

# CHAPTER 1

## INTRODUCTION

### 1.1 INTRODUCTION

The commonly used cutting tool material in conventional machine tools is high speed steel. The high speed steel is used as a cutting tool since it has good quality and reliability. So improvement in tool life of HSS tool is important. For improving tool life we should improve tool's properties. So the best way is to improve the hardness and wear resistance of tool. There are various techniques are available for those improvement. One of the best techniques is cryogenic treatment. It is a heat treatment at low temperatures: many degrees below zero. Cryogenic treatment offers much better wear and hardness resistance. We take three grades of HSS. They are M2, M35 and T42.

### 1.2 SCOPE

The project provides a better understanding of cryogenic treatment and the tool life will increase after the treatment of the cryogenic by through the Experimental method. Most popular M2 and M35 high speed steels are used for the smooth machining operations while higher cobalt containing T42 tool steel used for the rough machining working on the lathe machines. The cryogenic treatment (below minus 150°C) is not widely used in industry for tool steels although shallow sub-zero treatment (till minus 80°C) is commonly practiced in the industry. Recent published research indicated that the cryogenic treatment induces definite metallurgical changes only below -150°C. Hence user of the tools can surely be benefitted by practicing cryogenic treatment. It facilitates transformation of retained austenite into the martensite, grain refinement and Nano sized formation of carbides in the microstructure that results in the enhancement of the wear resistance to the extent of 90% or more. This results in enormous cost saving by the user.

### **1.3 OBJECTIVES**

- To measure the hardness and wear for the cryogenic treated tools and untreated tools (M2, M35, T42 grade HSS tools).
- To compare the treated and untreated tools.
- To study microscopic changes.

### **1.4 TOOL LIFE**

Tool Life is defined as the time elapsed between two consecutive tool resharpening. During this period the tool serves effectively and efficiently. Tool failure criteria depends on

1. The requirements of the component being produced.
2. Types of Operation

Roughing: Force and power requirement.

Finishing : Surface finish & dimensional accuracy.

### **1.5 VARIOUS FACTORS AFFECTING TOOL LIFE**

- Tool Geometry (all six angles, and nose radius).
- Workpiece Material.
- Cutting Conditions (V, D, f).
- Cutting Fluid.
- Machine Tool and Workpiece Region.
- Tool Material.
- Machinability.

### **1.6 PROBLEM IDENTIFICATION**

As with most engineering problems we want to get the highest return, with the minimum investment. While increasing cutting speed, tool life decreases. Tipped tungsten carbide tool has higher wear resistance, good surface

finish and greater tool life than the High speed steel (HSS). Cost of tungsten carbide is costlier than other tools. To overcome this low cost HSS is processed to cryogenic treatment by this treatment we can obtain good wear resistance, surface finish and improvement in tool life.

## **1.7 TOOLS, EQUIPMENTS, MATERIALS REQUIREMENTS**

### **1.7.1 TOOL AND EQUIPMENTS REQUIREMENTS**

- Scanning Electron Microscope (SEM).
- Tool And Cutter Machine.
- Cryogenic Chamber.
- Heater.
- Lathe.
- Rockwell Hardness Tester.
- Diamond Indenter.
- MS Rod.
- Tool Makers Microscope.

### **1.7.2 MATERIAL REQUIREMENTS**

The following HSS Square Tool Bits were bought from the market.

Table 1.1 Materials Requirements

S.No	Tool	Grade	Size (inches)
1	HSS Square Tool Bit	M2	3/8 × 3/8 × 3
2	HSS Square Tool Bit	M35	3/8 × 3/8 × 3
3	HSS Square Tool Bit	T42	3/8 × 3/8 × 3

## CHAPTER 2

### LITERATURE REVIEW

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.

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 the boiling point of liquid nitrogen ( $-196\text{ }^{\circ}\text{C}$ ), maintenance of the temperature for about twenty four hours, followed by a controlled rising of the temperature back to room temperature. Subsequent tempering processes may follow Barron after cryogenically treating several materials including the M2 high speed steel at  $-84\text{ }^{\circ}\text{C}$  (maintaining it at this temperature for 24 hrs) 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  $-196^{\circ}\text{C}$ , 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. He verified that the tool steels submitted to conventional heat treatment presented only a small

amount of retained austenite, but those submitted to cryogenic treatment showed better performance during machining. This new mechanism would be time and temperature dependent due to the long period (8 hrs or more) during which the tools would have to stay at cryogenic temperatures. Before the cryogenic treatment the microstructure showed relatively large carbides (20  $\mu\text{m}$ ) dispersed in the matrix. After the cryogenic treatment, carbide particles as small as 5  $\mu\text{m}$  were found. The carbide refinement could in such a way contribute to the improvement of the wear resistance of the tool. Barron thus attributed this achievement both to austenite transformation and to the presence of hard and small carbide particles well distributed among the larger carbide particles within the martensite matrix

Donig 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

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 facilitates the carbide formation but can also make the carbide distribution more homogeneous.

Mohan Lal 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 favorable. Hence tempered samples if treated at still lower temperatures may yield still better results on par with untemper cryo treated samples. This also suggested concluding 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 favorable which may be because of uneven contraction of the coating material and the substrate leading to incipient cracks at the interface. Hence cryo treatment should not follow Tin coating.

The conventionally heat-treated and cryogenically treated specimens showed the largest and smallest wear volume at all sliding distance, respectively. From the microstructure of the steel it is reported that the improvement in wear resistance after cryogenic treatment can be attributed to  $\eta$ -carbide precipitates.

The wear resistances and tool life of M35 HSS tools significantly improved under dry machining conditions of stainless steels due to transformation of retained austenite to martensite.

The effects of cryogenic treatment on metallurgy of various tool steels investigated by various researchers have been reported in detail. The improvement in mechanical properties by cryogenic processing is attributed to

the combined Effects of the conversion of retained austenite to martensite and participation of fine carbide.

DR.N. B. Dhokey The cryogenic treatment (below minus  $150^{\circ}\text{C}$ ) is not widely used in industry for tool steels although shallow sub-zero treatment (till minus  $80^{\circ}\text{C}$ ) is commonly practiced in the industry. Recent published research indicated that the cryogenic treatment induces definite metallurgical changes only below  $-150^{\circ}\text{C}$ . Hence user of the tools can surely be benefitted by practicing cryogenic treatment. It facilitates transformation of retained austenite into the martensite, grain refinement and Nano sized formation of carbides in the microstructure that results in the enhancement of the wear resistance to the extent of 90% or more.

The conventionally treated T42 and M35 show higher carbide density than M2. The peak carbide density and hardness with maximum reduction in wear rate by 55 %, 90 % and 96 % at 8 h, 16 h, and 32 h for T42, M35, and M2 steels respectively that might be attributed to high rate of nucleation of carbides and completely transformation of retained austenite to martensite.

## CHAPTER 3

### TOOL GEOMETRY AND SELECTION

#### 3.1 SINGLE POINT CUTTING TOOL

A single point cutting tool has only one cutting edge or point. It consists of a sharpened cutting part called its point and shank. A single point cutting tool used for turning, boring, shaping and planing operations, that is tool used on the lathes, boring machines, shaper, planner etc. are single point cutting.

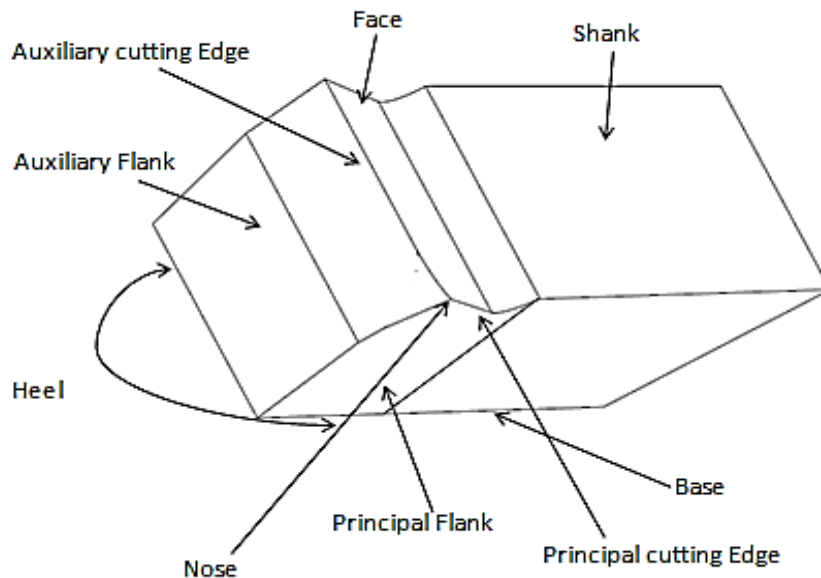


Figure 3.1 Single Point Cutting Tool

#### 3.2 PARTS OF SINGLE POINT CUTTING TOOL

- **Shank**

It is main body of tool. The shank used to gripped in tool holder.

- **Face**

It is top surface of the tool along which the chips slides.

- **Flank**



The surface or surface below the adjacent of the cutting edge is called flank of the tool.

- **Base**

It is actually a bearing surface of the tool when it is held in tool holder or clamped directly in a tool post.

- **Heel**

It is the intersection of the flank & base of the tool. It is curved portion at the bottom of the tool.

- **Nose**

It is the point where side cutting edge & base cutting edge intersect.

- **Cutting edge**

It is the edge on face of the tool which removes the material from work piece. The cutting edges are side cutting edge (major cutting edge) & end cutting edge ( minor cutting edge)

- **Tool angles**

Tool angles have great importance. The tool with proper angle, reduce breaking of tool, cut metal more efficiently, generate less heat.

- **Noise radius**

It provide long life & good surface finish sharp point on nose is highly stressed, & leaves grooves in the path of cut. Longer nose radius produce chatter.

### **3.3 TOOL ANGLES AND PURPOSE**

1. Side Cutting Edge Angle
2. End Cutting Edge Angle
3. End relief angle
4. Side relief angle

5. Side cutting angle Back rake angle

6. End cutting angle Side rake angle

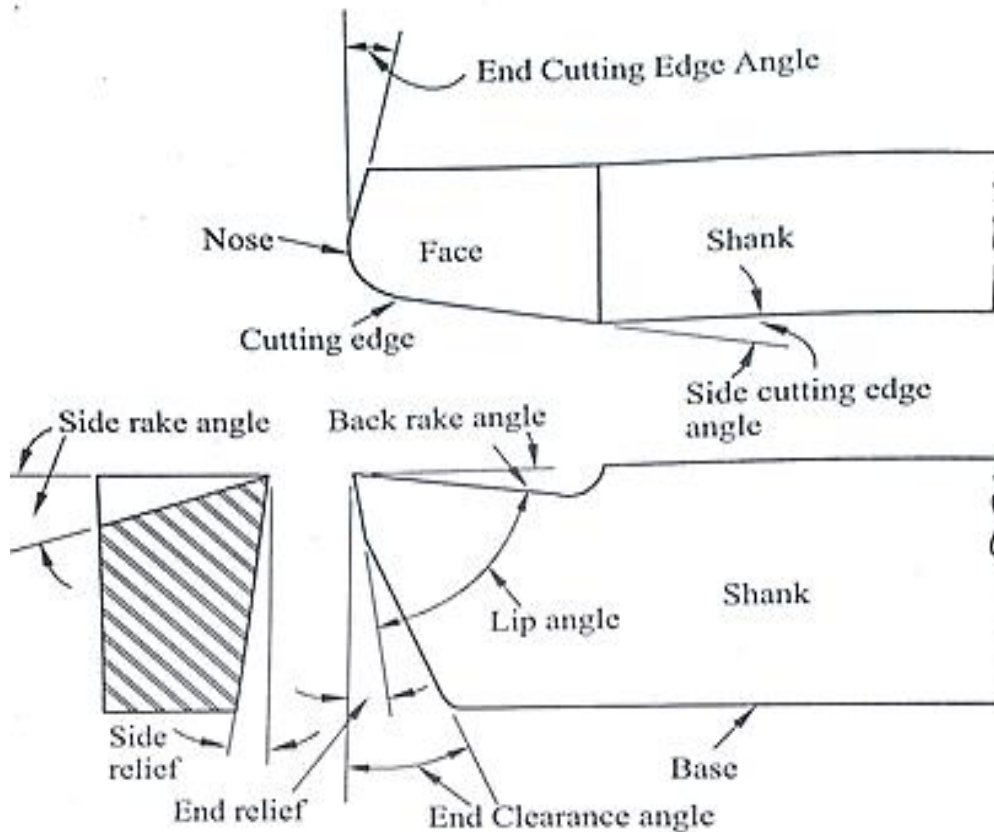


Figure 3.2 Tool Geometry

### 3.3.1 SIDE CUTTING EDGE ANGLE

The angle between side cutting edge and the side of the tool shank is called side cutting edge angle. It is often referred to as the lead angle. It is the angle which prevents interference as tool enters the work materials.

### 3.3.2 END CUTTING EDGE ANGLE

The angle between the end cutting edge and a line perpendicular to the shank of the tool shank is called end cutting edge angle. This angle provides a clearance Or relief to the trailing end of cutting edge to prevent rubbing.

### **3.3.3 SIDE RELIEF ANGLE**

The angle between the portion of the side flank immediately below the side cutting edge and a line perpendicular to the base of the tool. Clearance Angle is essentially provided to avoid rubbing of the tool (flank) with the machined surface which causes loss of energy and damages of both the tool and the job surface.

### **3.3.4 END RELIEF ANGLE**

The angle between the end flank and the line perpendicular to the base of the tool is called end relief angle.

### **3.3.5 BACK RAKE ANGLE**

The angle between the face of the tool and line perpendicular to the base of the tool measures on perpendicular plane through the side cutting edge. It is the angle which measures the slope of the face of the tool from the nose, towards the rack. If the slope is downward the nose it is negative back rake.

### **3.3.6 SIDE RAKE ANGLE**

The angle between the face of the tool and a line parallel to the base of the tool measured on plane perpendicular to the base and the side edge.

It is the angle that measures the slope of the tool face from the cutting edge, if the slope is towards the cutting edge it is negative side rake angle and if the slope is away from the cutting edge, it is positive side rake angle. If there is no slope the side rake angle is zero.

Positive rake – helps reduce cutting force and thus cutting power requirement.

Negative rake – to increase edge-strength and life of the tool

Zero rake – to simplify design and manufacture of the form tools

## CHAPTER 4

### HIGH SPEED TOOL STEEL

#### 4.1 INTRODUCTION

High-speed steel (HSS or HS) is a subset of tool steels, commonly used in tool bits and cutting tools. It is often used in power-saw blades and drill bits. It is superior to the older high-carbon steel tools used extensively in that it can withstand higher temperatures without losing its temper. This property allows HSS to cut faster than high carbon steel, hence the name high-speed steel. At room temperature, in their generally recommended heat treatment, HSS grades generally display high hardness and abrasion resistance (generally linked to tungsten and vanadium content often used in HSS) compared with common carbon and tool steels.

#### 4.2 TYPES OF HSS

High speed steels are alloys that gain their properties from either tungsten or molybdenum, often with a combination of the two. ASTM standards recognize 7 tungsten types and 17 molybdenum types.

Table 4.1 Chemical Compositions of Important Grades of HSS Tools

Grade	C	Cr	Mo	W	V	Co	Mn	Si
M1	0.80	4	8	1.5	1.0	-	-	-
M2	0.95	4	5	6.0	2.0	-	-	-
M7	1.00	4	8.75	1.75	2.0	-	-	-
M35	0.92	4.3	5	6.4	1.8	5	-	0.35
M42	1.10	3.75	9.5	1.5	1.15	8	-	-
T1	0.65–0.80	4.00	-	18	1	-	0.1–0.4	0.2–0.4
T42	1.20	4	3.30	9.20	3.10	9.60	-	-

## **4.2.1 TUNGSTEN - BASE HIGH SPEED TOOL STEELS**

### **4.2.1.1 T1 HSS TOOL**

The original HSS, it has been generally superseded by M2.

## **4.2.2 MOLYBDENUM BASE HIGH SPEED TOOL STEELS**

Adding molybdenum to tungsten steel creates several alloys commonly called "HSS", measuring 63-65 Rockwell Hardness.

### **4.2.2.1 M1 HSS TOOL**

M1 lacks some of the red-hardness properties of M2, but is less susceptible to shock and will flex more.

### **4.2.2.2 M2 HSS TOOL**

M2 is the "standard" and most widely used industrial HSS. It has small and evenly distributed carbides giving high wear resistance. Recommended for use on non-ferrous metals or mild steel or free cutting material.

### **4.2.2.3 M7 HSS TOOL**

M7 is used for making heavier construction drills where flexibility and extended drill life are equally important.

## **4.2.3 COBALT HIGH SPEED STEELS**

The addition of cobalt increases heat resistance, and can give a Rockwell Hardness up to 85.

#### **4.2.3.1 M35 HSS TOOL**

M35 is similar to M2, but with 5% cobalt added. M35 is also known as Cobalt Steel, HSSE or HSS-E. It will cut faster and last longer than M2. Recommended for heavy metal cutting work on difficult materials and an ideal general purpose HSS tool bit for machine shops where high production rates are required.

#### **4.2.3.2 T42 HSS TOOL**

T42 is a molybdenum-series high-speed steel alloy with additional 10% cobalt. It is widely used in metal manufacturing industries because of its superior red-hardness as compared to more conventional high-speed steels, allowing for shorter cycle times in production environments due to higher cutting speeds or from the increase in time between tool changes. Recommended for cutting High Alloy Steel in annealed condition

### **4.3 APPLICATIONS OF HSS**

The main use of high-speed steels continues to be in the manufacture of various cutting tools: drills, taps, milling cutters, tool bits, gear cutters, saw blades, planer and jointer blades, router bits, etc., although usage for punches and dies is increasing.

High speed steels also found a market in fine hand tools where their relatively good toughness at high hardness, coupled with high abrasion resistance, made them suitable for low speed applications requiring a durable keen (sharp) edge, such as files, chisels, hand plane blades, and high quality kitchen, pocket knives, and swords.

High speed steel tools are the most popular for use in woodturning, as the speed of movement of the work past the edge is relatively high for handheld tools, and HSS holds its edge far longer than high carbon steel tools can.

#### **4.4 SELECTION OF TOOLS**

We selected three grades of tools. They are M2 HSS TOOL, M35 HSS TOOL, T42 HSS TOOL. M2 HSS TOOL is one of the best tool used in small scale industry. M35 HSS TOOL has 5% cobalt content .It is harder than M2 grade. It is used for smooth machining. T42 HSS TOOL has 10% cobalt content. It is used for rough machining. It is harder than M2 & M35.

## CHAPTER 5

### CRYOGENIC TREATMENT

#### 5.1 INTRODUCTION

A cryogenic treatment is the process of treating work pieces to cryogenic temperatures (i.e. below  $-190\text{ }^{\circ}\text{C}$  ( $-310\text{ }^{\circ}\text{F}$ )) in order to remove residual stresses and improve wear resistance on steels. In addition to seeking enhanced stress relief and stabilization, or wear resistance, cryogenic treatment is also sought for its ability to improve corrosion resistance by precipitating micro-fine eta carbides. Cryogenic hardening is a cryogenic treatment process where the material is cooled to very low temperatures. By using liquid nitrogen, the temperature can go as low as  $-190\text{ }^{\circ}\text{C}$ . It can have a profound effect on the mechanical properties of certain materials, such as steels or tungsten carbide.

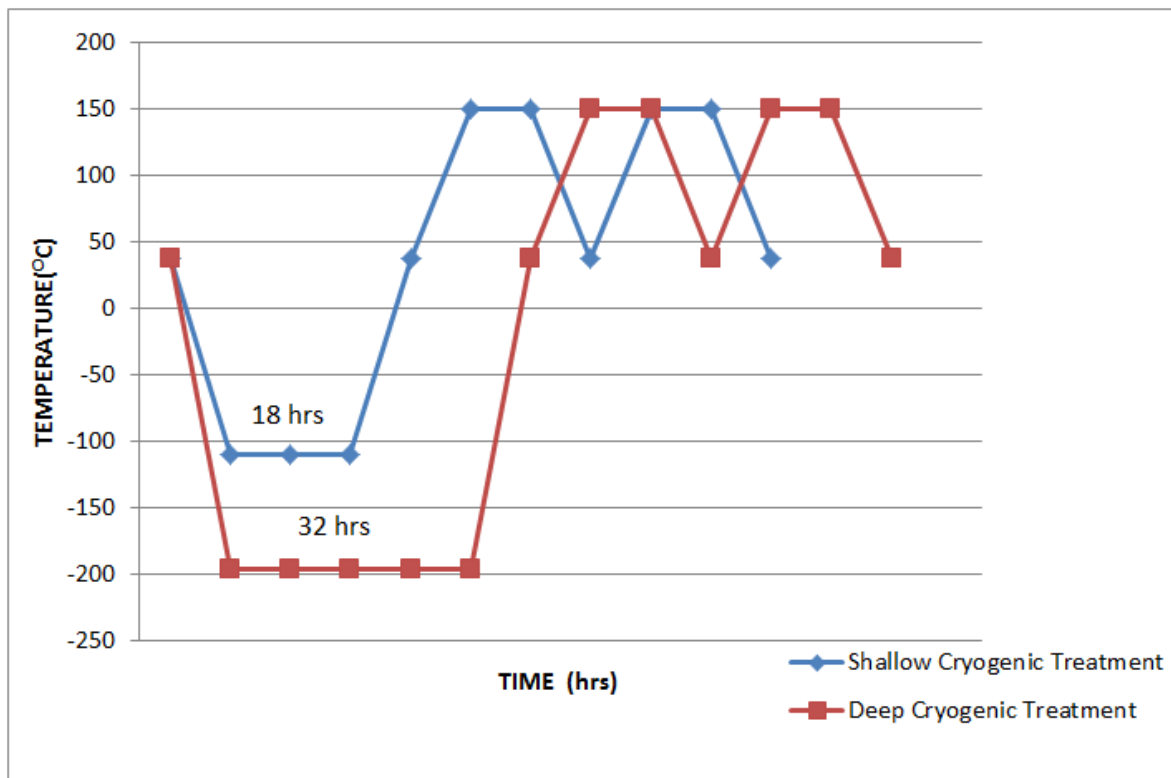


Figure 5.1 Cryogenic Treatment Types



## 5.2 TYPES OF CRYOGENIC TREATMENT

There are two types of Cryogenic Treatment. They are

1. Shallow Cryogenic Treatment
2. Deep Cryogenic Treatment

### 5.2.1 SHALLOW CRYOGENIC TREATMENT

Shallow Cryogenic process involves cooling down samples to  $-110^{\circ}\text{C}$  with soaking period of 18 hrs. Then brought back to room temperature by heating, followed by two tempering cycles consisting of heating to  $150^{\circ}\text{C}$  then bring back to room temperature.

### 5.2.2 DEEP CRYOGENIC TREATMENT

Deep Cryogenic process involves cooling down samples to  $-196^{\circ}\text{C}$  with soaking period of 32 hrs then brought back to room temperature by heating, followed by two tempering cycles consisting of heating to  $150^{\circ}\text{C}$  then bring back to room temperature.

## 5.3 CRYOGENIC TREATMENT SETUP

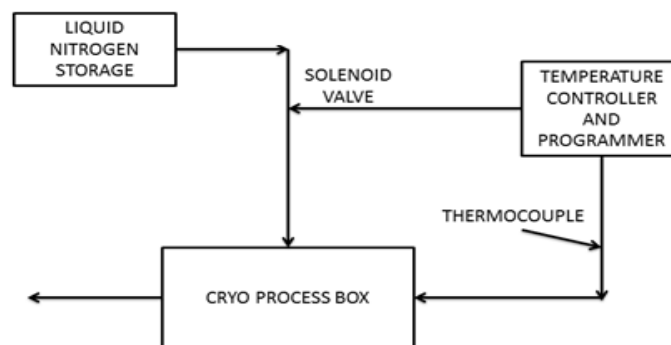


Figure 5.2 Cryogenic Treatment

The heat-exchanger system passes liquid nitrogen through a heat exchanger, and the exhaust gas from the unit is piped into the main gaseous-nitrogen header line. The chamber atmosphere is drawn over the heat-exchanger coils by a fan. In some versions of the system, the cooling is boosted by spraying liquid nitrogen directly into the chamber.

The direct spray system sprays liquid nitrogen directly into the chamber, while a fan circulates the gases over the work. In this system, the spent gas cannot be recovered for use as a furnace atmosphere. The equipment design does not permit the liquid nitrogen to come into direct contact with the work, thereby reducing the probability of thermal shock

#### **5.4 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. 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 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 assuring that the dangers of cracking from too rapid cooling are eliminated.

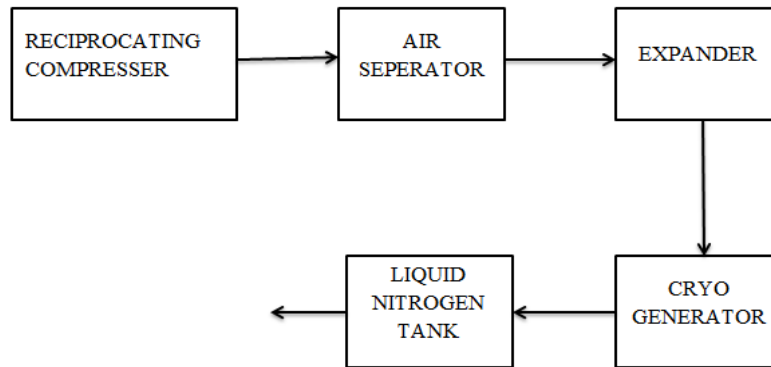


Figure 5.3 Experimental Setup for Making Liquid Nitrogen

## 5.5 SUITABLE TYPE OF TREATMENT

Recent published research indicated that the cryogenic treatment induces definite metallurgical changes only below  $-150^{\circ}\text{C}$ . Hence user of the tools can surely be benefitted by practicing cryogenic treatment. so we chose deep cryogenic treatment.

## 5.6 CRYOGENIC TREATMENT PROCEDURE

Cryogenic treatment involves the following sequence:

1. Slow cooling to predetermined low temperature
2. Soaking for predetermined amount of time
3. Slow heating to room temperature
4. Tempering

The cryogenic treatment was given to all conventionally treated specimens in a computer controlled Cryogenic chamber (Deep cryogenic treatment service center, hosur). These specimens were placed in Cryogenic chamber at room temperature and subsequently the temperature of the chamber was brought down to  $-195^{\circ}\text{C}$  at a cooling rate of  $3^{\circ}\text{C}/\text{min}$  by supplying calculated gasified liquid nitrogen through solenoid valve. The cryo soaking period was varied for each grade of tool. All tools were removed from the Cryogenic chamber after soaking period of 32hrs then brought back to room

temperature then brought back to room temperature by heating, followed by two tempering cycles consisting of heating to 150°C then bring back to room temperature.

## **5.7 IMPORTANCE OF CRYOGENIC TREATMENT**

Cryogenic processing with materials at the molecular level at Cryogenic treatment resulting in

- Homogenizes the crystal structure: Achieved by specially designed advanced ramp-soak time programs.
- Grain structure refinement: New ultra-fine carbide particles are formed which are uniformly dispersed throughout the material matrix.
- Prevent concentrated heat built up: Tools, Carbide tools, ball and roller bearings and tools, turbine blades, combustion, chamber, steel industry automobile industry etc. significantly benefit from this improvement.
- Regained austenite is converted to a fine martensite matrix: Significant improvement in dimensional stability.
- Relieves residual stresses.
- Significant improvement in material toughness.

## CHAPTER 6

### METHODOLOGY

#### 6.1 EXPERIMENTAL STEPS

- The commercially available three grades of HSS tool blank were bought from market.
- Required tool signatures were obtained from by help of Tool and Cutter machine and Tool Maker's Microscope.
- Then microstructures of tools were obtained using scanning electron microscope.
- Then the three grades of tool were selected (one tool from each grade).
- They were Cryogenic Treated.
- After the treatment changed microstructure was obtained using SEM.
- Then the hardness of all the tools were measured by using Rockwell Hardness Tester.
- Turning operation of work piece was performed in centre lathe by using treated and untreated tools.
- Flank wear was measured by using toolmakers microscope in certain intervals of machining time.
- Readings were tabulated and Graphs were drawn.

## 6.2 FLOW CHART

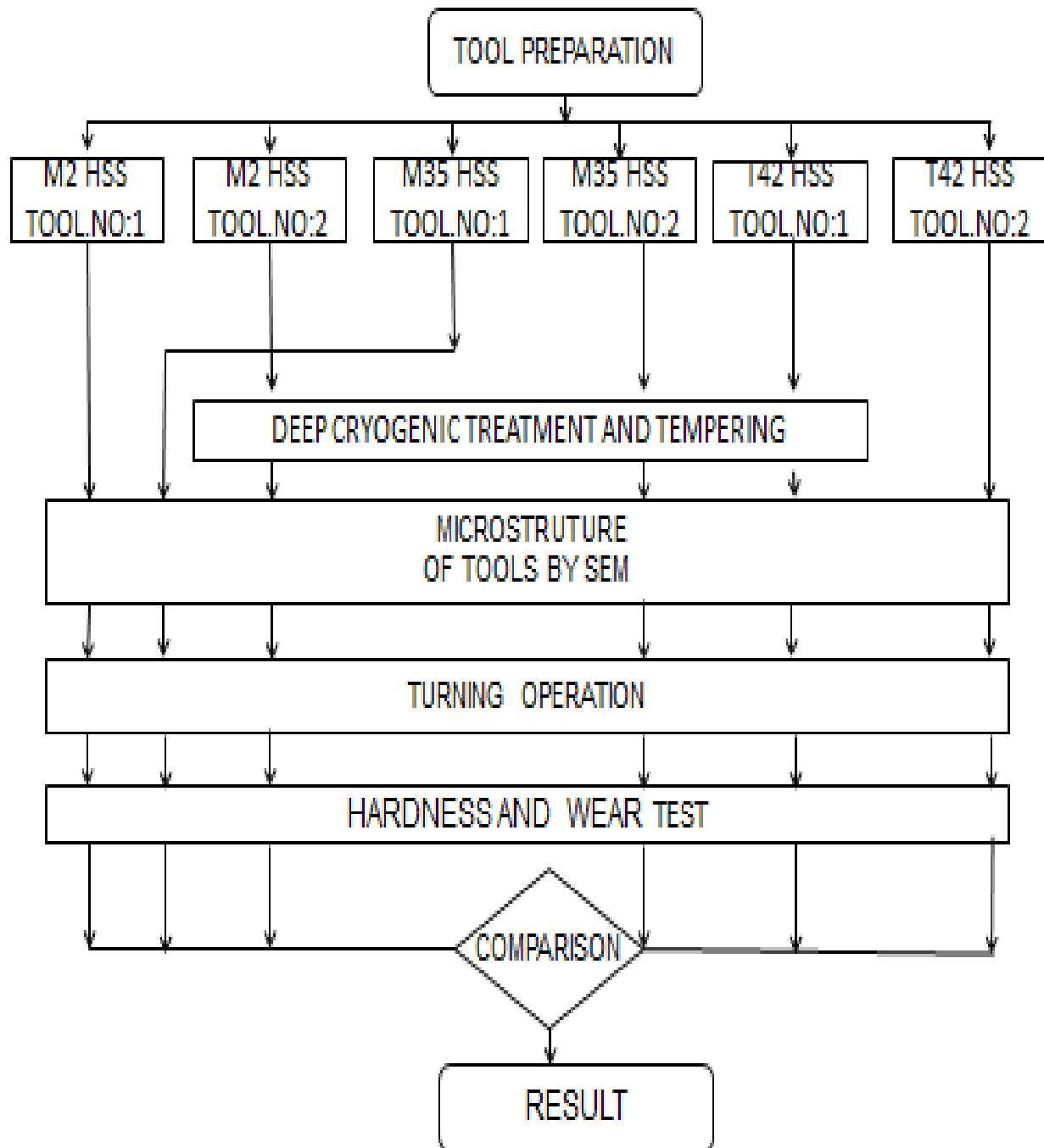


Figure 6.1 FLOW CHART

## CHAPTER 7

### MACHINING OPERATION AND MEASUREMENTS

#### 7.1 CENTRE LATHE

A lathe is a machine tool that rotates the work piece on its axis to perform various operations such as cutting, sanding, knurling, drilling, or deformation, facing, turning, with tools that are applied to the work piece to create an object with symmetry about an axis of rotation.

#### 7.2 TURNING

Turning is a machining operation for all types of metallic and non-metallic materials and is capable of producing circular parts with straight or various profiles. The cutting tools may be single-point or form tools. The most common machine tool used is a lathe; modern lathes are computer-controlled and can achieve high production rates with little labour. The basic operation is shown in Fig. 7.1, where the work piece is held in a chuck and rotates at  $N$  r/min; a cutting tool moves along the length of the piece at a feed  $f$  (in/r or mm/r) and removes material at a radial depth  $d$ , reducing the diameter from  $D1$  to  $D2$ .

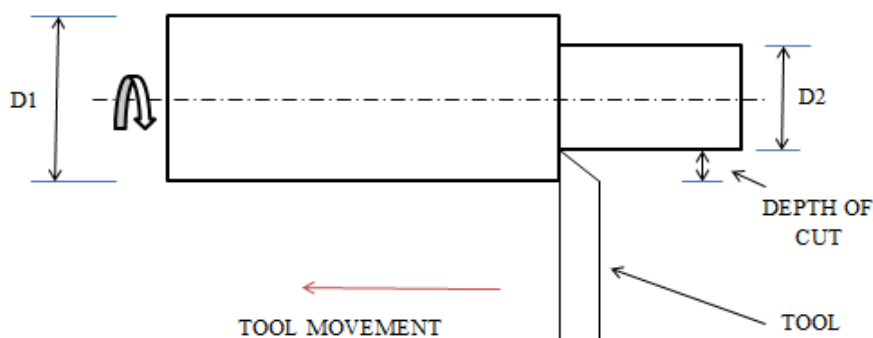


Figure 7.1 Turning

### 7.3 SUITABLE OPERATION

In recent years ,much research has dealt with effect of cryogenic treatment on cutting tools in turning operations.it is understood that the cryogenic treatment of inserts provides many positive effects in turning including reduction of cutting force and surface roughness along with greater wear resistance and tool life. So our experimental work mainly focused on turning operation.

### 7.4 TOOL WEAR

Tool wear changes tool shape, decrease efficacy. Tool wear induce loss of dimensional accuracy, loss of surface finish. It increases power consumption. Normally, tool wear is a gradual process. There are two basics zones of wear in cutting tools: flank wear and crater wear. Flank and crater wear are the most important measured forms of tool wear.

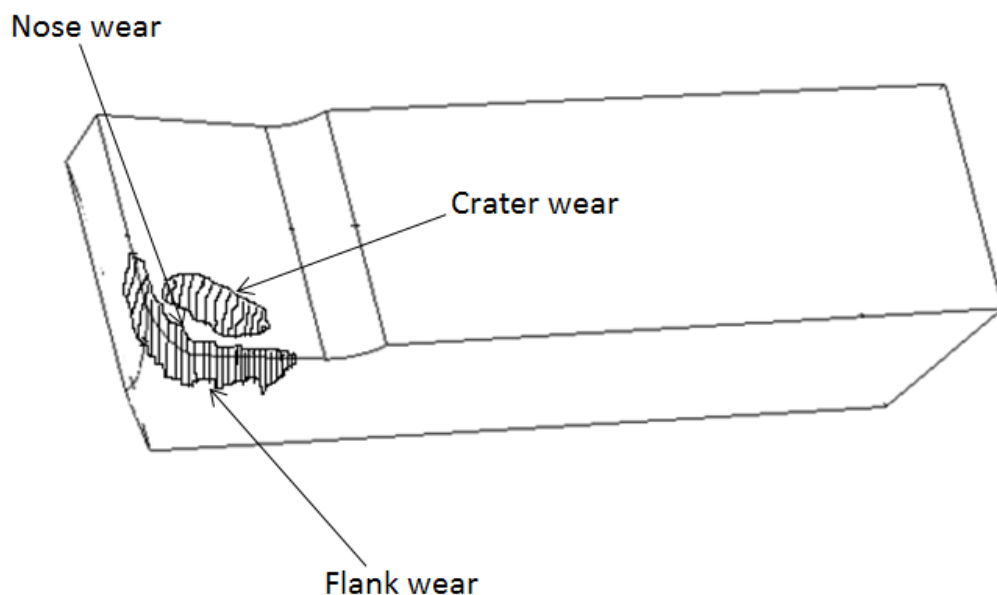


Figure 7.2 Flank wear , Crater wear and Nose wear



## **7.5 VARIOUS TYPES OF WEAR**

### **7.5.1 FLANK WEAR**

Flank wear in which the portion of the tool in contact with the finished part erodes. The amount of flank wear is often used as a criterion because it is the flank wear that influences work material surface roughness and accuracy.

### **7.5.2 CRATER WEAR**

Crater wear in which contact with chips erodes the rake face. This is somewhat normal for tool wear, and does not seriously degrade the use of a tool until it becomes serious enough to cause a cutting edge failure.

### **7.5.3 NOSE WEAR**

It occurs on the tool corner. It can be considered as a part of the wear land and respectively flank wear since there is no distinguished boundary between the corner wear and flank wear land. We consider corner wear as a separate wear type because of its importance for the precision of machining. Corner wear actually shortens the cutting tool thus increasing gradually the dimension of machined surface and introducing a significant dimensional error in machining,

## **7.6 WEAR MEASUREMENT**

The various methods are,

- By loss of tool material in volume or weight, in one life time – this method is crude and is generally applicable for critical tools like grinding wheels.
- by grooving and indentation method – in this approximate method wear depth is measured indirectly by the difference in length of the groove or the indentation outside and inside the worn area

- using optical microscope fitted with micrometer – very common and effective method
- using scanning electron microscope (SEM) – used generally, for detailed study; both qualitative and quantitative
- Talysurf, specially for shallow crater wear.

In our project we have chosen Tool Maker's Microscope for measuring flank wear.

## 7.7 TOOL MAKERS MICROSCOPE

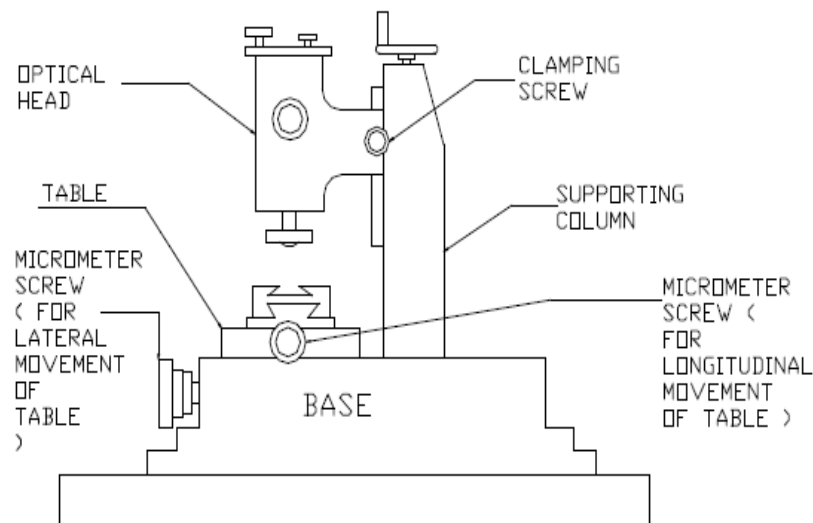


Figure 7.3 Tool Maker's Microscope

The tool maker's microscope is a versatile instrument that measure by optical means with no pressure being involved, thus very useful for measurement on small and delicate parts.

Tool maker's microscope is shown in fig. The optical head can be moved up or Down the vertical column and can be clamped at any height by means of clamping screw. The table which is mounted on the base of the instrument can be moved in two mutually perpendicular horizontal directions by means of accurate micrometre screw having thimble scale and venires.

### **7.7.1 WEAR MEASUREMENT BY TOOL MAKERS MICROSCOPE**

Fix the tool as specified in the following picture. Tool side which makes back rake angle which makes slightly arc shape. Adjust the work table by rotating to touch that arc end with the vertical line. And note the reading in the working table & micro meter readings. Do the machining process by that tool flank radius reduced to some mm. To measure that fix the arc end with the vertical line and make the tool edge parallel or merge with the horizontal line. By screwing the micro meter to some mm, so that the difference between current and before machining is the flank wear.

### **7.8 ROCKWELL HARDNESS TESTER**

Rockwell hardness testing is a general method for measuring the bulk hardness of metallic and polymer materials. 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  $F_0$  usually 10 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.



Figure 7.4 Rockwell Hardness Tester

When equilibrium has again been reached, the 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. 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.

## **7.9 TOOL AND CUTTER GRINDER**

A tool and cutter grinder is used to sharpen milling cutters and tool bits. The operation of this machine requires a high level of skill. The main skills needed understand of relationship between the grinding wheel and metal being cut and knowledge of tool geometry.



Figure 7.5 Tools and Cutter Grinder

## **CHAPTER 8**

### **SEM ANALYSIS**

#### **8.1 INTRODUCTION**

A Scanning Electron Microscope (SEM) is a powerful magnification tool that utilizes focused beams of electrons to obtain information. 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 image. 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.



Figure 8.1 SEM Lab

#### **8.2 SPECIFICATIONS OF SEM**

- Magnification range 15x to 200,000x.
- Resolution of 50 Å.
- Excellent depth of focus.
- Relatively easy sample preparation.

#### **8.3 SEM ANALYSIS**

Scanning Electron Microscope scans focused electron beam over surface to create an image. The electrons in the beam interact with samples, producing various signals that can be used to obtain information about the surface

topography and composition. SEM was carried for both cryogenic treated and untreated HSS tools (various grades) to study the microstructural changes. Results of the SEM analysis are shown in the table10.1 .The results showed presence of the fine precipitated carbide particles in the case of cryogenically treated samples which verify that the refinement of carbides takes place after the cryogenic treatment for all grades of tools.

## CHAPTER 9

### EXPERIMENTATION

#### 9.1 TOOLS PREPARATION

We bought commercially available tool blanks from the market. We bought three grades of HSS tool bits. The tools were prepared as per desired tool geometry. By help of Tool and Cutter required tool signatures were obtained. All the angles were measured by help of tool maker's microscope.

Table 9.1 Tool Signature

Grade of single point cutting tool	Back Rake Angle	Cutting Edge Angle	Side relief Angle	End relief Angle
M2	4°	60°	8°	8°
M35	4°	60°	8°	8°
T42	4°	60°	8°	8°

#### 9.2 SEM TEST BEFORE TREATMENT

After the tool preparation tools were cleaned .They were placed in the vacuum chamber of Scanning Electron Microscope(SEM) Microstructure of each tool was scanned by using SEM. The images having magnification 5000x.The images were captured in various surfaces of tool.

### 9.3 CRYOGENIC TREATMENT

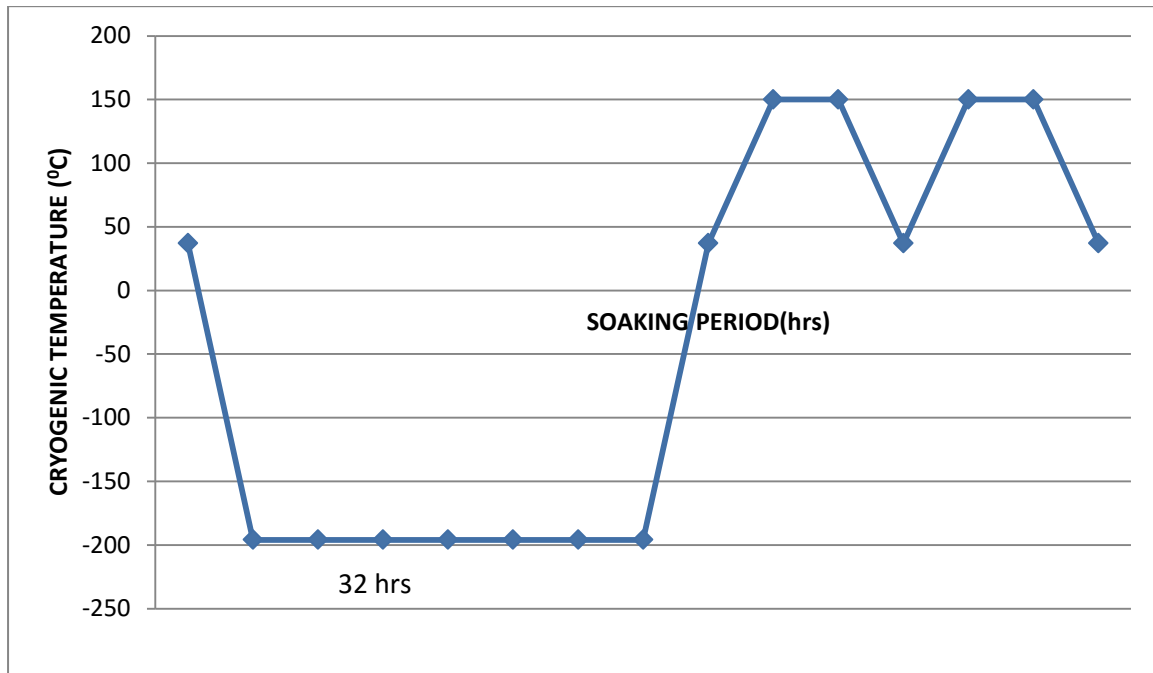


Figure 9.1 Cryogenic Treatment

Deep Cryogenic process involves cooling down samples to  $-196^{\circ}\text{C}$  with soaking period of 32hrs then brought back to room temperature then brought back to room temperature by heating, followed by two tempering cycles consisting of heating to  $150^{\circ}\text{C}$  then bring back to room temperature. One tool from each grade selected and Cryogenic treated.

### 9.4 SEM TEST AFTER TREATMENT

After the cryogenic treatment the microstructure of tools were changed. Thus the Microstructure of each tool was scanned by using SEM once again. Each image from SEM having resolution 5000x. The microscopic changes was analysed.

### 9.5 ROCKWELL HARDNESS TEST

Hardness of each tool before and after cryogenic treatment was measured by Rock well Hardness Tester. Rockwell hardness tester was used for



measurement of hardness on C scale. A minor load of 10 kg was first applied to seat the Diamond indenter. Hardness was represented as HRC number. Then major load of 150 Kg was applied for 3 minutes and resistance to indentation was recorded on the dial gauge. An average of three readings was noted as a measure of hardness.

Table 9.2 Hardness Test Before Cryogenic Treatment

HARDNESS TEST (HRC)				
BEFORE CRYOGENIC TREATMENT				
Tool	Trail1	Trail 2	Trial3	Average
M2 HSS TOOL	81	82	82	81.67
M35 HSS TOOL	84	83	83	83.33
T42 HSS TOOL	85	85	84	84.67

Table 9.3 Hardness Test After Cryogenic Treatment

HARDNESS TEST (HRC)				
AFTER CRYOGENIC TREATMENT				
Tool	Trail1	Trail 2	Trial3	Average
M2 HSS TOOL	83	84	83	83.33
M35 HSS TOOL	86	87	86	86.33
T42 HSS TOOL	88	87	88	87.67

## 9.6 TURNING OPERATION

Turning operation of work piece was done by using Centre Lathe. The following conditions were followed in that operation. Turning operation was

performed by using various selected tools of treated and untreated. Turning operation was performed for certain length up to maximum flank wear reached.

Table 9.4 Cutting Conditions

Spindle speed	237 rpm
Depth of Cut	0.75 mm
Feed	0.5 mm/rev
Work piece	M.S rod

## 9.7 WEAR TEST

Flank wear of tool was measured by using Toolmakers Microscope. After the certain period (machining time) of machining wear was measured. Flank wear for the each grade of both treated and untreated tools were measured.

Table 9.5 Wear Test for Untreated M2 HSS Tool

S.No	Length (mm)	Machining Time (min)	Flank Wear (mm)
1	500	4.22	0.34
2	1000	8.44	0.61

Table 9.6 Wear Test for Cryogenic Treated M2 HSS Tool

S.No	Length (mm)	Machining Time (min)	Flank Wear (mm)
1	500	4.22	0.16
2	1000	8.44	0.32
3	1500	12.66	0.56
4	1750	14.77	0.63

Table 9.7 Wear Test for Untreated M35 HSS tool

S.No	Length (mm)	Machining Time (min)	Flank Wear (mm)
1	500	4.22	0.19
2	1000	8.44	0.36
3	1500	12.66	0.46
4	2000	16.88	0.62

Table 9.8 Wear Test for Cryogenic Treated M35 HSS Tool

S.No	Length (mm)	Machining Time (min)	Flank Wear (mm)
1	500	4.22	0.08
2	1000	8.44	0.12
3	1500	12.66	0.26
4	2000	16.88	0.33
5	2500	20.44	0.42
6	3000	25.32	0.51
7	3500	29.54	0.60

Table 9.9 Wear Test for Untreated T42 HSS tool

S.No	Length (mm)	Machining Time (min)	Flank Wear (mm)
1	500	4.22	0.13
2	1000	8.44	0.17
3	1500	12.66	0.23
4	2000	16.88	0.31
5	2500	20.44	0.36
6	3000	25.32	0.41
7	3500	29.54	0.45
8	4000	33.76	0.53
9	4250	35.87	0.59

Table 9.10 Wear Test for Cryogenic Treated T42 HSS Tool

S.No	Length (mm)	Machining Time (min)	Flank Wear (mm)
1	500	4.22	0.06
2	1000	8.44	0.11
3	1500	12.66	0.15
4	2000	16.88	0.21
5	2500	20.44	0.26
6	3000	25.32	0.31
7	3500	29.54	0.37
8	4000	33.76	0.42
9	4500	37.98	0.46
10	5000	42.20	0.52
11	5500	46.20	0.55
12	6000	50.64	0.61

## 9.8 MACHINING TIME CALCULATION

Machining time,

$$t = \frac{L}{fN}$$

Where

L = length of the shaft (mm)

f = feed rate (mm/rev)

N=spindle speed (rpm)

PAREMETRES

L = 500 mm                      f = 0.5 mm/rev      N= 237 rpm

$$t = \frac{L}{fN} \quad t = 500 / (0.5 * 237) = 4.22 \text{ min}$$

## 9.9 TOOL LIFE CALCULATION

Tool life generally indicates the amount of satisfactory performance or service rendered by a fresh tool or a cutting point till it is declared failed.

Tool life is defined in two ways:

In R&D Actual machining time by which a fresh cutting tool satisfactorily works after which it needs replacement or reconditioning. Tool life means the span of actual machining time by which a fresh tool can work before attaining the specified limit of tool wear. Mostly tool life is decided by the machining time till flank wear reaches 0.3 mm or crater wear, reaches 0.15 mm. The tool life criteria used in this investigation is the total cutting time required to reach 0.6 mm flank wear in accordance with ISO 3685-1993.[13]

In industries or shop floor: The length of time of satisfactory service or amount of acceptable output provided by a fresh tool prior to it is required to replace or recondition. We selected tool life determination by the tool reaches the max flank wear of 0.6mm.

Table 9.11 Tool life

SL.NO	Type of tool	Tool life (min)	
		Untreated	Treated
1	M2 HSS TOOL	8.44	14.77
2	M35 HSS TOOL	16.88	29.54
3	T42 HSS TOOL	35.87	50.64

## CHAPTER 10

### RESULT AND DISCUSSION

#### 10.1 HARDNESS

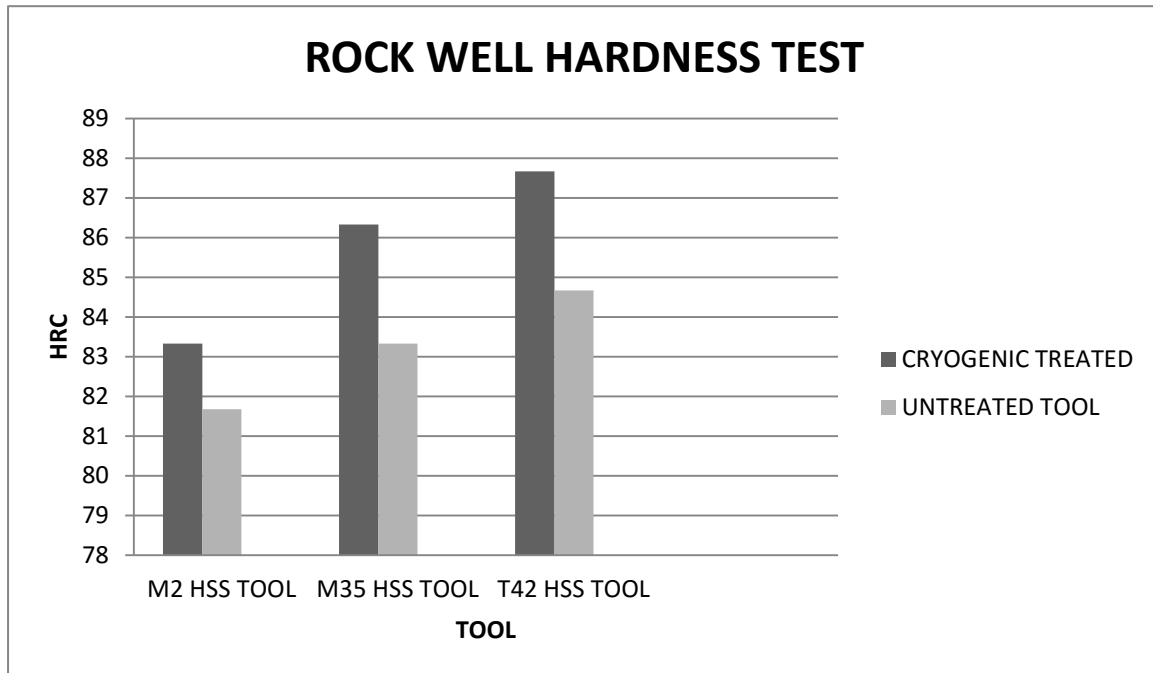


Figure 10.1 Comparisons Hardness of All Cryogenic Treated and Untreated Tools

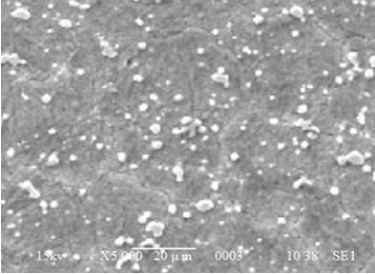
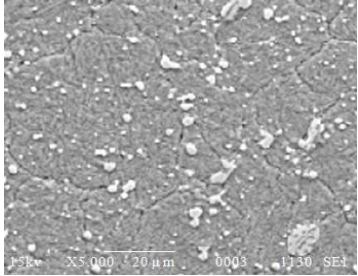
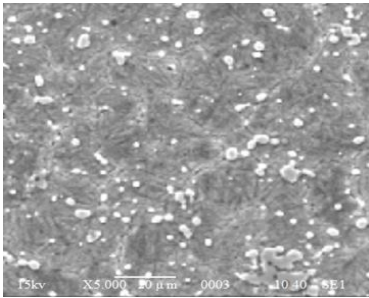
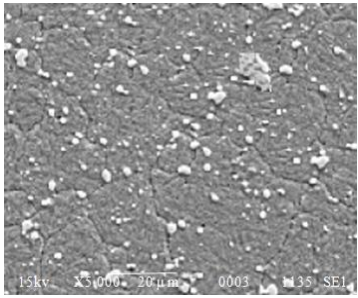
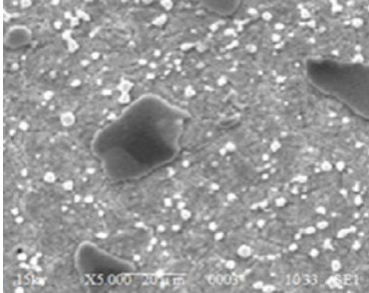
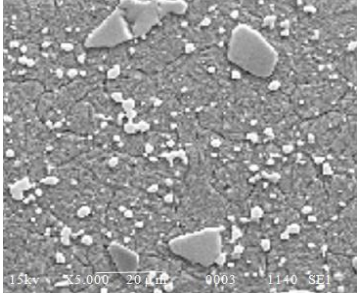
From the graph the hardness of all cryogenic treated tools have higher hardness than untreated tools. T42 have higher hardness than other tools. By using cryogenic treatment tool life is further increased.

#### 10.2 MICROSTRUCTURAL FEATURES

##### SEM IMAGES

Carbide desires the strength and wear resistance of the material, if the carbide density is increased then the strength will be more throughout the material. In untreated material carbide density is not good enough, if the material is once treated means then carbide density will be increased so that the strength and wear resistance will be increased. From the SEM images we know that carbide density more in cryogenic treated tools.

Table 10.1 Comparisons of SEM Images

Sl.no	Tool	SEM image (before Cryogenic treatment)	SEM image( after Cryogenic treatment)
1	M2 HSS		
2	M35 HSS		
3	T42 HSS		

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. for cryogenically treated and untreated HSS samples respectively. From the SEM images the conventionally treated T42 and M35 showing higher carbide density than M2. The results showed after the cryogenic treatment the presence of the fine precipitated carbide particles in case of each cryogenically treated samples which verify that the refinement of carbides takes place and complete transformation of retained austenite to martensite. The formation of

high carbide contraction will increase wear resistance, reduce friction, and improves stability.

### 10.3 WEAR RESISTANCE

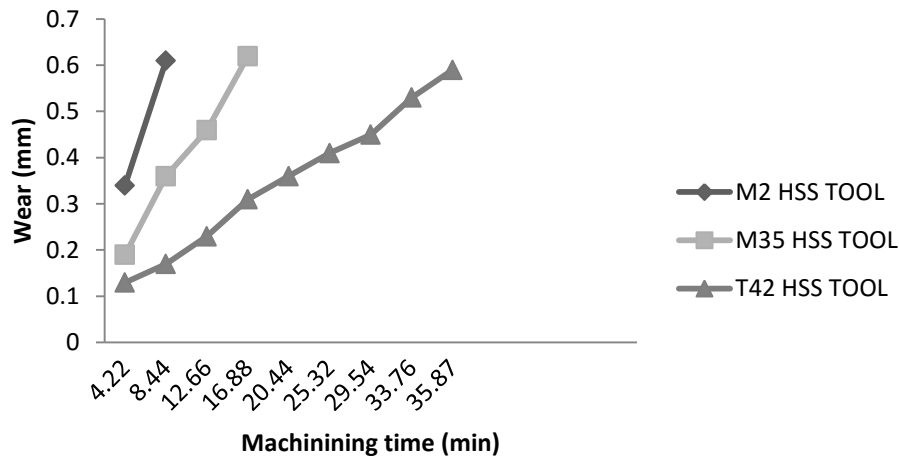


Figure 10.2 Flank Wear Comparisons of Cryogenic Untreated Tools

From the graph before the cryo treatment the wear resistance of T42 tool is higher than other tools. Because T42 having 9.60 % Co content. M35 Tool wear resistance of M35 tool is higher than M2. Because it having 5.00% Co content.

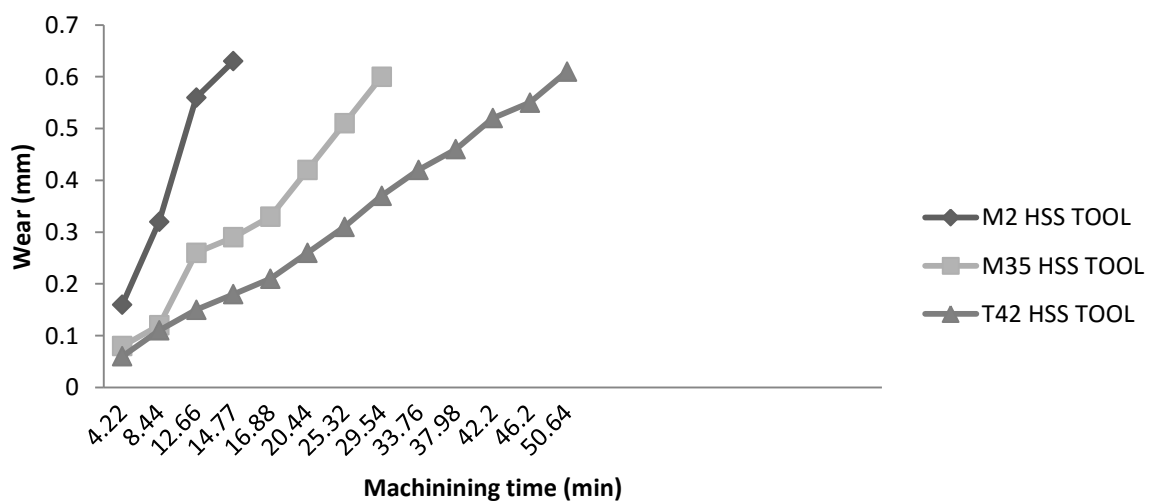


Figure 10.3 Flank Wear of Cryogenic treated Tools



From the graph the wear resistance of cryogenic treated T42 tool is higher than other cryogenic treated tools. By using cryogenic treatment tool life of all tools improved. M35 Tool and M2 Tool have higher wear resistance after the cryotreatment.

#### 10.4 TOOL LIFE

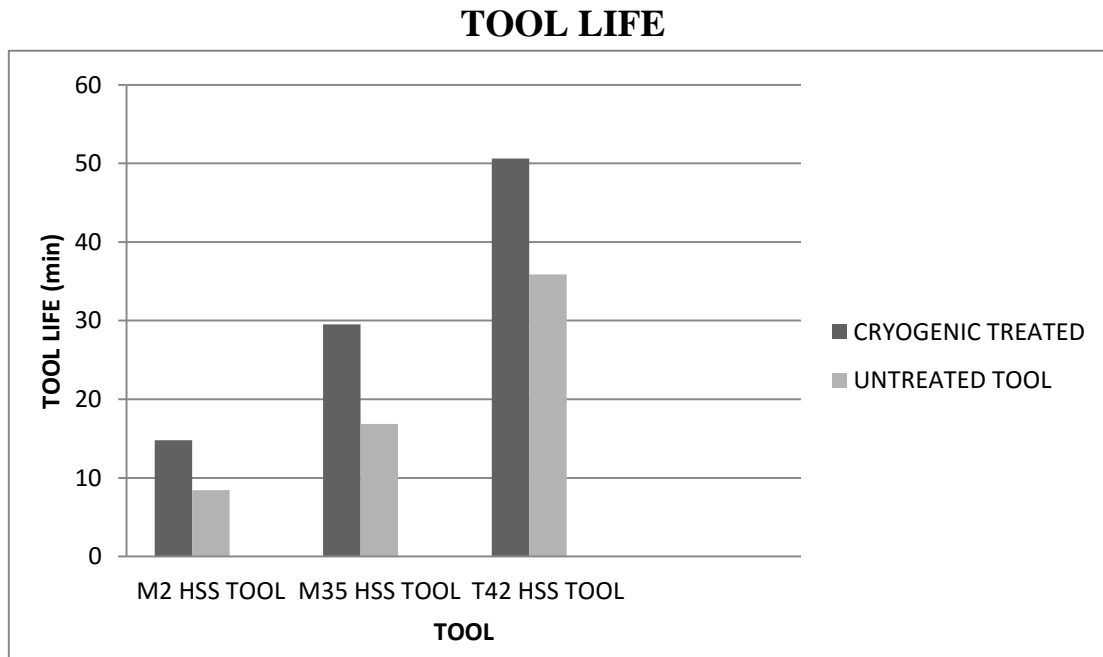


Figure 10.4 Comparisons of Tool life of All Cryogenic Treated and Untreated Tools

Tool life of all cryogenic treated tools has increased due to cryogenic treatment. Cryogenic treated M2 tool having tool life 14.77 min. Untreated M2 tool having 8.44 min. Cryogenic treated M35 tool having tool life 29.54 min. Untreated M35 tool having tool life 16.88 min. Cryogenic treated T42 tool having tool life 50.64 min. Untreated T42 tool having tool life 35.87 min.

**CHAPTER 11**  
**COST ANALYSIS**

Purchasing items/treatment/travel charge			Shop/industry name	Cost (RS)
S.No	Item	Qty		
1	ADDISON M2 HSS TOOL BIT	2	Jayalakshmi Tools,Trichy	368
2	ROHIT M35 HSS TOOL BIT	2	Sri Ganesh Tools,Trichy	450
3	ROHIT T42 HSS TOOL BIT	2	Sri Ganesh Tools,Trichy	800
5	CRYOGENIC TREATMENT		Deep cryogenic treatment services,hosur	5000
6	SEM TEST		Deep cryogenic treatment services,hosur	4000
7	MS ROD		Thanjavur	420
8	OTHERS			700
			Total cost	11,723

## **CHAPTER 12**

### **CONCLUSION**

From SEM analysis, it is evident that refinement of carbides is more in cryogenically treated HSS tools comparison with untreated tools. While doing hardness test, the hardness of Cryogenic treated HSS tools increased compared with untreated HSS tools. The tool life is increased for M2 grade HSS cutting tools, M35 grade HSS cutting tools and T42 grade HSS cutting tools after the cryogenic treatment. From wear test, the wear resistance of cryogenic treated HSS tools increased when compared with untreated HSS tools. For all grades (M2, M35 & T42), Cryogenic process helped to improve hardness and wear resistance. Thus cryogenic treatment of HSS tools is an effective method to improve tool life performance.

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