Study of the Effect of Cryogenic Treatment on HSS Single Point Cutting Tool for C-18000 Machining

DISSERTATION II

Submitted in partial fulfillment of the requirement for the award of the degree of

MASTER OF TECHNOLOGY
IN
MANUFACTURING ENGINEERING

By

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LOVELY PROFESSIONAL UNIVERSITY PUNJAB (INDIA)

CERTIFICATE

I, **Brain Choudhary**, hereby certify that the work which is being presented in the dissertation entitled **"Study of the effect of Cryogenic treatment on HSS Single point cutting tool for C-18000 machining"** in partial fulfillment of the requirement for the award of degree of **Master of Technology in Manufacturing Engineering** and submitted in Department of Mechanical Engineering, Lovely Professional University, Punjab is an authentic record of my own work carried out during period of Dissertation under the supervision of **Mr. Karanvir Singh**, **Assistant Professor**, Department of Mechanical Engineering, Lovely Professional University, Punjab. The matter presented in this dissertation has not been submitted by me anywhere for the award of any other degree or to any other institute.

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CANDIDATE'S DECLARATION

I, Brain Choudhary, Reg. No. 11210607 hereby declare that the work presented entitled **"Study of the effect of Cryogenic treatment on HSS Single point cutting tool for C-18000 machining"** in partial fulfillment of requirements for the award of Degree of Master of Technology (Manufacturing Engineering) submitted to the Department of Mechanical Engineering at Lovely Professional University, Phagwara is an authentic record of my own work carried out during the period from JAN 2017 to MAY 2017, under the supervision of Mr. Karanvir Singh (Assistant Professor), Department of Mechanical Engineering. The matter presented in this thesis has not been submitted in any other University/ Institute for the award of Degree of Master of Technology. Furthermore, I also declare that I will not publish this work in any other Journals/ Conferences/ Workshop seminars except the one chosen by supervisor. The presented work is the property of Lovely Professional University, Phagwara. If I found violating any of the above conditions, University has right to cancel my degree.

Date: Signature of Student

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I do not find enough words with which I can express my feeling of thanks to all my family members and friends for their help, inspiration and moral support which went a long way in completion of my thesis.

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ABSTRACT

Cryogenic treatment has been recognizing as means of extending life of tool of many single point cutting tool materials, which somehow helps in significant improvement in productivity. However real processes which assure better tool performance are still uncertain. This insinuated the demand of further study in order to check the technique in more informative way. In this study, C18000 which is also known as Cu-Ni-Si-Cr Alloy is used because it is widely accepted material where strength is main concern. Machining of Cu-Ni-Si-Cr Alloy is a tough job. This makes this material suitable for this study. The aim of this work is to optimize the cutting parameters for achieving good surface finish and to study the effect on tool life of the cryo treated HSS tool and non-cryo treated HSS tool. In this study tool is considered to be worn out when it will not able to machine workpiece properly means value for surface roughness increases. It was also found that the life of the cryo treated HSS tool increases by 24% in comparison to the non-cryo treated HSS tool, it means that the number of machining cycle performed by the cryo treated tool is more than the non-cryo treated HSS tool. CCI HD non-contact profiler is used to take images for tool wear in case of both cryo treated and non-cryo treated tool and also for tool which is not gone under machining or any type of wear. All these images were taken at different magnification, in order to understand the wear more effectively and it was found that non cryo treated tool tip gets flattened after some number of cycles and in case of non-cryo treated tool it was found that there is sudden breakage in the tip of the tool. For obtaining better results in accordance to increase in tool life, optimization of cutting parameters such as spindle speed, feed rate and depth of cut is done with the help of Taguchi design because it provides different sets of combinations of levels of parameters. On the basis of which experimental work is done for measuring the value for surface roughness. All this is to be done to increase the tool life for both cryo treated and non-cryo treated tool.

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CHAPTER 1: INTRODUCTION

1.1BACKGROUND

The back bone of the engineering industry is none other cutting tools and their process of being cut. From the nomadic age to till date, human being and tools are sharing a strong bond of ever green companionship. Industrial revolution proved to be a mile stone in the field of engineering industry even today is it's full swing. Due to the scarcity factor of tangible materials, it is the high time to get the full potential out of any metal cutting operation. For the rapid growing needs of the engineering industry, many collective as well as individual researcher are taking place and attracting engineering industry. Not only just economic competition among contributing to the revolting task of metal cutting process. High possible productivity of new materials is in high demand and this need can be fulfilled by applying new material which should be lighter but strong and more fuel efficient. Further this demand leads to the advancement of cutting tools. In the design point of view of cutting tool, construction and judicious selection play important role. Following are the must have properties of the good tool material;

- Stability during high cutting speed against thermal shock.
- Fabrication cost and ease
- Strong resistance against fracture
- Resist capacity against diffusion
- Resist mechanical and thermal variation

The external condition of the stress and temperature being produced the guiding lines for the development activities in the cutting tool material process. Tool wear is mostly a combination of complex mechanisms including abrasive wear, chipping at the cutting edge, thermal cracking etc. The most important requirement for tool material is to maintain it's physical, mechanical and chemical properties even at the elevated temperature during high cutting speed high temperature resistance capacity is the center of whole labor.

1.2 TECHNOLOGY DEVELOPMENT

Last seventy decades have been proved a transitional phase of tool materials. This development has laid the roads for the change in the physical look of machine tools for the sake of maximum utilization of the tool materials for high productivity. The application of higher speed at each stage of development has been facilitated progress from carbon tool steel, high speed steels and cast alloys to carbides and ceramics. The design of tool holders and cutters have radically changed with the advent of carbides and ceramics. The advanced metal removing technology in the process of mechanical inserting has reduced the concept of throwing away tipped tools.

Upto 1900 plain carbon tool steel was only way for machining purpose. After 1900 HSS was launched and many modifications has been done in order to give rise to various types of HSS. Cobalt bounded sintered tungsten carbide was next mile stone in the field of machining. But the scarcity of the introduction of materials. Ceramics tools are best example of high hardness and wear resistance cutting tool material. But irony of progress is that we are yet fail to have a single tool material with all desired properties to withstand wide range of stress, temperature, thermal shocks and abrasion to which a cutting tool is subjected during metal cutting. Every cutting tool holds a special blend of properties which are very important for its performance. Therefore by a finely adoption of tool material composition, cooling and geometries tool make more parts faster and at cheap cost.

The high-speed steel tool materials are still under substantial improvement in their properties through suitable modifications in their composition by optimizing the processing technique as well as by various surface treatments. Because of these technological advancement HSS are still in use having a neck to neck surviving competition with carbide and ceramics. Many cutting industries have carbide as their first choice because of their ability to retain its strength and hardness at very high temperature, and more over these are economical. And at last not least, its wear life and properties can be hiked even more with the use of suitable surface treatment.

1.3 MACHINING

It a process in which chips are removed from work-piece to give it standardised shape and ordered size. With time the term machining had changed. So many operation has done on machining like turning, drilling, facing, milling, broaching and reaming etc. the tools are used to cut material or to give a defined shape to the raw material. After the invention or non-traditional machining processes like electro discharge machining, water jet machining, photo chemical machine etc. These traditional methods of machining are called conventional machining. All types of materials like composite, plastics, ceramics even wood are machined to get the final product. Mostly machining of metals products is done more than all above products. In the today's era of innovation mostly the machining is done by computer numeric control.

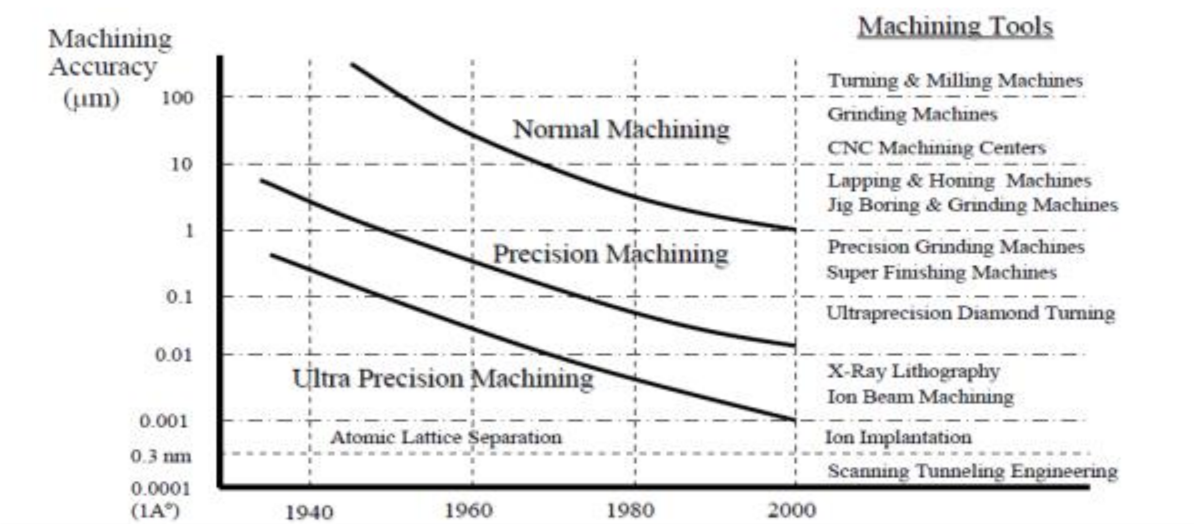

Figure1.1 Machining accuracy. (Source: Book-"Precision Engineering" by IzmanVenkatesh, V C Venkatesh, Page No. 7.)

To exchange products and to set a standard for all product there is need to archive high accuracy. These for It is the necessity to archive high accuracy and good surface finish with economical and suitable methods. Based on precision attained machining is classified into following three types.

1. Conventional machining,
2. Precision machining.
3. Ultra-precision machining.

In conventional machining the precision is least out of the all three type like lathe machine. In precision machining, these machines are the once which have replaced the conventional machine by their quality of achieving more precision, more surface texture enhanced reliability and more careful and save environment for the worker. Ultra-precision machining is the once with highest possible precision till now.

1.4 FACTOR AFFECTING THE SURFACE ROUGHNESS

Wearing of the matting parts takes place when these parts come in contact with each other. Surface finish is the main factor on which the amount of wear depends. When the surface roughness is increases wearing of the matting parts is also increases. Various tool geometry and machining parameters and other factors governs the surface irregularities, roughness and waviness.

- Machining variables are
  1. Cutting speed
  2. Depth of cut
  3. Feed rate
- Geometry factors are
  1. Rake angle
  2. Tool noise radius
  3. Side cutting edge angle
- Lubricant and Auxiliary tooling
- Work-piece and tool material mechanical properties
- Machine tool type

1.5 SURFACE TOPOGRAPHY

It is difficult to display ideal geometrical surface of machined surface. Both macro and micro irregularities are there on the machined surface. The difference form the nominal surface of the third upto sixth order is known as surface roughness. The order of deviation is set by the international stranded. The first and second order of deviation includes flatness, circularities and waviness. Reason for the first and second order of the deviation are abnormality in the shape of the workpiece, flaws in the machine tool. Failure of tool holding device, machine vibrations and nature of the workpiece material. Crakes disintegration and periodic trenches come under the categories of third and fourth order the main reason of third and fourth order deviation is tool geometry, cutting tool edges, type of the chip flow during machining and other primary machining parameter such as depth of cut, cutting speed and feed rate. Fifth and sixth order of deviation comes due to change in structure of workpiece material. In this deviation there is change in the physical and chemical changes in the grain and lattice scale like slip, diffusion, oxidation, residual stress etc. The various order or deviation

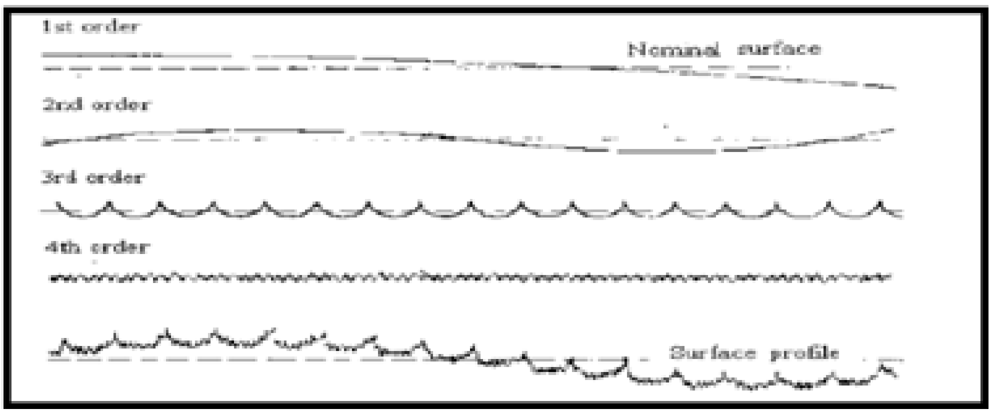

Figure 1.2: Surface topography

Ref:Mc Keown, Precision Engineering, Tata McGraw-hill (2001)

1.6 SURFACE TREATMENT

Improved manufacturing technology has flagged the fast-commercial growth of many surface treatment for cutting tools, and also enable advance in manufacturing technologies. However, no single treatment solves every problem and it also need more money.

The process of surface treatments modifies following trades of surfaces of engineering materials to

- Stimulate friction and wear
- Enhance corrosion resistance
- Terminate physical properties
- Change appearance
- More economical

Hence the functions on service lines of materials can be improved. There are mainly two major categories of surface treatment.

i. Surface covering treatment

ii. Surface altering treatment

Surface covering treatment

- Organic coating like paints, fused, powders, floor tapping, cements and laminated on the surface of materials.
- Inorganic coating for example hot dipping, electroplating, autocatalytic, plating's, conversion coating thermal sprayings, furnace fusing or coat thin films on the surface of the materials CPVD and CVD.

Surface altering treatment

- Iron implantation laser, glazing or fusion and electron beam treatment.
- Diffusion treatment include boron zing and other high temperature relating process.
- Hardening- flame, induction, laser or electron beam.
- Carburization, nitriding and carbonitriding
- Special treatment suck as cryogenic, magnetic and sonic treatment.

Cryogenic treatment is the best among all and one time permanent and most economic. This treatment is one step ahead from conventional heat treatment. In it cutting tool material is firstly given heat treatment then quenching treatment by deep dipping in liquid nitrogen and then heated back to room temperature. This cooling treatment is known as cryogenic treatment. The wear and life of cutting tool get substantially extend due to this cryoprocessing. However, controversies among the researchers for its results. And processing is also nonpredictable and thus does not hold a single support treatment.

1.7 CRYOGENIC TREATMENT

Cryogenic is advanced stage of refrigeration but far worthy than the later. Cryogenic is an herb for the long lives of cutting tools. It blesses the cutting tools with productivity, efficiency, durability and improves the wear resistance, abrasion, erosion etc. cryogenic is a method of cooling a material at subzero temperature. Etymology ---→Cryo + genic. Cryo derived from Greek word "krys" means cold and genic means relating to thus cryogenic means cold treatment. In simple words it's a product of cooling treatment till the properties of material go significantly terminated. During 1930s to 1940s reports from Europe and United States conveyed the excellent effects of cryogenic treatment at 77K temperature. Cryo concept was used by Swiss watch maker. They keep their castings out in cold of Alps for months to improve the life span and working. Cryoprocessing use extreme level of coldness. Kelvin and Rankine scales are used as temperature measuring scale.

Cryogenic treatment is generally taken as low temperature treatment but it is a misconception. No doubt refrigeration and cryogenic both are two branch of same root. But where the refrigeration ends, there is the starting of cryogenic treatment. both have huge different on the level of temperature. Moreover, even the different- different researcher in the field of cryoprocessing does not holds a single level of (coldness) low temperature. but most studies have voted that below -180˚C (95.15 K) temperature. The normal boiling point of so called permanent gases i.e. helium, hydrogen, neon, nitrogen, oxygen lie below 95.15 K. Cryogenic temperature are gained either by rapid evaporation of volatile liquids or by the expansion of gases confirmed initially at pressure of 150 to 200 atmospheres. Two methods could be applied one thought a valve to the region of lower pressure, or second by using a cylinder of a reciprocating engine. Later method is more efficient but difficult too.

Cryogenic treatment is very economic as it is one time treatment affecting the entire cross section of the material usually treated after the heat treatment and quickly followed by tempering. At is not an option of conventional heat treatment but an add on to it. Many studies and experiments have shown positive results of cryogenic treatments upon the wear hardness, thermal stability of the various materials. The role need of this cryogenic treatment is to cut retained austenite from its roots during quenching. The solid solution of carbon and iron, when steel is at hardening temperature is known as austenite.

The product of lowest temperature in quenching is the amount of martensite. At any given temperature of quenching there is always a certain amount of martensite and equal untransformed austenite. This untransformed austenite is very brittle in nature and decreasing the hardness strength, dimensional instability and cause cracking.

Figure1.3 Structure of austenite and martensite

Quenching is usually done at room temperature. The room temperature is the best for the transformation of martensite of most medium carbon steel and low alloy steel. liquid nitrogen and liquid helium are best for the cryogenic temperature. liquid nitrogen is most common element in cryogenic and easily available all over the world. Both gases are kept in either special containers dewar flasks or in giant tanks in large commercial operations. The pumps as same which are used for Liquefied Natural Gas transfer from LNG carriers to LNG storage.

1.8 THE MAKING OF LIQUID NITROGEN

Liquification of air is the common method for production of liquid nitrogen. Liquification is the process of changing a substance from gaseous stage. The air is compressed, expanded and cooled via the joule-Thompson's effect in the nitrogen compressors. Because nitrogen hold different boiling point than oxygen, so it is easily picked out of the liquid air. Then it is recompressed and re liquefied, and stored in a pressurized tank or a well-insulated dewar flask. Liquid nitrogen is converted to a gas before it enters the chamber for the sake of danger of cracking of material due to direct contact of liquid nitrogen. Liquid nitrogen is the best and most economic for this cryogenic treatment.

1.9 CRYO TREATMENT PROCEDURE

In this process, liquid nitrogen is used. The liquid nitrogen as produced from the nitrogen plant is kept in a storage containers. Further it was transferred to a closed vacuum evacuated chamber also known as cryogenic freezer with the help of transfer lines. Solenoid valves are used to supply liquid nitrogen into cryo freezer. Inside the chamber there is gradually increase in cooling temperature i.e. 0.5˚C per min from the room temperature to the temperature of -196˚C. Once the subzero temperature is reached specimen are transfer to the soaking chamber where they last for 24hours with the continue supply of liquid nitrogen.

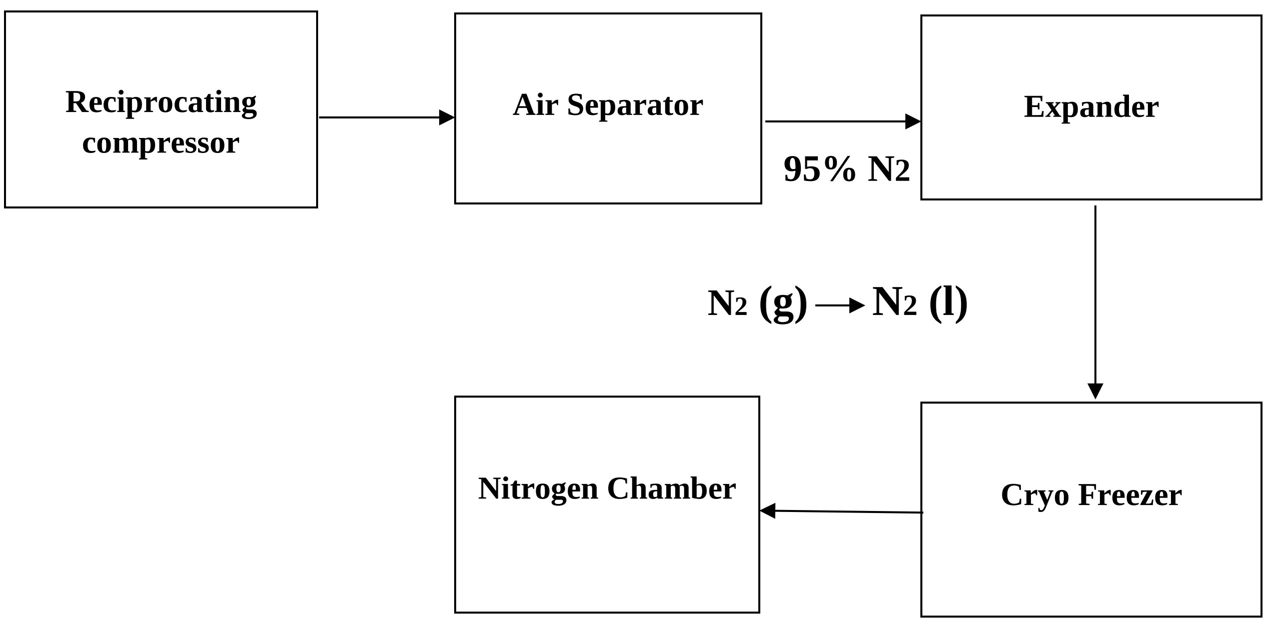

Figure 1.4 Schematic representation of cryogenic treatment procedure

CHAPTER 2: SCOPE OF STUDY

C 18000 is a material on which very less amount of research had been done so there is a need to do some work on it. C 18000 have great mechanical properties like high thermal conductivity and good corrosion resistance. So, in this study uniform rapid and sudden failure zone of the HSS cutting tool will be found out. It has been decided to find the tool life in terms of total volume removed in mm^3/min, effective cutting time in minutes, total length travelled in kms before the next regrinding. It will become easy for the manufacturers using this material to identify the exact tool life. Not only identifying the tool life but it will also be seen that what tool wears (crater wear, flank wear, notching etc.) are dominating in nature during machining of C18000 on optimized parameters.

In addition to that an attempt will be made to reduce these wears and hence increase the tool life by not sacrificing the surface texture quality. This will also help to reduce the concerned tooling costs. Once the cryogenic treated cutting tool will be received it will open a new box of research area.

CHAPTER 3: OBJECTIVE OF THE STUDY

- To analyze the effect of optimum machining parameter on wear of cryo-treated HSS tools. An attempt will be made to increase the tool life.
- To study microstructure of the tool pre-cryogenic treatment and post-cryogenic treatment. The changes observed will be discussed in the results.
- To study the tool wear pre-cryo treatment and post-cryo treatment using CCI HD non-contact image profiler
- To draw a comparison between hardness and wear resistance of cryogenically treated HSS sample V/s untreated tool

CHAPTER 4: LITERATURE SURVEY

1.T.V. Sreerama Reddy et al, (2009) studied the machinability of C45 steel with deep cryogenic treatment of tungsten carbide cutting tool inserts. Flank wear of the cutting tool inserts, cutting force and surface finish helps in evaluating the machinability of the C45 steel workpiece. The flank wear of untreated carbide tool after machining of C45 steel was greater than deep cryogenic treated carbide tool but the surface finish and cutting force of deep treated tool is better. The cryogenic treatment results show better machinability due to increase in hot hardness and thermal conductivity of tungsten carbide insert. This results in decrease of tool wear in cryo treated tungsten insert and, hence increases the tool life of workpiece.

2. R. Thornton et al, (2014) investigated the effects of deep cryogenic treatment on the wear development of H13A tungsten carbide inserts, while machining with AISI 1045 steel. The hardness of cryo treated H13A tungsten carbide insert got increased by 9.2 % and depicted an in increase abrasive wear resistance, as well. The change in microstructure of tungsten insert sub surface behavior with little decrease in the toughness resulted from increase in the red hardness. There is decrease in the flank wear by 6% and greater adhesion between H13A tungsten carbide and AISI 1045 steel workpiece. There is generation of built up edge that protect the tungsten carbide insert form the abrasion but large amount of stress is observed with subsurface cracking takes place. The results experience a significant change in the cobalt binder phase and increase in the abrasive wear resistance of workpiece.

3. Simranpreet Singh Gil (2012) studied that machining performance of cryogenically treated AISI M2 high speed steels tools. The performance of deep cryogenically treated (-196 ˚C) HSS is far better than that of shallow treated (-110˚C) HSS. Cryogenic treatment increases the service life of shallow the tool life increase by 35 % and with the deep cryogenic treatment the tool life increases by 50 %. The cutting force is less in case of deep cryo treated HSS tool. The deep cryogenic treatment change the morphology of the entire cross section of the M2 HSS tool steel which increases the tool life. Cryo treated tool sustain after number of re-happenings. Cryo treated tool is better than that of coated tool. Because coated tool breaks during re-

happenings. The performance of deep cryogenic treatment M2 HSS tool is better than shallow and from other traditionally heat treated tools, as well.

4.Amrita Priyadarshini (2007) studied the effect of cryogenic treatment on the performance of the HSS tools and carbide insert. The tool life of the high-speed tool and the carbide inserts increases. The tool life of the HSS increased by 12% and the carbide insert by 17%. After cryogenic treatment, the tool become brittle, exhibiting more weight loss of cryo treated tool when compare to untreated tools. There is increase in the refinement of carbide in the cryo treated HSS as compare to untreated tools. But there is very little change in the hardness of the HSS M2 steel and S400 steel after cryo process. The life of the cryogenic treated HSS tool steel is affected by feed rate, depth of cut and the cutting velocity during the machining of the mild steel.

5. T. V. Sreerama Reddy et al. (2009) performed turning of deep cryogenic treated P-40 tungsten carbide cutting tool insert. After cryo treatment the tool life factor increased by 1.27. The cutting force decreases in the cryo treated insert by 11% as compared to untreated carbide insert. The surface roughness increases by 20% with an increase in thermal conductivity and red hardness resulting in decrease in tool wear. All the outcome obtains while machining between 200-350 m/min.

6. K. N. Pande et al, (2012) investigated the effect of the cryogenic treatment on polyamide and optimized the parameters in order to enhance the wear performance. Cryogenic treatment under control temperature is an important aspect with soaking period playing an important role. The material required proper time for conversion of phase change from less stable to more stable phase. The abrasive wear performance of the polymer increases because of the change in crystal structure.

7. Zhao-zhu Zhang et al, (2009) performed experimentation to enhance wear resistance of hybrid PTFE/Kevlar fabric/phenolic composite by cryogenic treatment. Cryo treatment increased the wear resistance of the hybrid PTFE/ Kevlar fabric/phenolic composite. But excess treatment leads to the negative effect on the composite because of change in the

tribological properties. Due to this, the composite becomes weak and therefore cryo treatment should be done in a controlled manner. After cryo treatment the wear rate decreased and the material become less sensitive and have less effect on applying loads. The strength of the hybrid PTFE/Kevlar fabric/phenolic composite also increases by a significant amount.

8.Simranpreet Singh Gill and Harpreet Singh (2013) studied cryogenic treatment of materials: cutting tools and polymers. If the material is not properly tempered it leads to cracks formation, hence proper tempering is required. The order to be followed should be austenizing; quenching; cryoprocessing and tempering. In the cryoprocessing there are three main processes socking time, socking temperature and cooling rate. The increase in the wear resistance and hardness are due to change of the retained austenite to martensite and the formation of refined carbide precipitate in the tool steel. These carbides refined the precipitates and bounding strength of binder increases due to wear resistance.

9. Lakhwinder Pal Singh, Jagtar Singh (2011) studied the effects of cryogenic treatment on high-speed steel tools. The HSS tools significantly enhanced by the cryoprocessing because the microstructure of the HSS tool steel gets more refined and the distribution of particle are uniform throughout the microstructure. During machining, there is very less reduction in the noise radius and there is also very less loss of weight of tool steel. In lathe machine, power consumption in case of cryo treated steel tools are less than that of the untreated steel tools.

10. Baozhuang Cai enhanced the mechanical properties in Cu–Zn alloys with a gradient structure by surface mechanical attrition treatment at cryogenic temperature. With the help of cryogenic SMAT process (surface mechanical attrition treatment) on the Cu-Zn alloys, there is generation of gradient structure with fine grains. This gradient structure formed with the coarse grain interior and surface fine grained region. The microstructure of Cu-Zn alloy changed there is refinement in the structure and micro hardness of Cu-Zn alloy is increased. Also, there is an increase in tensile strength of the material at room temperature.

11. Fanju Meng et al, (1994) studied the wear resistance and microstructure of cryogenic treated Fe-I.4Cr-IC bearing steel. Comparing the wear resistance and microstructure of cryo

treated and untreated Fe–12Cr–Mo–V-1.4C tool steel. Outcome of the study is that there is significant improvement in the sliding wear test which increases by 110% to 600% when compared with conventional heat treatment methods. The wear volume in case of conventional heat treatment is more than that of cryogenic treatment. Due to formation of refined carbide precipitates the wear resistance also increases.

12. K. Vadivel et al, (2009) studied the performance analysis of cryogenically treated coated carbide inserts. The change in the microstructure can influence the tool life. Carbide tools such as tungsten carbide inserts are now widely used in the industry. This paper analyzes the performance of cryo treated and un treated coated tungsten carbide inserts in the machining of nodular cast iron. The performance of the cryo treated tungsten carbide inserts is far better than that of the un treated inserts on the basis power consumption, surface roughness and flank wear. The weight loss of treated carbide insert is also less than that of the untreated one.

13. Franjo Cajner et al, (2009) studied the effect of deep-cryogenic treatment on high speed steel properties. Compare the effect of traditional heat treatment and deep cryogenic treatments on the HSS tool steel. There is increase in the wear resistance, toughness, erosion wear resistance and abrasion by the deep cryogenic treatment of the high-speed steel. The micro structure gets changed along with formation of refined grained particle. Due to these refined grain the wear resistance increases. The thermal conductivity and the red-hot hardness also increased and the tool tip performance get enhanced. The reshaping of structure is possible with very less chance to cracks.

14. TugrulOzel, et al, (2004) studied the predictive modeling of surface roughness and tool wear in hard turning using regression and neural networks. The main motive of the study define a model based on feed-forwards neural network in predicting precisely both tool flank wear and surface roughness of the dry turning. Surface roughness and the tool flank wear experiment data measured according to neural networks models. The experiment done with the various different cutting conditions. The generated prediction system shows an accurate tool flank wear and surface roughness under specific range when regression models and neural network models were compared. The neural network models gives better prediction than that of the

regression models. The cutting force input and single output neural network model gives better result than that of the two-output surface roughness and tool flank wear neural network model.

15. A. Y. L. Yong et al, (2006) studies the performance of cryogenically treated tungsten carbide tools in milling operations. The soak segment hold at the temperature of -300 degree feranite for some time period near about 8 to 40 hour. While processing the soak segment, temperature of the process is maintained at the low temperature depicting a change in the crystal structure. There is formation of the refined grained carbide precipitate. More the socking time more will be the improvement of the properties of the material. During the soaking period the energy come out from the crystal lattice and crystal lattice becomes enhanced.

16 B. Podgornik et al, (2009) studied the influence of the deep cryogenic treatment on the tribological properties of P/M high speed steel. Examine the galling resistance and abrasion wear resistance under dry sliding machining. Evaluation of result in term of the coefficient of the sliding friction, HSS wear volume of the tool. Tribological properties of the P/M high speed steel improved by the deep cryogenic treatment. The abrasive wear resistance and galling properties become better by the deep cryogenic treatment. Austenite temperature plays an important role in the improvement of the HSS tool steel.

17. S. D. Bhole et al, (1990) studied the development of a prototype abrasive wear tester for tillage tool materials. Feed, depth of cut, tool material, heat treatment of the tool, heat treatment of the work piece material, nature of the cutting oblique/ orthogonal affect the tool life of the material, wear resistance, thermal heat conductivity, strength, abrasion resistance, impact resistance, surface roughness and red hot hardness are the main characteristics of the cutting tools. The factors such as heat generation and cutting velocity effects the tool life to a greater extent. Feed rate, depth of cut and cutting velocity are factors behind heat generation. Tool geometry also plays an important role in the tool life.

18. SıtkıAkıncıoğlu et al, (2015) studied the effects of cryogenic-treated carbide tools on tool wear and surface roughness of turning of Hastelloy C22 based on Taguchi method. Taguchi

method was employed to determine the effect of cryo treated tools in machining of C22 alloy on the surface roughness. The parameter like cryogenic treatment, feed rate and cutting speed is determined by Taguchi experimental design method. L9 orthogonal array used to calculate the signal noise ratio. The identification of factor affecting surface roughness is analyzed by ANOVA. The experiment is done by both deep cryo treated tool and shallow cryo treated tool. The surface roughness increase both by treated or untreated 28.3 and 72.3% respectively. Also, wear resistance of carbide tool increases. For better surface roughness, the cutting speed is 90 m/min and feed rate is 0.1mm/rev. The optimized surface roughness is experiment is obtained 0734 μm and by Taguchi method is 0615 μm very close to experimental value. Cryo processing improves surface roughness and wear resistance.

19 J. Tang. et al, (2016) enhanced the surface integrity and corrosion resistance of Ti-6Al-4V titanium alloy through cryogenic burnishing. The cryogenic processing enhances the corrosion resistance of Ti-6Al-4V titanium alloy. It also improves the surface roughness and refined grain structure. In cryogenic burnishing, the nano crystalline layer is formed over the Ti-6Al-4V titanium alloy. More is the cryogenic burnishing passes on titanium alloy more will be the surface refinement. Due to high density of grain boundaries and dislocation formed on the titanium alloy causes positive effect. Mott-Schottky, electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization curves are used to determine the corrosion behavior by 0.9% NaCl solution.

20 Mozammel Mia (2016) studied the effects of internal cooling by cryogenic processing on the machinability of hardened steel and also, optimizes the parameters of machining along with calculation of various parameter under different machining conditions. Cryogenic machining decreases the wear rate of the tool when compared with flood machining and dry machining. The heat generation on the tool tip is very less in case of the cryogenic machining which results in significant increase in tool life by less breaking of tool and hence, volume loss. The study calculates the effect of cutting force, feed rate under different conditions.

21. A. H. Kheireddine et al, (2014) studies the experimental and numerical study of the effect of cryogenic cooling on the surface integrity of drilled holes in AZ31B Mg alloy. The experiment study examines the in-process cryo cooling on drilled hole on AZ31B Mg alloy.

The study works on parameters such as surface roughness, cutting force, grain size, surface hardness, layer thickness and torque. FEM model generated the simulated effects of cryoprocessing with the corresponding work-study. Cryogenic cool drill hole shows better surface integrity as compared to use any cooling liquid.

22. Ineon Lee et al, (2015) studied the tool life improvement in cryogenic cooled milling of preheated Ti–6Al–4V. During cryo-machining, cutting force increases but decreases by 65% when the material is preheated. Maximum tool life is obtained during cryo-machining with pre-heating material. The chip morphology was also studied under different machining conditions. In preheating cryoprocessing condition, the chips are straight at low temperature and curved chip with high temperature. The combination of the cryo and preheating leads to increase in tool life of titanium alloy significantly.

23. Haisheng Lin et al, (2015) studied the tool wear in Ti-6Al-4V alloy turning under oils on water cooling comparing with cryogenic air mixed with minimal quantity lubrication. Titanium alloys required coolant at the time of machining. Minimum quantity lubrication (MQL) is very effective and eco-friendly cooling technique. But, MQL is not applicable because of very low thermal coefficient. Addition of cryo cooled air with MQL gives better heat transfer rate from tool tip. The study first compares the oil on water cooling type and water on oil cooling and then compares the both oil on water and water on oil with the cryo cooled air mix with MQL. Evaluate the chip morphology in each condition. And also, analyzed the other parameters such as surface roughness, tool wear, cutting force etc.

24. HadiGhasemiNanesa et al, (2015) studies cryogenic process parameters on microstructure and hardness evolution of AISI D2 tool steel. The study investigates the microstructure and hardness after cryo processing. The various parameters such as heating rate and surface density are selected using ANOVA for statistical analysis. Two different phases exist in cryogenic process and tempering process. In both the processes the phase transformation takes place. Transition carbide formed in tempering process at 473 K causes reduction in the hardness by 40 HV. AT 773K phase changes from transition carbides to martensite and cementite. In this step hardness is reduced by factor of 200 HV.

CHAPTER 5: MATERIAL AND EXPERIMENTAL SETUP

5.1 CUTTING TOOL

Cutting tools are used to remove unrequired material from the work-piece in order to get it in a desired shape by means of shear deformation. Cutting can be achieved by single point or multipoint tools. Where single point tools remove material by means of single cutting edge. Single point cutting tools are used for turning, shaping, planning and multipoint cutting tools are used for milling, drilling and grading. It should be kept in mind that the cutting tools which was used to remove material must be harder than the work-piece material. Which enable tool to with stand the heat generated in metal cutting process.

5.1.1 HIGH SPEED STEEL

In this study, the tool used for high speed metal cutting is high speed steel. Hardness of high speed steel cutting tools are about 60 to 65 RC and they easily work under the temperature range of 600 to 650 C. These cutting tools are logical choice of many cutting industry because they are available at economical price. Different application of High speed steel is that it can be used as turning tool, taps, twist drills, dies, counter bores, milling cutter, hobs, saws, reamers, etc. High speed steel possesses excellent harness and wear resistance properties along good toughness as it goes thought different heat treatment process.

The high-speed steel tool sample considered in this work are DOUBLE-H (M35) 5%Co steels procured from Matrix with dimension 6.35×101.60 mm. in this study turning operation was performed by single point cutting HSS tools. The following table depicts tool signature

Table 5.1 Description of single point high speed cutting tools

Back rake angle	0
Side clearance angle	10
Side rake angle	0
Principle cutting edge angle	45
End cutting edge angle	45
Nose radius	0.4mm
Tool over hang	14mm

5.2 MATERIAL SELECTION

In the recent years, less articles have been devoted towards machining of material C18000, an alloy of copper, chromium, nickel and silicon alloy, also known as Beryllium Free Copper alloy. The ultimate goal of any industry is to maximize the profits, hence the tools which can withstand severe wear, corrosion, resists microstructural changes and have long tool life are required. The application Of C18000 are found in the machining scenario where high mechanical strength is combined with moderate thermal and electrical conductivities. C18000 can also replace other copper beryllium alloys such as C17500 and C17510 in terms of machining applications. C1800 is fabricated through casting process and further, finishing processes such as grinding and coating are used. The heat treatment processes employed gives rise to a coarse grain structure and increase various mechanical properties such as strength, hardness, ductility along with significant increase in thermal and electrical conductivity. This alloy is manufactured by casting process. Therefore, this material is selected in the present work to calculate wear resistance on the optimized machining parameters.

C-18000 alloy

Figure 5.1 C-18000 Alloy

5.2.1 APPLICATION OF C18000:

- In manufacturing welding tips, wheels and fixtures.
- Used in stud welding tips and collets.
- In fabrication of hot runner systems used in injection moulding.
- Use to make cavities in bold moulds.
- In fabrication of welding dies used in wires and flashes.
- The core and ejector pins for injection moulds are made using C18000.

- In die casting machines tips of plunger are fabricated.
- Moulds of steel plastics use C18000 to manufacture heat sink inserts.

5.2.2 CHEMICAL COMPOSITION OF C1800 COPPER ALLOY

The chemical composition of C18000 copper alloy is presented in the following table.

Table 5.2 Chemical Composition

Copper	**96.4**
Chromium	0.45
Iron	0.15
Nickel	2.4
Silicon	0.6

5.2.3 MECHANICAL PROPERTIES OF C1800 COPPER ALLOY

The following table represents the various mechanical properties of C18000 copper alloy.

Table 5.3 Mechanical Properties

Rockwell Hardness	**90**	**90**
Tensile strength and ultimate strength	586 MPa	85000 psi
Tensile Yield strength	483 MPa	70100 psi
Elongation at break	10.0%	10.0%
Area Reduction	20.0%	20.0%
Elasticity Modulus	114 GPa	16500 ksi

5.3 CNC LATHE MACHINE

Computer Numeric Control also known as CNC lathe machine, works in three dimensions in a controlled space which inculcates a programmable logic control involving various codes. The input is given in the form of a programming model which guides the tool for the respective process occur relative to the dimensions required. The main characteristics of using CNC is the less time it take s to machine, high accuracy and ability to employ all the machining tools such as grinding, milling, tapping, drilling and boring. Two types of codes are characterized namely, G-codes which specifies the direction and movement of the tool, and M-codes called miscellaneous codes to control the machine operations such as turning coolant on and off, spindle start and stop, program end and changing tool. Generally, CNC machines is used in batch production. The various advantages of CNC are: less skilled labour with one person can operate many machines, uses virtual software, allows modification in the part programs LEADWELL T6 CNC Lathe will be used for this thesis.

Figure 5.2 LEADWELL T6 CNC Lathe

5.3.1 CONCEPT OF NUMERICAL CONTROL

The cutting tool and the work-piece material is direct contact with each other. The cutting tools are directly around the work-piece to obtain the finish product. In this system there is less human error. A program is given to the machine and according to the program machine doing their job. The tool profile is set by program. There is two type of code that understand by the machine. M code and G code. M code are the miscellaneous function code these functions are control the action of the machine and G code are preparatory function and special programming language that control the motion profile of the tool.

Table 5.4 Specification of the Machine

Capacity	450 mm
Bar Capacity	51 mm
Chuck size	6 inch
X axis travel	230
Z axis travel	105+20 MM
Spindle speed	45-4500 RPM
Spindle nose	A2-5
Through hole spindle	62 mm
Number of tool position	12
Turret indexing time	1 sec
X rapid traverse	20 m/min
Z rapid traverse	24m/min
Spindle motor	15 HP

5.3.2 THE MACHINE CONTROL UNIT (MCU) FOR CNC

The MCU is stands for machine control unit and a microcomputer hardware that differentiate the CNC from other conventional machines. Function of the machine control unit

- Read the code instruction
- Decoded the coded instruction
- Generate the axis motion commands by interpolation of the data

Subsystem of the machine control unit

(1) Central Processing Unit,

(2) Memory,

(3) Controls for Machine Tool Axes and Spindle Speed,

(4) Input/output Interface and

(5) Sequence Controls for Other Machine Tool Functions.

A system bus interconnects the above-mentioned subsystems, by which signals and data are communicated in a network.

• **Central Processing Unit:** Central Processing Unit (CPU), is also knows as brain of MCU. Because it performed basis arithmetic logical input output operation. All the programme of the machine are analyses by the CPU. All instruction of the machine are control by the CPU.

The CPU consists of three divisions such as

(1) Control unit,

(2) Arithmetic-logic unit

(3) Access memory.

(1) Control unit:

The function of control unit is to coordinate and control MCU function by generating a signal which in turn activate the components of MCU

(2) Arithmetic-logic unit

Multiplication, addition, counting, subtraction and other logical functions are performed by arithmetic logic unit. All these software's are installed in memory of MCU.

(3) Immediate access memory

CPU process data easily from immediate access memory and it further connect to the system memory

• Memory:

As we know that CNC is operated on the basis of different program and in ordered to save these programs large space of memory is required.

Types of CNC memory:

(1) Primary memory

(2) Secondary memory

Primary memory consists of read only memory and random access memory. Where ram consist of NC part program and rom consist of operating system software. Program can be erased and replace in RAM by jobs are change.

5.3.3 CNC LATHE OPERATIONS

Basically, there are mainly two type of operation done by CNC on the cylindrical bar turning operation and facing operation.

Facing (Fig 5.3) is an operation which involves feeding of the tool perpendicular to the axis of workpiece rotation.

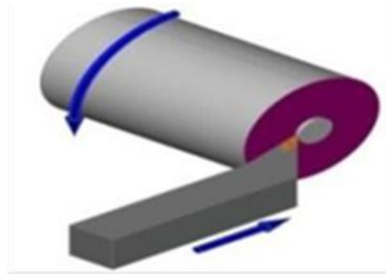

Figure 5.3 Facing Operation. Source: www.wikipedia.com

Turning (Fig 5.4) is an operation which involves feeding of the tool parallel to the axis of workpiece rotation.

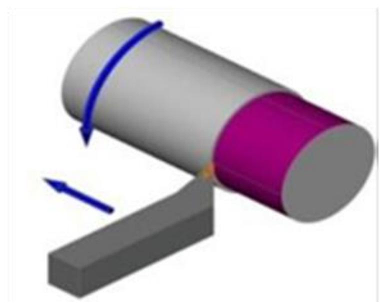

Figure 5.4 Turning Operation. Source: www.wikipedia.com

Source of error in operation

The following are the errors which are caused in CNC lathe during different process.

- Calibration error
- Off set error
- Tool wear
- Temperature variation

5.3.4 STAGES IN METAL CUTTING

There are mainly two type of metal cutting stages.

- Roughing
- Finishing.

In case of roughing cuts the large amount of material is drain from the workpiece in order to achieve the close shape of desired product. In roughing operation, there is high value of cutting velocity, depth of cut and feed rate. Some amount of material is left on the workpiece for the finishing operation.

In case of finishing cuts the amount of material remove is very less. Number of cycle for finishing cuts are also very less. Better surface finish and accurate dimensions are achieved in finishing cuts. The value of cutting speed is high but other two cutting parameter feed and depth of cut is very small.

The cutting fluids are used to overcome the heat generation during the machining. It also acts as a lubricant and reduce value of friction between tool and workpiece. The selection of cutting fluids are according to the nature of tool and workpiece

5.3.5 CNC PART PROGRAM

```
G71 G95 G90
M03 S1800
M06 T1 D1
G00 X35 Z10
G01 X32.46 Z5 F0.03
G01 Z-70 F 0.05
G00 X35 Z-5
G01 X32.43 Z5 F0.03
G01 Z70 F0.03
G00 X35 Z5
G01 X32.40 Z5 F0.03
G01 Z-70 F0.05
```

G00 X35 Z-5

M05

M30

(Spindle speed = 1800 rpm)

(depth of cut = 0.03 mm)

(feed rate = 0.03 mm/rev)

This part program is used for turning the work piece. The machining parametric quantities user are:

Spindle speed = 1800 rpm, Feed rate = 0.03 and depth of cut = 0.03mm. The above part program can be edited accordingly to use for performing turning operation with all the nine parametric combinations that has been selected by Taguchi method.

5.4 MECHANICAL CONTACT PROFILER

Mechanical contact profiler is used to analyse the surface roughness. Surface roughness was examined with the help of profiler's conical diamond tip stylus. The angle of diamond tip varies from 60 to 90 and radius of tip is also varying from 1 to 10 µm. The motion of tip of mechanical profiler is in linear motion which ranges from 1 to 10 mm and the direction of motion is perpendicular to the direction of machining. It gives the various value like R_A, R_Z, R_Q, R_T, R_P, and R_{PC}. But in this study only Ra value is required to examine the surface roughness to optimized the machining parameter. During the working of stylus there is no external force and the disturbance acting on the stylus. It moves over the workpiece surface with the constant speed and it is a two ways motion forward and backward motion. There is a transducer that reads the vertical variation of the stylus tip and converts the mechanical signal to the electrical signal. There is amplifier that converts the analog signal into digital signal. Further these digital signal is processed by computer to check roughness and surface waviness. The advantage of mechanical profiler is that it is portable and easy to use. For this thesis work Taylor-Hobson Talysurf surface profiler is used.

TAYLOR-HOBSON TALYSURF SURFACE PROFILER

Figure 5.5 Taylor-Hobson Talysurf surface profiler

5.5 TAGUCHI PARAMETER DESIGN

Taguchi is a technique which gives much reduced "Variance" for different sets of experiments with optimum settings of control parameters based on "ORTHOGONAL ARRAY". Where orthogonal array helps in achieving a set of well-balanced experiments and on the other side signal to noise ratio are the log functions of the output, which helps in analysis of data and forecasting of optimum results.

Procedure for applying Taguchi technique

1. Problem formulation

In order to optimize the desired parameters, we have to first formulate the problem. For which a detailed knowledge is required in order to examine the subject. So, first an objective is set which is to be achieved at the end of the study by this design of experiments. The process variables are found out after setting the objectives, which are also known as controllable factors or signals. The performance of whole process gets affected by two factors known as controllable and uncontrollable factors, where uncontrollable factor is also known as Noise. For example, in any precision machining, different environmental factors such as vibrations, temperature, humidity etc. affects the whole process. Combination of different levels of parameters are made for performing experimentation work to get the optimized parameters.

2. Experimental design

Orthogonal array is used for making an experimental design. The selection for required orthogonal array depends on the number of parameters and number of variables selected for the study. In this study L9 array is used for design of experiment as there are three parameters and three levels on which whole experimental work is performed. 27 combinations of different parameters forms from three parameters and three levels. The Taguchi orthogonal array helps in selecting the most affecting nine parameter combinations. About 99.5% accuracy can be achieved by conducting the nine experiments instead of twenty-seven experiments. This somehow reduces the time required for experimentation work.

3. Analysis of results

After performing the experimental work on the basis of the combination of the different levels of parameters, we have to analyze the result and for analyzing the result Signal to Noise ratio is used to process parameters. Where these process parameters gets affected by two factors known as controllable and uncontrollable also known as signal and noise respectively. Thus, with the help of S/N ratio we can found which are the parameters which are less affected by noise.

5.5.1 Signal to Noise ratio:

By Taguchi methods, uncontrollable factors such as noise can be minimized to identify the control factors, which are the one that decreases the liability of the product. Control factors are process variables that can be controlled by minimizing the noise factor. Where uncontrollable factors can be controlled while performing experimental processes. In this method, the noise factors are manipulated for variability to take place and from the results, the control factor settings are identified and optimized in order to obtain a robust product. The effects of noise factors are minimized by the Control factor settings, which can be identified with the help of higher signal-to-noise (S/N) values obtained from the Taguchi process. The whole process depends upon:

Step 1: In order to identify the optimal control factors signal-to-noise (S/N) ratio are used in order to reduce variability.

Step 2: Signal-to-Noise (S/N) ratio helps in identifying the least affecting factor. Which helps in bringing the mean values closer to the target. Different signal-to-noise ratios can be chosen according to the target of the experiment.

For the static experiments three different S/N ratio are generally used.

(1) Larger is better:

This signal-to-noise ratio is used to maximize the response.

S/N = -10 *log(Σ(1/Y^2)/n)

(2) Nominal is best (default):

This signal-to-noise ratio is used to target the response and the ratio is based on both standard deviations and mean.

S/N =10 * log ($\bar{y}^2 \div \sigma^2$)

(3) Smaller is better:

This signal-to-noise ratio is used when the response is to be minimized.

S/N = -10 *log(Σ(Y2)/n))

CHAPTER 6: RESULT AND DISCUSSIONS

6.1 INTRODUCTION

The Taguchi method has been used quite successfully in several industrial applications to optimize manufacturing processes and in the design of electrical and mechanical components. Taguchi's method helps to find the best set of specified process parameter level combinations which include the discrete setting values of the process parameters. Further S/N ratio and mean plots are used to find the optimal values for cutting and the geometric parameters. S/N ration consist of two variables known as controllable and uncontrollable also known as signal and noise respectively. In order to find optimal parameter, the value of S/N ratio should be high for which there must be reduction in uncontrollable factors.

6.2 RESULT ANALYSIS

In this section of this chapter the results for finishing machining i.e. Surface Roughness is being discussed. As discussed in chapter 3, experiment are performed by varying the cutting and geometrical parameters like spindle speed, Depth of cut, Feed rate, rake angel and nose radius respectively, in order to machine D3 steel by using carbide tool to obtain good surface finish. The experiments are performed on the basis of Taguchi design. The results obtained from the experimental investigation for Surface Roughness (Ra) are shown in Table 4.1. These results obtained are then used to develop a relationship between the surface roughness and process variables on the basis of signal to noise ratio by depicting graph between them.

6.2.1 SURFACE ROUGHNESS RESULT ANALYSIS

Using Taguchi design different levels of process parameters are generated, which are to be used for performing the experimental work, which are then analysed using signal to noise ratio. In this study L9 orthogonal array is used for attaining optimal result is calculated with good confidence level. Where these process parameters gets affected by two factors known as controllable and uncontrollable also known as signal and noise respectively. Thus with the help of S/N ratio we can found which are the parameters which are less affected by noise and can be easily controlled. Henceforth model developed is satisfactory to signify the relation between machining parameters and surface roughness.

Design of Experiment for cutting parameters

- Select Process Factors with Respective Levels
- Select Parameters to Optimize
- Conduct Experiments according to DOE
- Formulate Observed Responses in DOE Table

- Taguchi Design optimization
- Model Significance
  - Mean Ratio Plot
  - S/N Ratio Plot
- Compare the tool life of both tools cryo-treated or non-cryo treated tool on the optimized parameter

Figure 6.1: System procedure for optimized the machining parameter

6.2.2 DESIGN OF EXPERIMENT FOR CUTTING PARAMETERS

Table 6.1: Selected Process Factors/Levels for Optimizing Cutting Parameters

FACTORS/LEVEL	UNITS	I	II	III
FEED	μm	0.09	0.06	0.03
DOC	μm	0.07	0.05	0.03
SPEED	Rpm	1200	1500	1800

After going through literature survey, different levels of parameters are studied to get most optimized result to decrease surface roughness. Qureshi (2015) optimize the cutting parameters, in order to achieve good surface finish of P20 steel, while performing turning operation on CNC Lathe and further L9 orthogonal array and S/N ratio is being applied to get better results. Galanis (2014) uses Finite Element Analysis to optimize the cutting parameters, during turning of AISI 36L steel. So, different levels for process parameters are considered during turning operation on CNC. As, the different levels of process parameters are selected from literature survey which is to be discussed in chapter 2. These selected process parameters are further processed by using L9 orthogonal array, which results in providing different levels for performing the experimental work as discussed in table 6.2.

Table 6.2: Selected Process Factors with Respective Levels

S.no	Spindle speed (rpm)	Feed rate (mm/rev)	Depth of cut (mm)
1	1200	0.09	0.07
2	1200	0.06	0.05
3	1200	0.03	0.03
4	1500	0.09	0.05
5	1500	0.06	0.03
6	1500	0.03	0.07
7	1800	0.09	0.03
8	1800	0.06	0.07
9	1800	0.03	0.05

After getting the desired level of combinations of considered parameters, we have to perform our experimental work according to the value that are generated with the help of Taguchi L9 as discussed in table 6.2. Our experiment is to perform turning operation on CNC lathe. So, in order to perform turning operation on CNC we have to make a program for turning operation on the basis of which the CNC lathe will work. So, in order to get better results for surface finish three different values for surface roughness is calculated for each one level by using surface roughness tester. After performing the whole experiment according to the

Taguchi L9 array next step is to optimize the parameters for achieving the good surface finish, which is discussed in next section.

Table 6.3: Experimentally Calculated Results

S.no	Spindle speed (rpm)	Feed rate (mm/rev)	Depth of cut (mm)	Ra 1 (µm)	Ra 2 (µm)	Ra 3 (µm)
1	1200	0.09	0.07	0.65	0.62	0.67
2	1200	0.06	0.05	0.53	0.55	0.50
3	1200	0.03	0.03	0.47	0.42	0.43
4	1500	0.09	0.05	0.58	0.57	0.55
5	1500	0.06	0.03	0.34	0.38	0.32
6	1500	0.03	0.07	0.30	0.32	0.27
7	1800	0.09	0.03	0.29	0.27	0.25
8	1800	0.06	0.07	0.31	0.37	0.39
9	1800	0.03	0.05	0.20	0.21	0.22

6.2.3 TAGUCHI DESIGN OPTIMIZATION FOR CUTTING PARAMETERS

In order to get best result for surface finish, the results have to be analysed for which signal to noise ratio is being used, which works on the basis of L9 orthogonal array. Where S/N ratio gets affected by two factors controllable and uncontrollable. Controllable factors are also known as signal and can be controlled easily, whereas uncontrollable are known as noise which are to be minimized in order to identify control factors that decreases the variability in the products. In this way signal to noise ratio identifies the optimal factors means these are the factors which has less effect on S/N ratio in order to reduce variability means bringing values closer to the target. The following table shows values for mean and S/N ratio for surface roughness, which is achieved experimentally by conducting turning operation on different levels of parameters.

Table 6.4: Table for S/N Ratio and Mean

S.no	Spindle speed (rpm)	Feed rate (mm/rev)	Depth of cut (mm)	Ra 1 (µm)	Ra 2 (µm)	Ra 3 (µm)	Mean (µm)	S/N Ratio
1	1200	0.09	0.07	0.65	0.62	0.67	0.646667	3.7820
2	1200	0.06	0.05	0.53	0.55	0.50	0.526667	5.5627
3	1200	0.03	0.03	0.47	0.42	0.43	0.440000	7.1205
4	1500	0.09	0.05	0.58	0.57	0.55	0.566667	4.9313
5	1500	0.06	0.03	0.34	0.38	0.32	0.346667	9.1793
6	1500	0.03	0.07	0.30	0.32	0.27	0.296667	10.5338
7	1800	0.09	0.03	0.29	0.27	0.25	0.270000	11.3569
8	1800	0.06	0.07	0.31	0.37	0.39	0.356667	8.9155
9	1800	0.03	0.05	0.20	0.21	0.22	0.210000	13.5491

Surface roughness is calculated at different levels of input factor. In order to get optimal factors for attaining the good surface finish Minitab 17 software is used, which helps in getting optimal results. In this table, at different combinations of spindle speed, depth of cut and feed rate value of surface roughness (Ra) is checked. For every combination three different values of Ra is calculated. Now, by inputting all these values in Minitab 17 we have calculated what will be the mean of surface roughness and values for signal to noise ratio. The approach that is to be used for calculating the values and graphs for mean is smaller is better. S/N ratio is calculated using -10log1/n ($\sum Yi^2$). It is to be noted only that factor is considered as optimal factor for which S/N ratio value is high and this can only be achieved if value of signal is greater than noise means by lowering the effect of the noise we can control the controllable factor also known as signal. On, the basis of these value of mean and S/N ratio graphs are being generated by Minitab 17, which shows that what are the optimal parameters for achieving good surface finish while machining of C 18000.

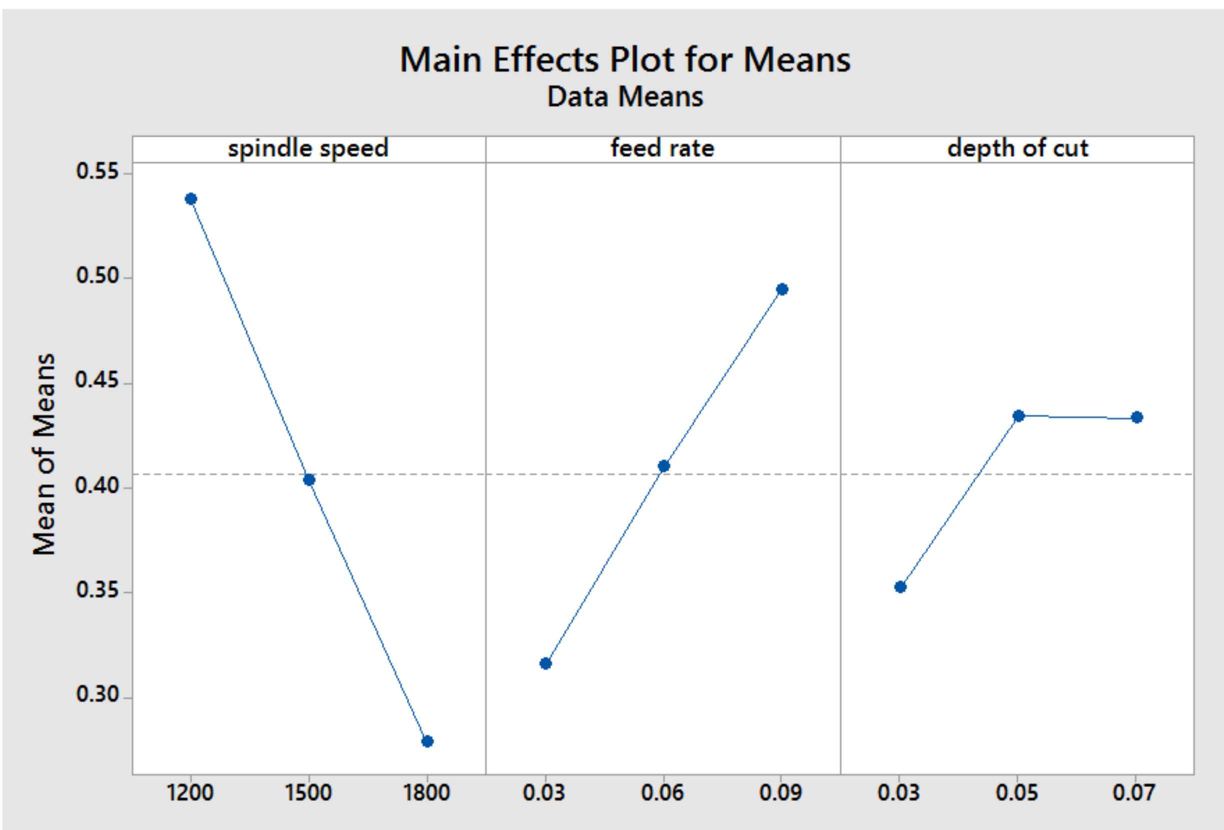

Figure 6.2 Graph for Main Effects Plot for Mean

The above figure depicts the mean plot in which the horizontal line is the value of the total mean of the means. Smaller the value of mean better is the quality characteristics for the material. As per the analysis of means from graph the levels of parameters which are to be set for getting optimum value for good surface finish are spindle speed 1800, feed 0.03 and DOC 0.03.

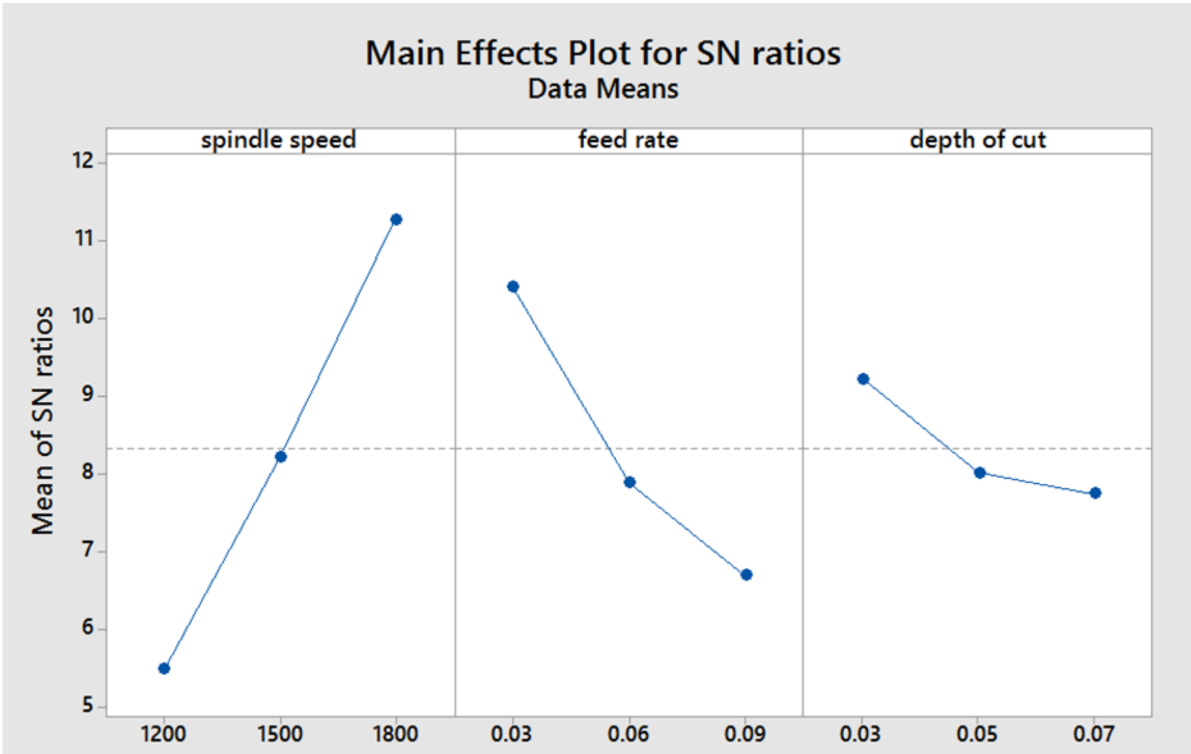

Figure 6.3: Graph for Main Effects Plot for SN ratios

The above figure depicts the SN ratio plot in which the horizontal line is the value of the total mean of the SN ratio. Larger the value of mean better is the quality characteristics for the material. As per the analysis of means from graph the levels of parameters which are to be set for getting optimum value for good surface finish are spindle speed 1800, feed 0.03 and DOC 0.03.

6.2.4 GRAPHICAL OPTIMIZATION:

Following are graphs are also made in excel for the validation of the results that we get through Taguchi design.

Key points:

Signal to noise ratios are calculated using -10log1/n (Σ Yi^2)

We need maximum Signal to Noise ratio & minimum average surface roughness.

1. Spindle speed and average Surface roughness:

The following table shows the value of average surface roughness and S/N ratio, which is being calculated by taking mean of all the values of Ra and S/N ratio at particular spindle speed.

Table 6.5 Table for Optimal Spindle Speed

Spindle Speed	1200	1500	1800
Avg. Ra	0.538	0.403	0.279
S/N ratio	5.488	8.2148	11.278

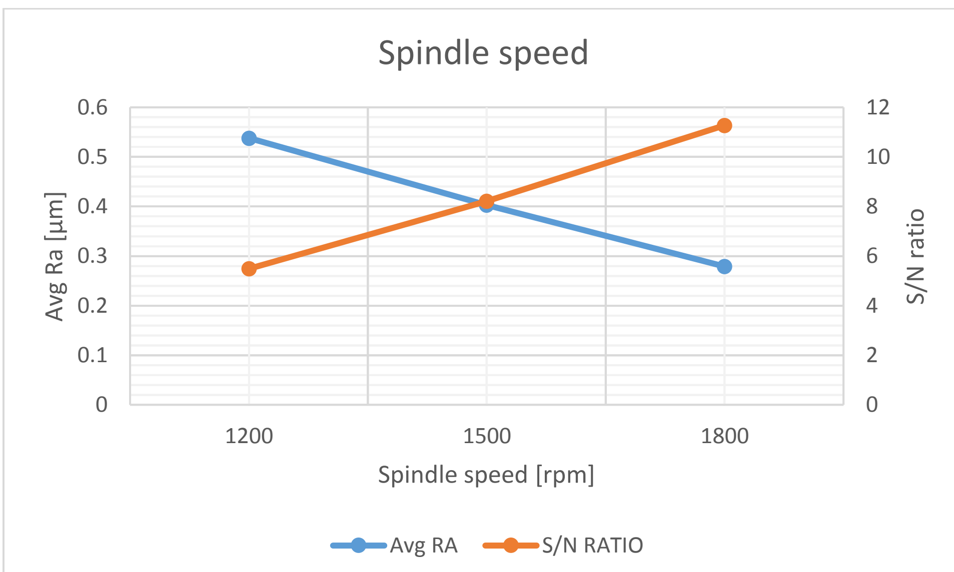

Figure 6.4: Graph for Optimal Spindle Speed

From the above graph it can be easily concluded that the value of S/N ratio is getting increased and the value of average surface roughness decreases. So, when spindle speed is 1800 the value of S/N ratio is high and the value of surface roughness is low, from this we can conclude that 1800 is the optimal value of spindle speed.

2. Feed & average surface roughness

The following table shows the value of average surface roughness and S/N ratio, which is being calculated by taking mean of all the values of Ra and S/N ratio at particular Feed Rate.

Table 6.6 Table for optimal Feed Rate

Feed Rate	0.09	0.06	0.03
Avg. Ra	0.4944	0.41	0.315
S/N ratio	6.69	7.886	10.4011

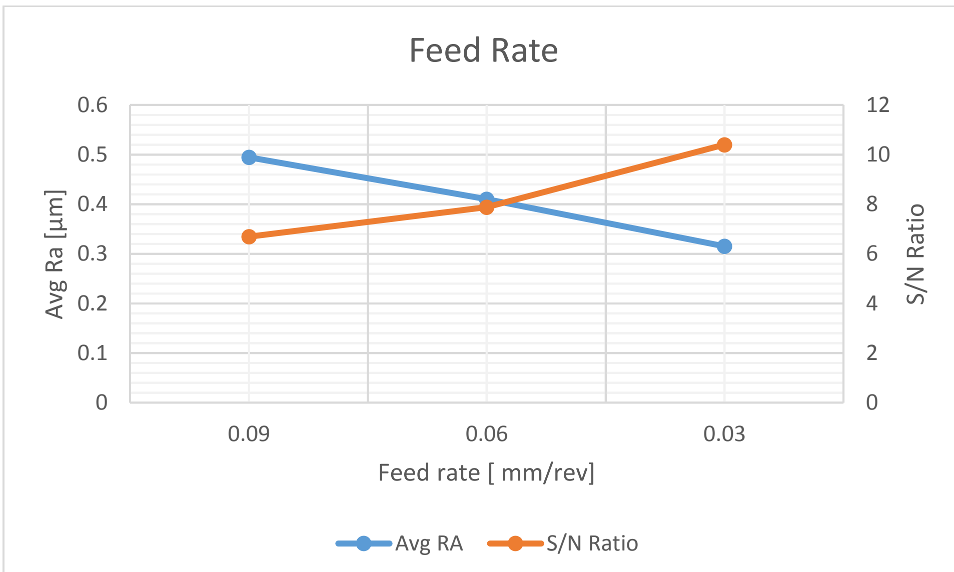

Figure 6.5: Graph for Optimal Feed Rate

From the above graph it can be easily concluded that the value of S/N ratio is getting increased and the value of average surface roughness decreases. When feed rate is 0.03 the value of S/N ratio is high and the value of surface roughness is low, from this we can conclude that 0.03 is the optimal value for feed rate.

3. Depth of cut and average surface roughness:

The following table shows the value of average surface roughness and S/N ratio, which is being calculated by taking mean of all the values of Ra and S/N ratio at particular Depth of Cut.

Table 6.7 Table for Optimal Depth of Cut

Depth of cut	0.07	0.05	0.03
Avg. Ra	0.433	0.4044	0.3522
S/N ratio	7.743	8.008	9.2189

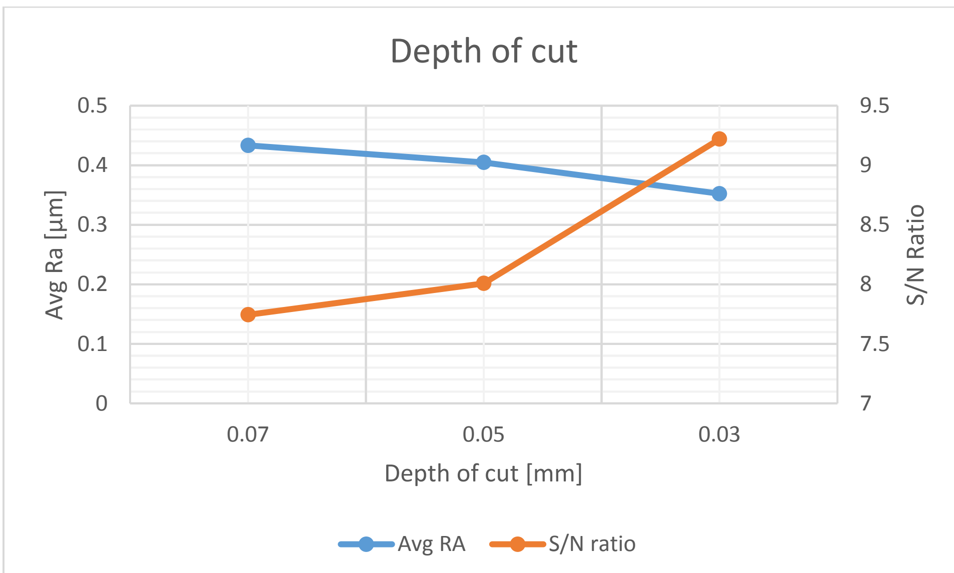

Figure 6.6: Graph for Optimal Depth of Cut

From the above graph it can be easily concluded that the value of S/N ratio is getting increased and the value of average surface roughness decreases. When Depth of Cut is 0.03 the value of S/N ratio is high and the value of surface roughness is low, from this we can conclude that 0.03 is the optimal value for Depth of Cut.

6.3 TOOL WEAR CALCULATION

Tool wear is studied on the basis of the optimized cutting parameter that we have got while machining of C18000 with high speed steel. The optimized cutting parameter that we have got from this study are 1800 rpm, 0.03 feed rate per rev and 0.03 mm depth of cut. The tool wear is studied on standard high speed steel M35 tool and cryo treated HSS M35 tool on the basis of number of cycles performed by tool on each step of length 20mm. In this study tool is considered to be worn out at that point when it provides bad surface finish in comparison to the previous steps performed by the same tool. Comparison of tool wear between standard and cryogenated HSS tool were done on the basis of how much material is removed i.e. MRR, surface finish means how good surface finish the tool will prove until it got worn out. The tool wear is further studied on the basis of the micro images produced by CCI- NON-CONTACT PROFILER.

Tool Wear Calculation formulas

N= Rotational Speed of Workpiece RPM

F= Feed, mm/rev

L= Length of Cut, mm

D_o= Original Diameter of Workpiece, mm

D_f = Final Diameter of Workpiece, mm

D_{avg} = Average Diameter of Workpiece $(D_o + D_f)/2$, mm

D= Depth of Cut, mm

T= Cutting Time, sec/min (L/F * N)

MRR= Material Removal Rate, mm^3/min $(\pi * D_{avg} * D * F * N)$

Working Parameters of Machining

N=1800 rpm

F= 0.03 mm/rev

L= 20mm

D= 0.03mm

6.4 CALCULATION FOR STANDARD HSS TOOL:

Table 6.8 Table of outcomes of standard HSS tool

Outer Diameter (mm)	Final Diameter (mm)	Number of Cycles	Surface Roughness (Ra) µm	Machining Time (sec)	Material Removal (mm^3)	Length in (km)
28.50	27.99	17	0.1996	6.30	905.32	1.005
27.20	26.69	17	0.2494	6.30	863.66	0.964
24.10	23.59	17	0.2869	6.30	764.13	0.848
22.10	21.59	17	0.3100	6.30	700.22	0.777
20.00	19.10	30	0.3182	11.10	1104.42	1.290

Total Number of Cycle= 98

Machining Time for One Cycle= L/F*N

= 20/0.03*1800

= 0.37 min

Total Machining Time of standard HSS tool= 98*0.37

= 36.30 min

Total Material Removed by standard HSS tool = 4337.75 mm^3

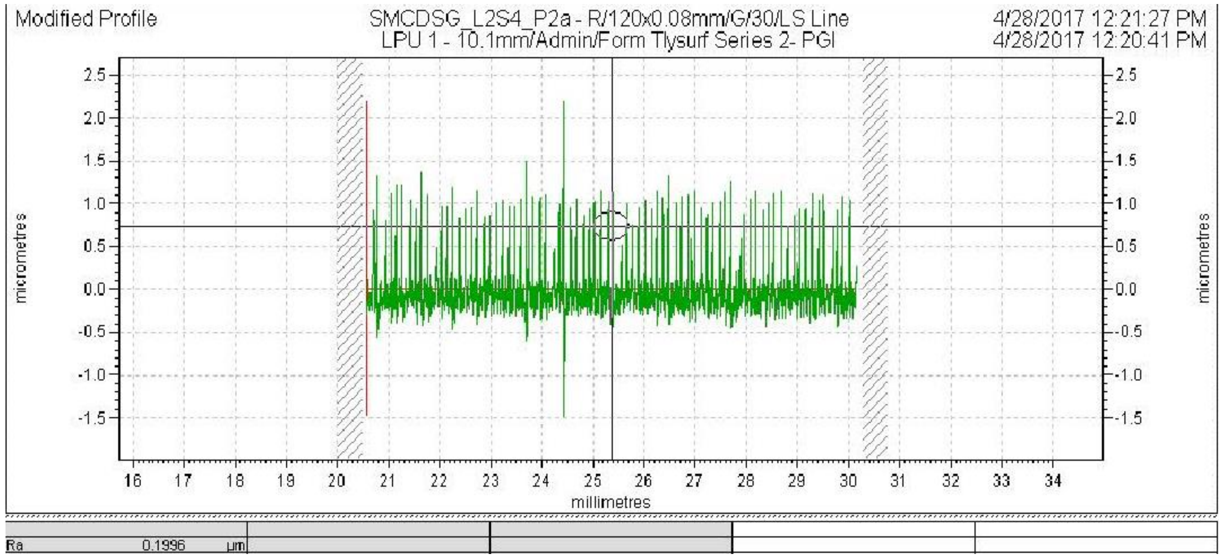

Figure 6.7 Surface roughness of standard HSS after 17 cycle

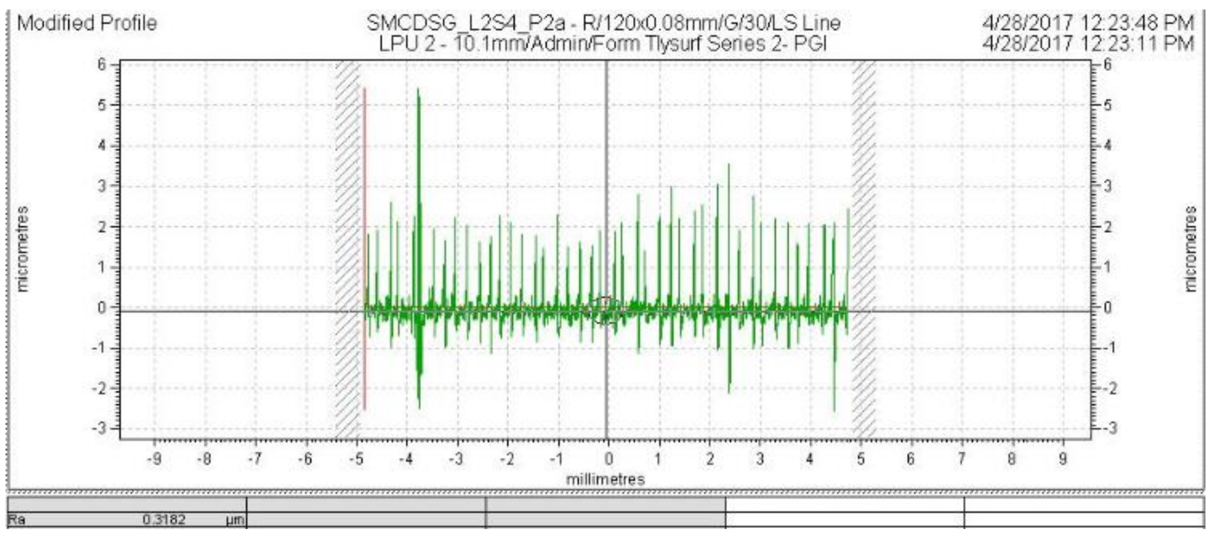

Figure 6.8 Surface roughness of standard HSS tool after 98 cycle

The above image of the surface roughness of the C-18000 machined material surface. In figure 6.7 the value of Ra is 0.1996 µm after 17 cycle with the optimized parameter. And in the second figure 6.8 the value of Ra is 0.3182 µm after completion of 98 cycle. After 98 cycle the machined surface become rough means tool become worn out.

Table 6.9 Table of surface roughness and time

Surface roughness (μm)	Time (min)
0.1996	6.30
0.2494	12.60
0.2869	18.90
0.3100	25.2
0.3182	36.30

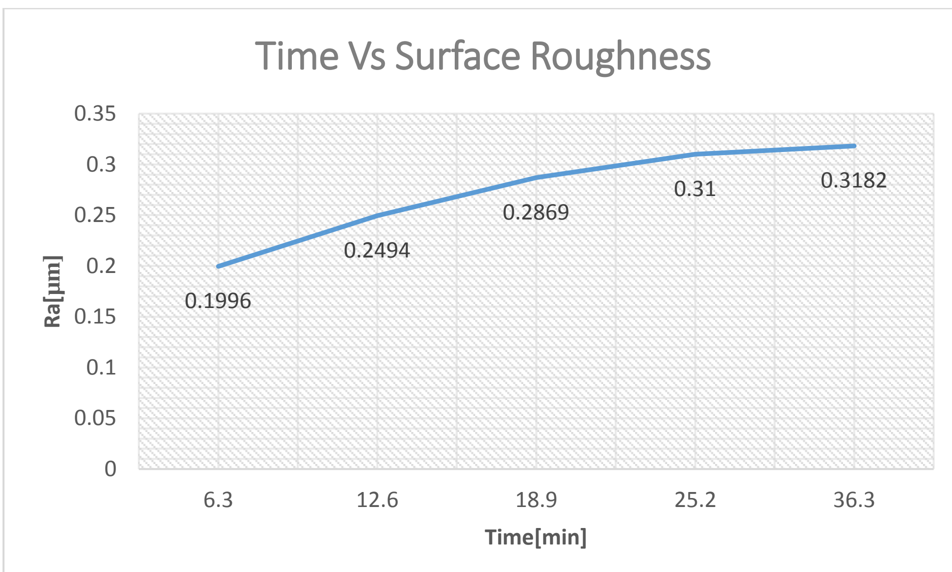

Figure 6.9 graph between surface roughness with respect to time

As our study depicts that surface roughness is one of the factor, which effects the tool life. So, with increase in surface roughness with respect to time indicates that our tool will get worn out.

Table 6.10 Table of surface roughness and length travel by tool

Surface Roughness (µm)	Travel Length (km)
0.1996	1.005
0.2494	1.969
0.2869	2.817
0.3100	3.594
0.3182	4.884

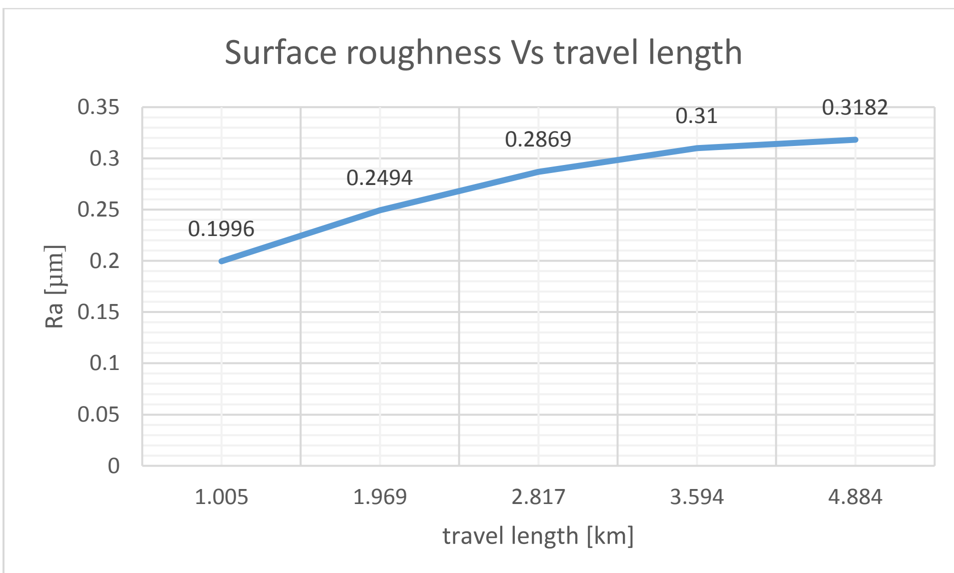

Figure 6.10 graph surface roughness and length travel by tool

The above graph depicts that there is sudden increase in surface roughness but as the processes goes on the value for surface roughness remains stable and in the end as the tool got wear out the value of surface roughness increases.

6.5 CALCULATION FOR CRYOTREATED HSS TOOL:

Table 6.11 Table of outcomes of Cryo-treated HSS tool

Outer Diameter (mm)	Final Diameter (mm)	Number of Cycles	Surface Roughness (Ra) µm	Machining Time (sec)	Material Removal (mm^3)	Length in (km)
28.61	28.10	17	0.2348	6.30	909.149	1.008
26.61	26.10	17	0.2440	6.30	845.023	0.937
24.61	24.10	17	0.2479	6.30	780.896	0.866
22.61	22.10	17	0.2680	6.30	716.769	0.795
20.78	18.80	66	0.5906	24.44	2461.567	2.733

Total Number of Cycle= 134

Machining Time for One Cycle= L/F*N

= 20/0.03*1800

= 0.37 min

Total Machining Time of standard HSS tool= 134*0.37

= 49.58 min

Total Material Removed by standard HSS tool = 5713.40 mm^3

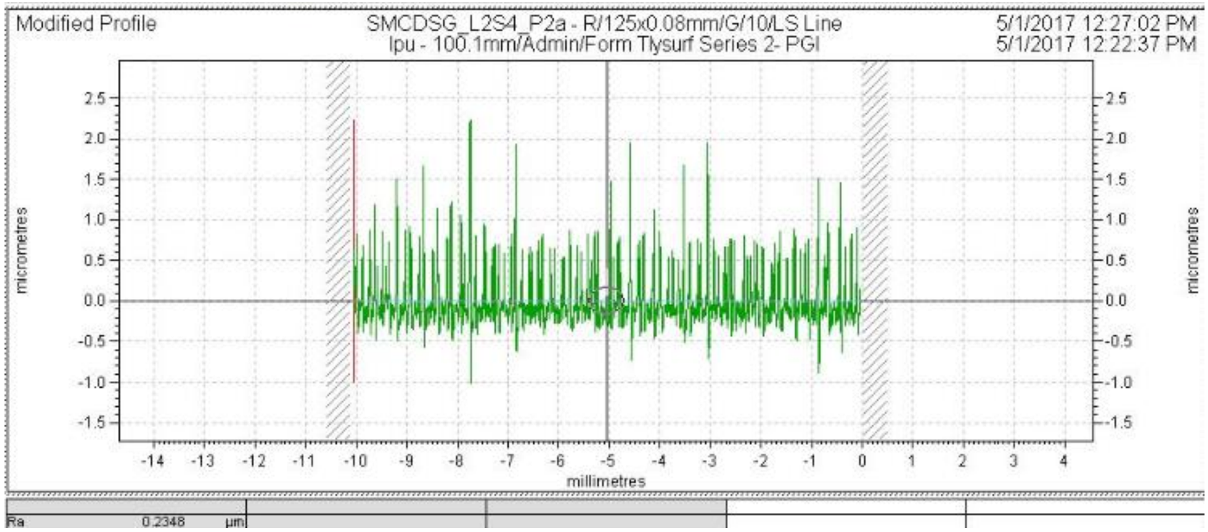

Figure 6.11 Surface roughness of Cryo treated HSS after 17 cycle

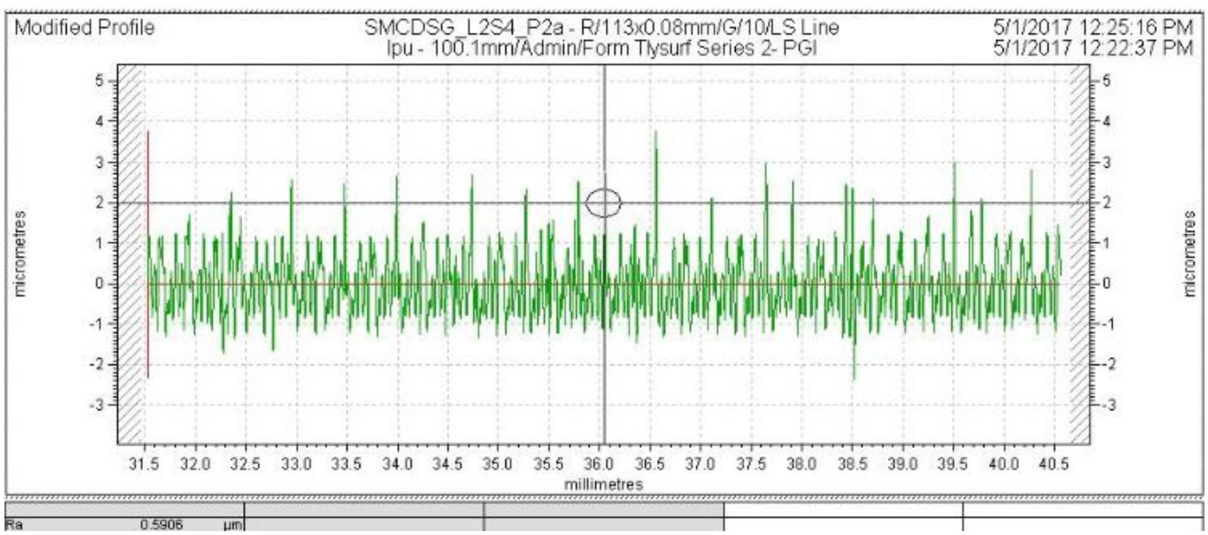

Figure 6.12 Surface roughness of Cryo treated HSS after 134 cycle

The above image of the surface roughness of the C-18000 material surface with cryo-treated HSS tool. In figure 6.11 the value of Ra is 0.2348 µm after 17 cycle with the optimized parameter. And in the second figure 6.12 the value of Ra is 05906 µm after completion of 134 cycle. After 134 cycle the machined surface become rough means tool become worn out.

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Table 6.12 Surface roughness and length of tool travel

Surface roughness (µm)	Travel Length (km)
0.2348	1.008
0.2440	1.945
0.2479	2.811
0.2680	3.606
0.5906	6.339

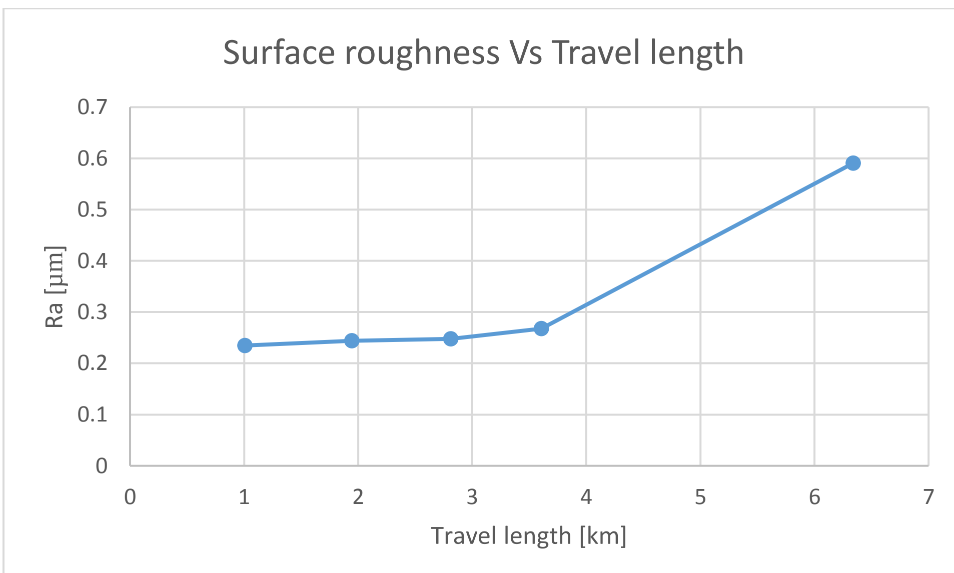

Figure 6.13 Graph between surface roughness and travel length

The above graph is between Surface roughness and Travel length of cryo treated length. Which shows that the surface roughness is getting improved in comparison to the non-cryo treated HSS tool as the travel length increases and it was also found that there is sudden break in tip of the tool due to increased hardness in cryo treated HSS tool.

6.6 METALLOGRAPIC EXAMINATION

Coherence correlation interferometer (optical profilometer)

CCI HD is also known as non-contact 3D optical profiler which has a capability to measure thin and thick films. It works on the basis of correlation algorithm which in turns to find the coherence peak and face position of an interference pattern. The CCI HD also have the capability of measuring dimension and roughness of the desired film. Following are the features of CCI HD helps in attaining the goals for our study:

(i) It has high resolution upto 2048 x 2048-pixel array.

(ii) Resolution of 0.1 Angstrom over the entire measurement range

(iii) It can accommodate upto 0.3% to 100% surface reflectivity

(iv) The analysis software that is used in CCI HD has Multilanguage feature, which makes it more user friendly.

Figure 6.14 Coherence correlation interferometer HD non-contact profiler

IMAGES OF STANDARD HSS

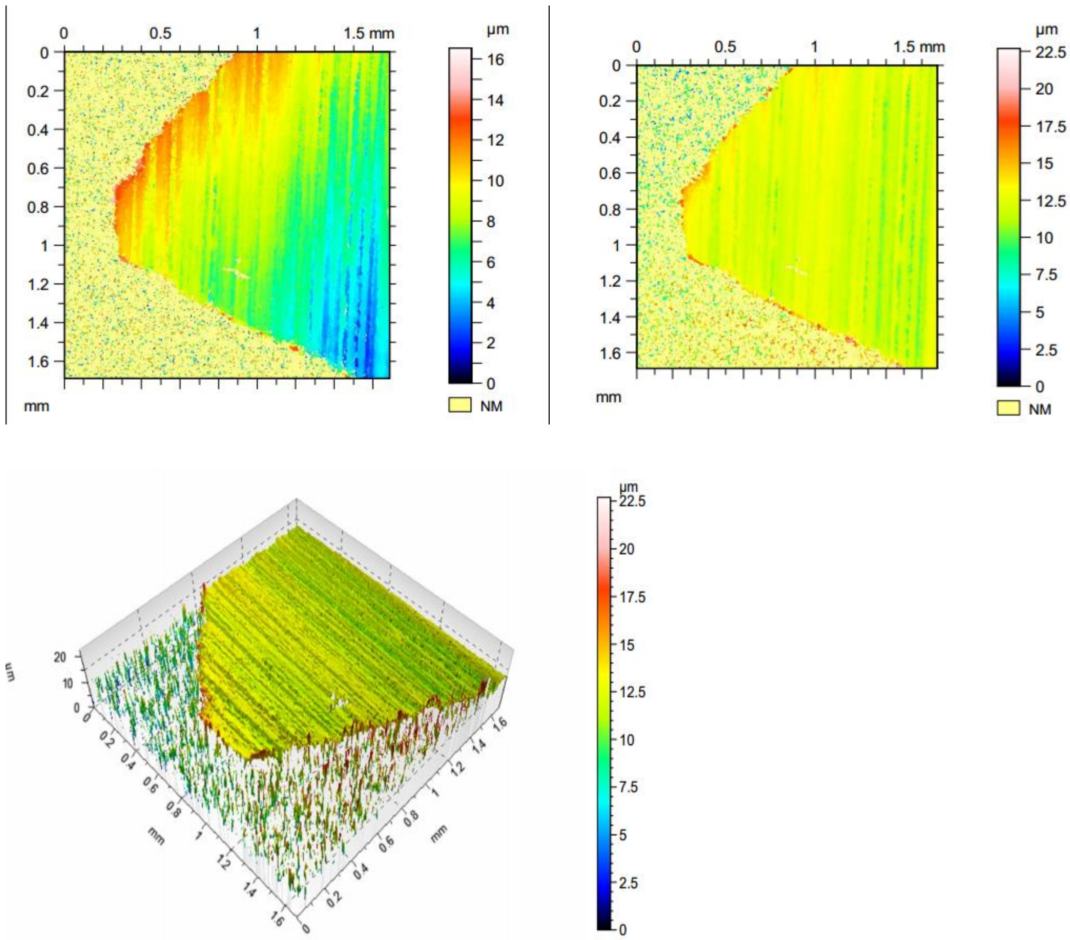

Figure 6.15 CCI HD image of standard HSS tool without machining

The above images are taken off the standard HSS tool having 4µm tool tip radius under different magnifications, which shows the Profile of the tool. The above images are of the tool which has not gone under any process, this was done in order to compare the results of the standard HSS and cryogenic HSS tool, which went under process with the non-processed tool.

STANDARD HSS TOOL AFTER MACHINING:

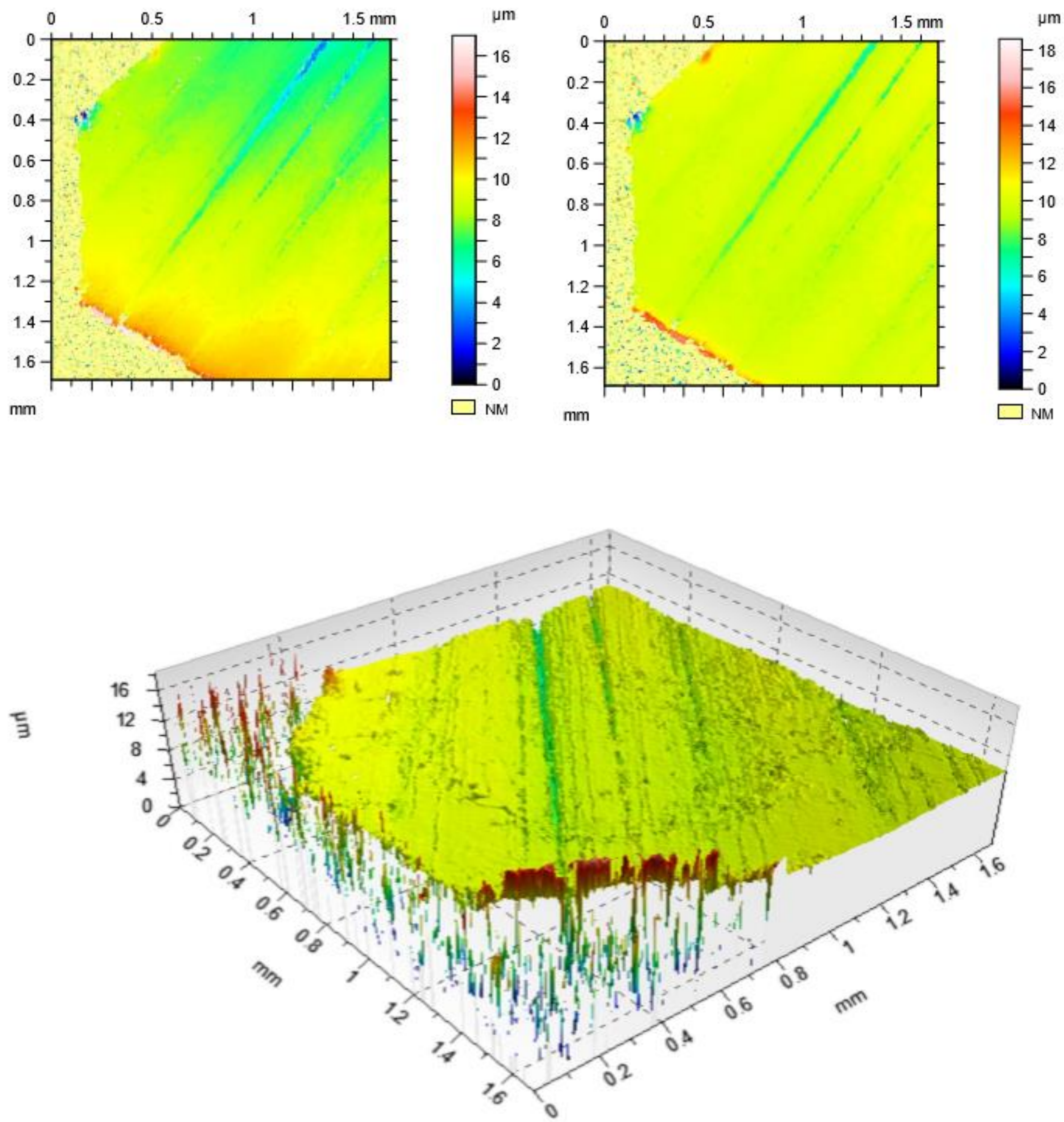

Figure 6.16 CCI HD image of standard HSS tool after 98 cycle

The above images are of the non-cryo treated tool which is used for machining of C18000. The tool tip was studied at different magnification, in order to understand the effect on tool after machining of the workpiece. The tool which was used for machine the workpiece was having 4µm tip radius and after 98 cycles of machining, which takes about 36.30 min. It was observed that the tool is providing bad surface finish because the tip of the tool gets flattened to 8 µm, which was studied with the help of CCI HD non-contact image profiler.

CYRO TREATED HSS TOOL AFTER MACHINING:

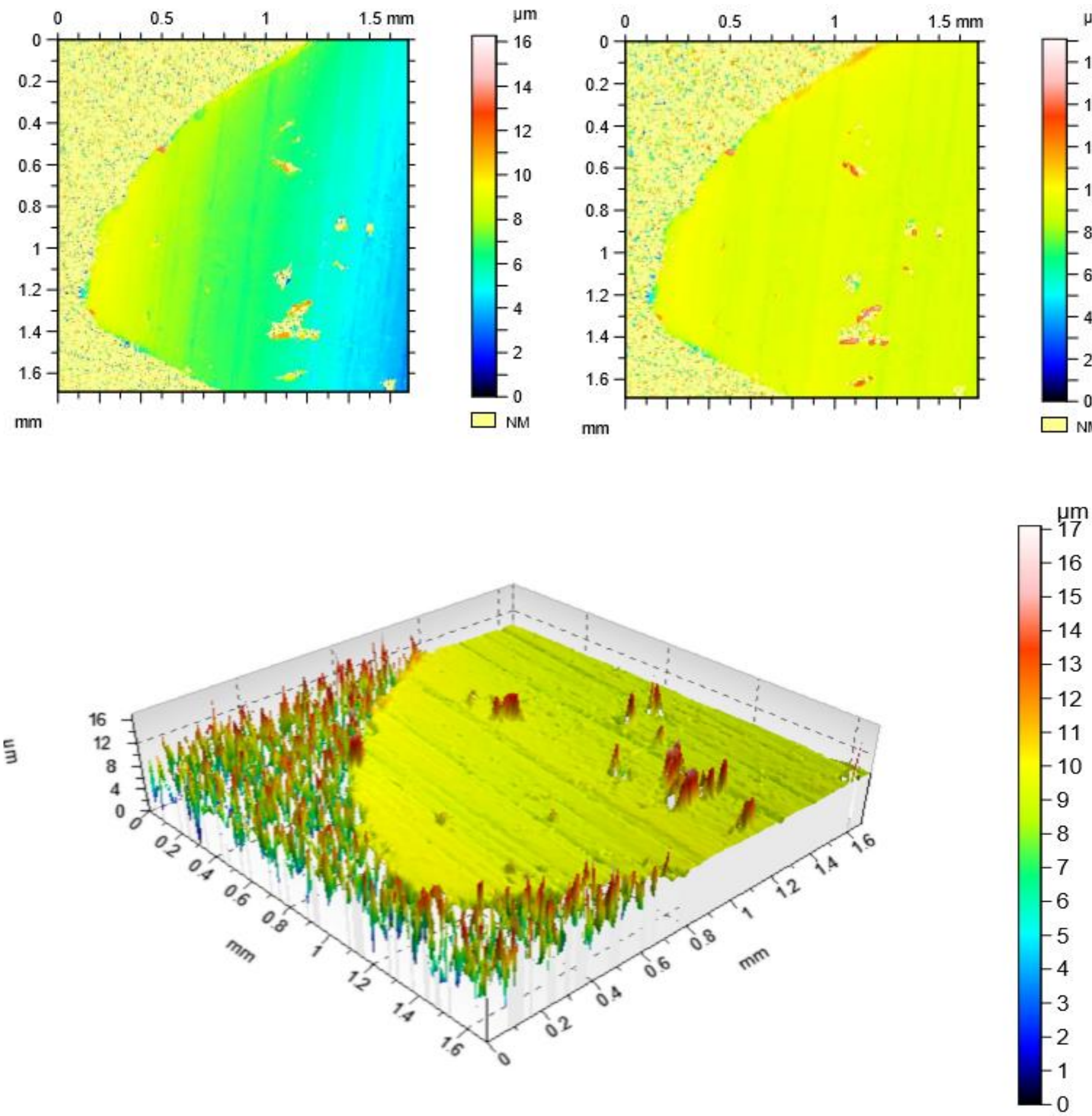

Figure 6.17 CCI HD image of Cryo-treated HSS tool after 134 cycle

The above images are of the Cryo treated tool which is used for machining of C18000. The tool tip was studied at different magnification, in order to understand the effect on tool after machining of the workpiece. The tool which was used for machine the workpiece was having 4µm tip radius and after 134 cycles of machining, which takes about 49.58 min. It was observed that the tool is providing bad surface finish because of the sudden wear in tool tip, which was studied with the help of CCI HD non-contact image profiler.

6.7 COMPARISON

Table 6.13 Table of Comparison between standard HSS tool and Cryo-treated HSS tool

Tool	Time (min)	Number of Cycles	Tool Travel Length (km)	Amount of material remove (mm^3)
Standard HSS	36.30	98	4.884	4337.75
Cryo Treated HSS	49.58	134	6.339	5713.40
Comparison (%)	26.78	26.86	22.95	24.08

It was observed that the factor which are considered to examine the performance of the tool are machining time, number of cycle performed by tool, tool travel length and amount of material removed by the tool. All these factors get significantly increase in case of cryo-treated HSS tool. Further it was observed that the value for machining time, number of cycle, tool travel Length and amount of material remove increased within the range of 22 to 26%.

CHAPTER 7: CONCLUSION

C18000 alloy was used in this study because less of work has been done on it and it is widely used in industries because of its major acceptability criteria that is strength. The following conclusion are drawn from this study.

1. The optimised cutting parameters for finishing machining of C-18000 are 1800 rpm, 0.03mm depth of cut and 0.03mm/rev feed rate.
2. Feed rate was found to be the most significant factor affecting the tool life followed by spindle speed and depth of cut respectively during the machining of C-18000 alloy with HSS tool
3. The tool life of cryo treated cutting tool increased by 24% for M35 single point cutting tools in comparison to non-cryo treated tool.
4. It was observed that the factor which are considered to examine the performance of the tool are machining time, number of cycle performed by tool, tool travel length and amount of material removed by the tool. All these factors get significantly increase in case of cryo-treated HSS tool. Further it was observed that the value for machining time, number of cycle, tool travel Length and amount of material remove increased within the range of 22 to 26%
5. From inverted metallurgical microscope 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. There is no much difference in hardness between cryogenically treated and untreated M35.

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