardness than tool steel. After cryogenic treated and then WC coated material shows more hardness than untreated and treated coated M2 and M35 HSS. In this M35 HSS after cryogenic treated and coated material shows higher hardness.

Table 6.4 Hardness of cryogenically treated and untreated WC coated HSS

<table>
<thead>
<tr>
<th>SI No</th>
<th>Specimen (HSS coated with WC)</th>
<th>Hardness (HRc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M2(coated/untreated)</td>
<td>43</td>
</tr>
<tr>
<td>2</td>
<td>M2(coated/treated)</td>
<td>46</td>
</tr>
<tr>
<td>3</td>
<td>M2(treated/coated)</td>
<td>44</td>
</tr>
<tr>
<td>4</td>
<td>M35(coated/untreated)</td>
<td>45</td>
</tr>
<tr>
<td>5</td>
<td>M35(coated/treated)</td>
<td>63</td>
</tr>
<tr>
<td>6</td>
<td>M35(treated/coated)</td>
<td>48</td>
</tr>
</tbody>
</table>

XII. METALLOGRAPHIC EXAMINATION CHARACTERIZATION BY OPTICAL MICROSCOPE

Fig 6.5 shows the microstructures of M2 and M35 grade HSS samples. Not much could be inferred from this as any significant changes in microstructure after the cryogenic treatment observed literature data indicates transformation of retained austenite into martensite as well as carbide refinement. But it was very difficult to detect such changes with the help of an optical microscope.
Fig 6.5 450x magnified microstructure of cryogenically treated and untreated M2 and M35 HSS

SEM ANALYSIS
SEM was carried for both cryogenically treated and untreated HSS samples to study the microstructural changes. Results of the SEM analysis are shown in fig 6.8 and fig 6.9 for cryogenically treated and untreated HSS samples respectively. The results showed the presence of the fine precipitated carbide particles in case of cryogenically treated samples which verify that the refinement of carbides takes place after the cryogenic treatment.

Fig 6.6 SEM images of untreated HSS

Fig 6.7 SEM images of treated HSS

XIII. IMPLEMENTATION OF ANSYS AND SOLID WORKS FOR SHEAR AND STRESS ANALYSIS

Finite element structural analysis is a method of predicting the behavior of a real structure under specified load and displacement conditions. The finite element modeling is generalization of the displacement or matrix method of structural analysis to two and three-dimensional problems and three-dimensional problems. The basic concept of FEM that structure to be analyzed is considered to be an assemblage of discrete pieces called elements that are connected together at a finite number of points or nodes. The finite element is a geometrically simplified representation of a small part of the physical structure. Discretizing the structure requires experience and complete understanding of the behavior of the structure can behave like a beam, truss, plate, and shell. From the solid modeling can easily predict the behavior of real model under specified load and displacement conditions

The general procedure of performing drill bit analyses using ANSYS:

- Building the model of the drill bit.
- Definition of element types and appropriate key options of tool steel.
- Definition of element types and appropriate key options of coating material
- Mesh generation of the drill bit.
- Assigning material properties.
- Application of the appropriate boundary conditions.
- Defining impact force and tangential force.
- Defining the analysis type.
- Selection of the required solver.
Solving for the analysis.
- Post processing the obtained results.

XIV. SELECTION OF ELEMENTS

In ANSYS, elements for drill bit model should be chosen based upon the criteria that the element should support. The element type Solid 72 is being used because it is having 6 degrees of freedom and can apply impact load and torsional force.

Solid 72

Solid 72 is well suited to model irregular meshes (such as produced from various CAD/CAM systems). The element is defined by four nodes having six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z directions. The element also has stress stiffening capability. The element input data includes the orthotropic material properties. Orthotropic material directions correspond to the element coordinate directions. The element coordinate system is used for orthotropic material input directions, applied pressure directions, and, under some circumstances, stress output directions.

Designing of drill bit

The design of drill bit is by solid works

Modelled drill parameters are

- Flute length=69.85mm
- Point angle=118 deg
- Shank length=34.925mm
- Shank dia=6.35mm
- Helix angle=20deg

Fig 6.10 shows the drill bit designed by using solid works software

<table>
<thead>
<tr>
<th>Young’s modulus</th>
<th>Poisson’s ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before cryogenic treatment</td>
<td>2 * 10^5 N/mm²</td>
</tr>
<tr>
<td>After cryogenic treatment</td>
<td>2.2 * 10^5 N/mm²</td>
</tr>
</tbody>
</table>

Table 6.4.1 material properties of the tool

After modelling the tool in solid works import the work into ANSYS software steps are

- Open ANSYS – file menu – import – IGES – ok
- Material properties – element type – SOLID 72 – 4 nodes and 6 dof at nodal x,y,z
- Pre-processor – material property – orthotropic
- Structural – Ex – Prxy – ok
- Mesh – Hypermesh – ok
- Boundary condition- structural – impact force =500N – tangential force = 5000N
- Solve – shear stress and shear intensity

By from before cryogenic test and after cryogenic test results we got that before cryogenic test the tool cannot withstand the load and after cryogenic test the tool withstand the load by the given datas. The result of the Ansys and solid work of Fig 6.7, 6.8, 6.9, 6.10 is shown below.

Fig 6.10 Design of drill bit

This shape is complicated to mesh in Ansly, so meshing is done by Hypermesh software and the impact force is given as 500N and the tangential force is given as 5000N. Then the shear stress and stress intensity is formed as shown in fig 6.13 and fig 6.14 respectively.

XV. ANSYS PROCEDURE

First prepare a model for drill bit. Modelling is done through solid work software and then imported to the Ansys software to find the stress and shear of the tool before and after cryogenic test. In solid works select the M2 tool material giving the material properties of the tool is given below.
XVI. CONCLUSION

1. In the sliding wear test, the weight loss of cryogenically treated tools is less as compared to that of untreated tools. Hence the tool life of the tool steel will increase after cryogenic treatment.

2. Effective less wear shows that the tool steel after treatment and coated material of both M2 and M35 grade HSS. In the case of coated M2 and M35, M2 HSS shows less wear than M35 grade HSS.

3. The hardness results did not show conspicuous difference between the treated and untreated tool steel.

4. The coated material shows more hardness than tool steel. After cryogenic treated and WC coated material shows more hardness than untreated and treated, coated M2 and M35 HSS. In this M35 HSS after cryogenic treated and coated material shows higher hardness.

5. From SEM analysis, it is evident that refinement of carbides is more in case of cryogenically treated HSS tools in comparison to that of untreated tools.

6. Before the cryogenic treatment the analysis result shows the failure of the tool when the described force applied on it.

7. After the cryogenic treatment the tool withstand the force applied and the analysis is been done

XVII. ACKNOWLEDGMENT

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XVIII. REFERENCES


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