MACHINING OF INCONEL 718 (DIFFICULT TO CUT MATERIALS) USING CRYOGENIC AND NON-CRYOGENIC CUTTING TOOLS

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ABSTRACT

The purpose of this study was to analysis the flank wear and surface roughness resulted between cryogenic treated and non treated carbide by turning process on material ASSAB 718HH. Dry turning machining process was carried out using cutting speeds of 50, 70 and 90 m/min with feed rate 0.10 and 0.15 mm/rev, with the depth of cut 0.50 and 0.75mm. The performances of turning process was evaluated based on the flank wear occurred to the cutting tool and the surface roughness on the work piece. The flank wear was measured by Scanning Electron Microscope while the surface roughness was determined by Surface Roughness Tester. The experimental work showed the cryogenic treated inserts could last longer as the inference with non-treated inserts. The cryogenic treated inserts showed lower value of flank wear with the same amount of process. The reading of surface roughness is lower at the higher cutting speed. The limitation in carrying out this work due to machine vibration had been taken account. This experimental work will ease and provide other researchers with information to proceed with other parameters while turning ASSAB 718HH.

ABSTRAK

Tujuan utama penyelidikan bertujuan menganalisa "*flank wear*" dan "*surface roughness*" yang dihasilkan di antara "*cryogenic treated*" dan "*non-treated carbide*" dengan melalui proses "*turning*" pada bahan ASSAB 718HH. Proses "*turning*" secara kering telah dilaksanakan dengan kelajuan pemotongan 50, 70 dan 90m/min pada "*feed rate*" 0.10 dan 0.15mm/rev dengan kedalaman pemotongan 0.50 dan 0.75mm. Hasil proses "*turning*" dinilai berpandukan pada "*flank wear*" yang terhasil daripada proses pemesinan dan "*surface roughness*" pada bahan kerja. "*Flank wear*" diukur dengan menggunakan "*Scanning Electron Microscope*" dan '*surface roughness*" adalah melalui penggunaan "*Suface Roughness Tester*". Hasil ujikaji menunjukkan "*cryogenic treated inserts*" lebih lasak dibandingkan dengan "*non-treated inserts*". "*Cryogenic treated inserts*" menunjukkan nilai "*flank wear*" yang lebih rendah pada jumlah proses pemesinan yang sama. Nilai "*surface roughness*" adalah lebih rendah pada kelajuan yang lebih tinggi. Batasan perlaksanaan ujikaji disebabkan oleh getaran mesin larik adalah diambil kira. Hasil ujikaji dapat menyenangkan dan menyediakan penyelidik yang lain dengan maklumat supaya dapat meneruskan ujikaji dengan parameter lain sekiranya melarik bahan ASSAB 718HH pada ujikaji seterusnya.

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LIST OF ABREVIATIONS AND SYMBOLS

C	-	Carbon
Si	-	Silicon
Mn	-	Manganese
Cr	-	Chromium
Ni	-	Nickel
Mo	-	Molybdenum
S	-	Sulfur
AISI	-	American Iron And Steel Institute
HB	-	Brinell hardness
HRC	-	Rockwell C hardness
CNC	-	Computer numerical control
m	-	Meter
mm	-	Milimeter
rev	-	Revolution
SEM	-	Scanning Electron Microscope
R_{MR}	-	Material removal rate (mm^3/s)
v	-	Cutting speed (m/s)
f	-	Feed (mm)
d	-	Depth of cut (mm)
°C	-	Degree Celcius
VB	-	Width of flank wear land
VB_k	-	Flank wear land criterion
V_C	-	Cutting Speed
min	-	Minute
Ø	-	Diameter
rpm	-	Revolutions per minute

CHAPTER 1

INTRODUCTION

This chapter described the main concept of the project including the title of the project, background of the problem, problem statement, research justification, purpose, importance and scope. This chapter provide a brief explanation about the guidance and information of the project.

1.1 Introduction

Machining is a part of activity in manufacturing of metal production through material-removal process into a desired product in term of size and shape. One of the traditional machining is turning operations. Turning operation is where the work piece is turned against a single edge cutting tool in purpose to remove material from the work piece to produce a cylindrical shape of work piece. The speed action is to rotate the work piece while the feed motion is obtained through the slow movement of the cutting tool slowly in a direction parallel to its axis of rotation of the work piece.

ASSAB 718HH is a type of mould steel which has gone through the vacuum smelting chromium, nickel, and molybdenum alloy steel in factory after quenching and tempering treatment. It has benefits of not hardening risk and cost. Yet it allows time saving by not require heat treatment and lower tool cost as no distortion to rectify. Modification is easily carried out and subsequently nitride to increase surface wear resistance and locally flame hardened to reduce surface damage.

ASSAB 718HH had gone through consistent high quality standards with a very low sulphur content, with the outcome characteristics of good polishing and photo-etching properties, good machine-ability, uniform hardness, high purity and good homogeneity. It has been 100% ultrasonic tested in factory.

Table 1.1 Chemical Composite and Character of ASSAB718HH

Typical analysis %	C 0.37	Si 0.3	Mn 1.4	Cr 2.0	Ni 1.0	Mo 0.2	S <0.010
Standard Specification	AISI P20 Modified,WNr.1.2738						
Delivery condition	Hardened and tempered to 340 – 380 HB						
Colour code	White / Brown						

Source: www.assab-china.com/718HH_081112_Ed.pdf

ASSAB 718HH has been widely used in injection moulds for thermoplastics, extrusion dies for thermoplastics, blow moulds, aluminium die casting prototype dies, structural components, shafts ,and forming tools like press-brake dies.

ASSAB 718HH is used as plastic mould steel block. Its usage is applicable for large and medium sized and precision mould, and low-melting point alloy. It is with good machining performance excellent polishing performance, harden-ability, high-hardness and wear resistance. At the same time the cross-section of a large size will enable a more uniform hardness.

Pre-hardened mould steels of (29-40 HRC) are utilized in almost all application of preparing the plastic mould steel. That is because the pre-hardened mould steels provide the easiest mould making process. Hence, today around 80% of the plastic mould steels are delivered in pre-hardened condition of around 40 HRC.

The unique specification of mechanical strength, wear resistance and polish-ability are sufficiently high for many mould applications.

1.2 Background of the Problem

The development of the cutting tools has been critically essential in metal cutting due to the advancement of material advancement and demand. Hence the manufacturing industry is steadfastly in steps to minimise the cutting costs and the same time making sure is quality of the machined parts are ensured with the persuasive demand of high tolerance manufactured goods is speeding advancing. The increasing need to energize productivity, to machine more difficult material and improving quality in high volume by manufacturing industry has been the urge of demand behind the advancing development of cutting tool materials (Yoshio et al., 2007).

1.3 Problem Statement

In manufacturing line, an exact degree of roughness is considerable essential, influence the capability and function of the part, and particulars that may have direct relate is the cost. Metal cutting process involves abrasion of cutting tools due to the presence of friction and generation of heat at the tool chip interface. Continuous application of the cutting tool for machining, eventually end up with its failure.

1.4 Research Justification

The advancement in metal machining operations make the needs to determine and quantify micro-structural changes of metal alloys implied in metal cutting processes. The use of thermal treatment has been used to improve mechanical properties of metal components is and historical art that has been implied till today.

Cryogenic treatment also known as sub-zero treatment is a very old process and is widely used for high precision parts. Cryogenic treatment is the process of submitting a material to subzero temperature (below 0°C) in order to enhance the service life through morphological changes that occurs during treatment (Simranpreet Singh Gill et al., 2012). The outcome has been rather encouraging, refering to the application of some reports acclaimed 92-817% increases in tool lives after the tool metal have been treated at -196°C (Gill, Singh, Singh, & Singh, 2008, 2010a, 2010b, 2010c; Paulin, 1993). Flank wear is known best in simulatenous contributing to surface finish, residual stresses and microstructural changes in the form of whicte surface layer (Dawon & Kurfess, 2010). Hence the tool flank wear land width is the markinf of the tool life.

1.5 Purpose of Study

The purpose of this study is the outcome of ASSAB 718HH through dry condition of turning process by using cryogenic treated and non-cryogenic treated carbide cutting tools with the CNC Machine. The objective of this study is to determine the effect and correlation of cutting parameters to the surface roughness

1.6 Objective of the Study

The life of cutting tools has plays the main role in increasing productivity and indirectly to the importance of the economic factor. The tool can be cheap, but it just might backfire with means of machining process interruption, which will claim dearly cost time in a short time. The practice of the cryogenic treatment on quenched and tempered high speed steel tools increases hardness and improves hardness homogeneity, reduces tool consumption and down time for the equipment set up, thus leading to cost reductions of about 50% (A, Molinari et. al., 2001). The research is important to study the effect and correlation of cryogenic cutting tool to the surface roughness and tool wear.

1.7 Scope of Study

The research will be focused on:

1. Understand the concept of cryogenic treated cutting tool.
2. Measure various tool wears, and surface roughness.
3. Study the effect of cryogenic cutting tool wear, over non-cryogenic treated tool.
4. Study the effect of cutting parameter like cutting speed, feed rate and depth of cut.
5. Cutting speed: 50, 70, 90 m/min was used
6. Feed rate: 0.10 and 0.15 mm
7. Depth of cut: 0.50 and 0.75 mm
8. Material: ASSAB 718HH
9. Machining machine: Nexus 100-II Quick Turn Mazak

10. Measuring Instrument: Surface Roughness Tester (Mitutoyo SJ-400) and Scanning Electron Microscope (SEM) (Joel JSM 6380 LA)
11. Preparation Machine: Conventional Lathe Machine
12. Cutting tools: Carbide Inserts (cryogenic treated and non-treated).
13. The cryogenic process of inserts is done by outside source.

1.8 Conclusion

This chapter had discussed the introduction, problem statement, background of problem, problem statement, research justification, purpose of study, objective of study, and scope of study. In the next chapter, the study will proceed to the literature review of some useful sources such as journal, reference books and which are related to the topic.

CHAPTER 2

LITERATURE REVIEW

The basic criteria and information for developing the project is being identified in the literature review. In literature review, the related ideas, concepts and findings of research from vary of sources of articles, books, thesis, and internet has been brought forth. The literature review summarized the essential essence of information of the sources and arranged systematically. It basically elaborates the terms and theories for the better apprehension toward this experimental study.

2.1 Review on Machining Process

Variety of machines, tools and labour has been used to have the product manufactured to meet the demands of application or to end user. It is advancing in parallel with the human activities from simple products to complicated and high technology products. Machining has been one of the processes applied for industrial production to transform the raw material into product for the end user. Hence proper schematic planning and execution is needed to produce a quality product for the need of consumers.

Machining is a process in which cutting tool is used to remove small chips of material from the work piece. But List et al., (2005) stated the cutting tool removes a part of work piece by a process of intense plastic deformation at high strain rate within the primary and secondary shear zone. Thamizhmanii & Hassan (2010) mentioned the cutting forces are required to deform the material plastically and remove unwanted materials. All this happen due to the relative motion occurred between the tool and the work piece.

There has been variety of machining operations, that each having there capability of generating a certain part of geometry and surface texture. As Child et al., (2001) highlighted that machining operation such as turning, milling, boring, drilling and shaping cost a lot annually throughout the world. While Davim (2008) highlighted turning machining operation having capability to machine the components having critical features which required specific surface finishing. In turning process, a cutting tool with a single cutting edge is applied to remove material from a rotating work piece to generate a cylindrical shape. Where the speed motion provided to rotate the work piece and the feed motion is achieved by moving the cutting tool slowly in a direction parallel to its axis of rotation of the work piece.

The cutting operations are carried out by attached to the lathe machine. The parameters that can be adjusted from the machine as the rotational speed of the work piece (v) depths of cut, (d) and feed rate (f) resulting the material removal rate for the process. Generally the material removal rate will give different roughness and tool life time.

$$R_{MR} = vfd \tag{2.1}$$

where

R_{MR} - the material removal rate in mm^3/s

v - the cutting speed in m/s

f - the feed in mm

d - the depth of cut in mm

Sharma et al., (2009) mention that the cost of machining depends on material removal rate. The material removal rate cease the life span of tool due to the heat generation that results from the friction occurred. Hence heat is generated due to the mechanical factors will enhance the decrease of tool life and increase the surface roughness. Thamizhmanii & Hasan (2010) mention the generation of heat will produce low cutting forces due to thermal softening of the chips. It is known that 60% of the heat generated by the turning is carried away by chips and the remaining is retained by work material and tool cutting edges.

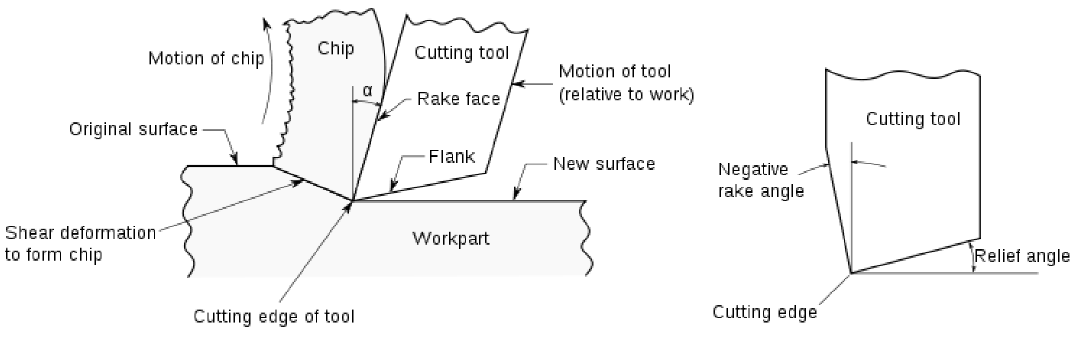

Figure 2.1: Basic Machining Process

(http://upload.wikimedia.org/wikipedia/commons/6/61/Metal_Cut_diag.svg)

2.2 Review on Cutting Tool

Cutting tool is a device to be used to remove the unwanted part of the work piece. The tool itself is generally has at least one sharp cutting edges and having properties that are harder than the work piece material. The cutting edge serves to separate chip from the parent work material. Connected to the cutting edge are the rake face and the flank of the tool.

The rake face is part which directs the flow of newly formed chip is oriented at a certain angle and called rake angle (α). It is measured relative to the plane perpendicular to the work piece surface. The rake angle can be positive or negative. The flank of the tool provides a clearance between the tool and newly formed work surface, thus protecting the surface from abrasion, which would degrade the finish. This angle between the work surface and flank surface is called the relief surface.

To make a right decision of cutting tool materials for particular application is among the essential factors in machining operations as stated by Kalpakjian and Schmid (2001). While Sharma (1982) highlighted that the proper selection of tool type depends upon many factors, such as, work piece material, the machine tool, the type of set up, the power available at the machine, the amount of material to be removed and the kind of operations. The cutting tool is the most critical part of the machining system. It is clearly shown that the cutting tool material, cutting parameters and tool geometry selected have direct influence to the productivity of machining operations.

The characteristic of cutting tool are hardness, toughness and wear resistance. These characters very important to cutting tool because it always expose to heat and pressure during cutting process. Kalpakjian (2001) mentioned that the cutting tool is subjected to high temperature, contact stresses and sliding along the tool-chip interface and along the machined surface. The result from this situation will increase the tool wear. As Degarmo (2003) mentioned that during machining the tool is performing in hostile environment wherein high contact stresses and high temperatures are commonplace, and therefore tool wear is always an unavoidable consequence.

2.3 Review on Tool Wear and Tool Life

In Manufacturing Technology by Valery Marinov mentioned the life of a cutting tool can be terminated by a number of means, although they fall broadly into the categories of gradual wearing of certain region of the flank of the cutting tool and the abrupt tool failure. The gradual wear occurs at three principal locations on a cutting tool. They are the crater wear, flank wear and corner wear.

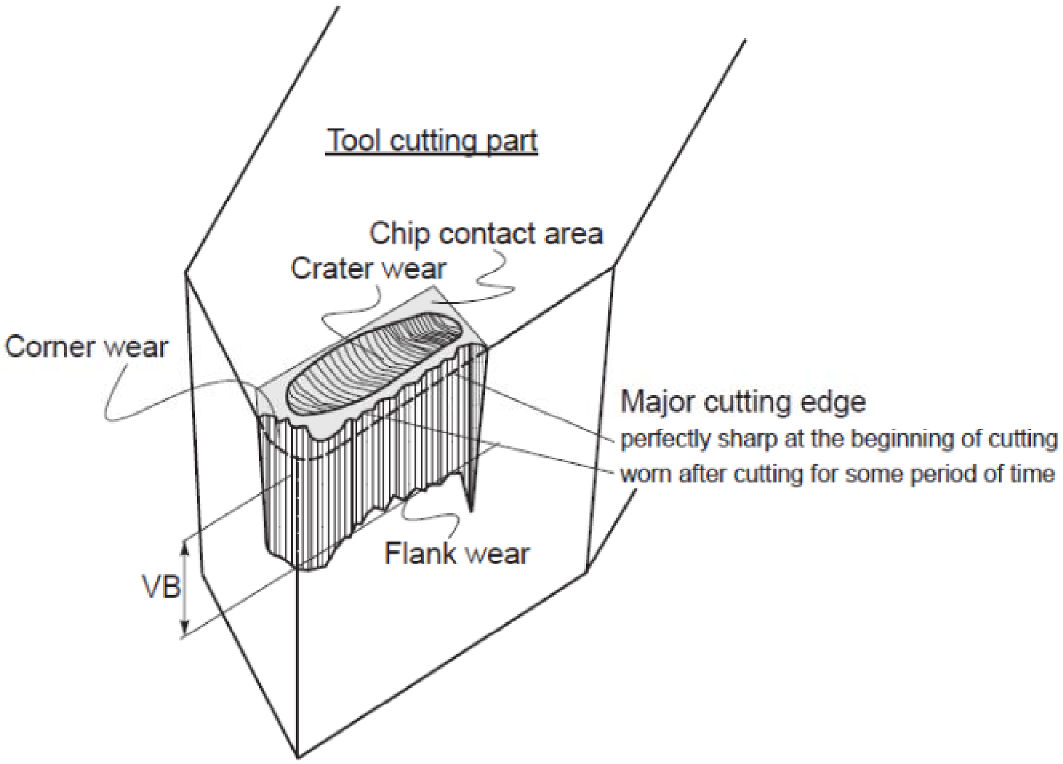

Figure 2.2 Types of wear observed in cutting tools

(http://me.emu.edu.tr/me364/ME364_cutting_wear.pdf)

Crater wear consists of a concave section on the tool face formed by the action of the chip sliding on the surface. Crater wear affects the mechanics of the process increasing the actual rake angle of the cutting tool and consequently, making cutting easier. At the same time, the crater wear weakens the tool wedge and increases the possibility for tool breakage. In general, crater wear is of a relatively small concern.

Flank wear occurs on the tool flank as a result of friction between the machined surface of the work piece and the tool flank. Flank wear appears in the form of so-called wear land and is measured by the width of this land, VB. Flank wear affects to the great extend the mechanics of cutting. Cutting force increase significantly with flank wear exhibited at the cutting tool.

Tool wear is a time dependent process. As cutting proceeds, the amount of tool wear increases gradually. But tool wear must not be allowed to go beyond a certain limit in order to avoid tool failure. The most important wear type from the process point of view is the flank wear, hence the parameter which has to be controlled is the width of flank wear land, VB. This parameter must not exceed an initially set safe limit. The safe limit is referred to as allowable wear land or also known as wear criterion, VB_k. The cutting time required for the cutting to develop a flank wear land of width VB_k is called tool life, T , a fundamental parameter in machining.

The general relation of VB versus cutting time is shown in the Figure 2.3 about wear curve. In Figure 2.3, flank wear (VB) is applied as a function of cutting time while tool life (T) is defined as the cutting time required for flank wear to reach the value of VB_k. Although the wear curve is for flank wear, while a similar relationship occur to other wear type.

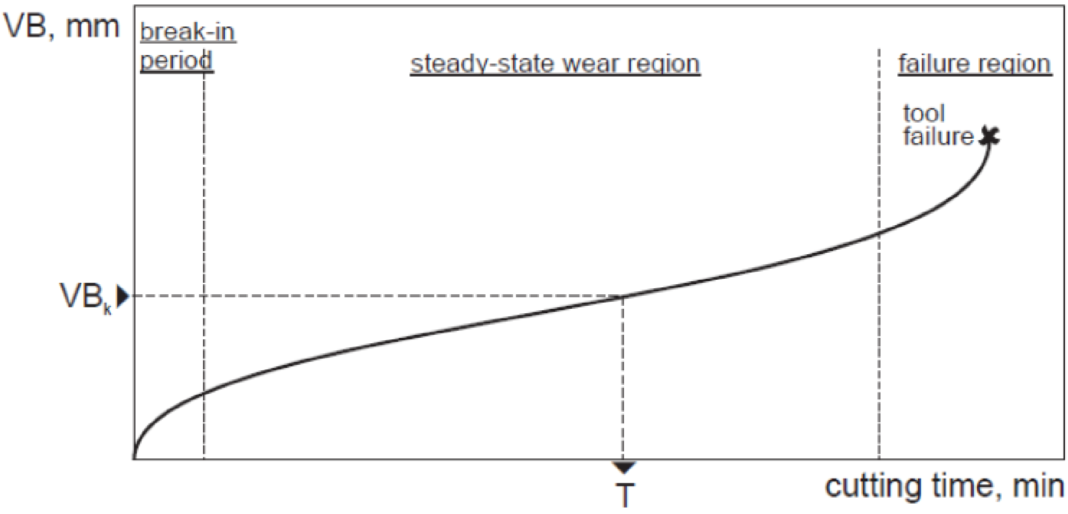

Figure 2.3: Wear curve

(http://me.emu.edu.tr/me364/ME364_cutting_wear.pdf)

The parameters which affect the rate of tool wear are:

i. Cutting conditions (cutting speed (V), feed (f), depth of cut (d))
ii. Cutting tool geometry (tool orthogonal rake angle)
iii. Properties of work material

With the parameters, cutting speed is the most important one. As cutting speed increased, wear rate increases, so the same wear criterion is reached in less time, for example life decreases with cutting speed:

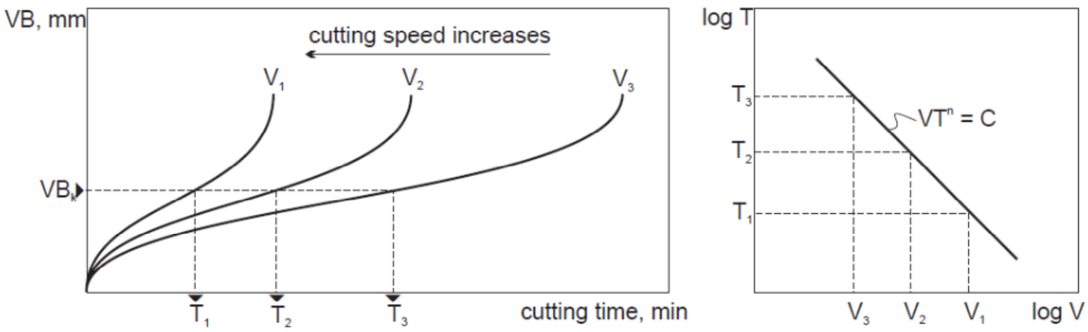

Figure 2.4: (Left) Effect of cutting speed on wear land width and tool life for three cutting speeds. (Right) Natural log-log plot of cutting speed versus tool life.

(http://me.emu.edu.tr/me364/ME364_cutting_wear.pdf)

If the tool life values for the three wear curves are plotted on a natural log-log graph of cutting speed versus life as shown in the right Figure 2.4, the resulting relationship is a straight line expressed in equation form called the Taylor tool life equation:

$$V_C T^n = C \qquad (2.2)$$

where V_C is cutting speed, while n and C are constants, whose values depend on cutting conditions, work and tool material properties, and tool geometry. These constants are well tabulated and easily available.

Flank wear is has been identified as a form of tool wear that occur in metal cutting. It is found to have detrimental effects on surface finish, residual stresses and micro-structural changes in the form of white surface layer (Dawson & Kurfess, 2010). Hence tool flank wear land width (VB) is often used to characterize the tool life.

2.4 Review on Cryogenic Treatment

The application of thermal treatments to improve mechanical properties of metal components is an ancient art and used till present days. Many of the developed processes apply treatments in a range of temperature higher than room temperature. But, till recently the researchers shifted their focus towards the concept of sub-zero treatments and this was introduced to check the effect on industrial field.

Cryogenic Treatment is a supplementary process to conventional heat treatment which involves deep freezing of materials at cryogenic temperature which is -190°C to enhance the mechanical and physical properties. The execution of cryogenic treatment on cutting tool materials increases wear resistance, hardness, toughness, corrosion resistance, reduce friction, dimensional stability, but at the same time, reduces tool consumption and down time for the machine tool set up, thus leading to cost reductions. The dry cryogenic process is put at high precision controlled and the materials to be treated are not directly exposed to any cryogenic liquids. Overall, all the treated materials retain their size and shape. Cryogenically treated materials with

Cryogenic treatment can be categorized into shallow cryogenic treatment and deep cryogenic treatment. The Shallow Cryogenic Treatment or also known as Subzero Treatment where the samples are placed in a freezer at -80°C and then they are exposed to room temperature. While the Deep Cryogenic Treatment is where the samples are slowly cooled to -196°C, held-down for many hours and gradually warmed to room temperature.

The process for this study is carried out using Deep Cryogenic Treatment. Simranpreet (2009) illustrate the dry cryogenic treatment is where the inserts being treated were not exposed to the liquid nitrogen to eliminate the risk and damage of thermal shock. The procedure sued for the treatment is illustrated as Figure 2.5. Inserts were placed in a container and the temperature was brought to -196°C in intervals by computerized control at the rate of 0.5°C/min. At each interval, the inserts were allowed to stabilize in 2 hours increments. The temperature was held constant for 24 hours before the process reversed. The inserts were slowly brought to room temperature allowing the material to stabilize. Then the inserts were subjected to two tempering cycle to relieve the stresses induced by cryogenic treatment. This was accomplished by increasing the temperature to +196°C and then a slowly reducing the temperature at the rate of 0.5°C/min.

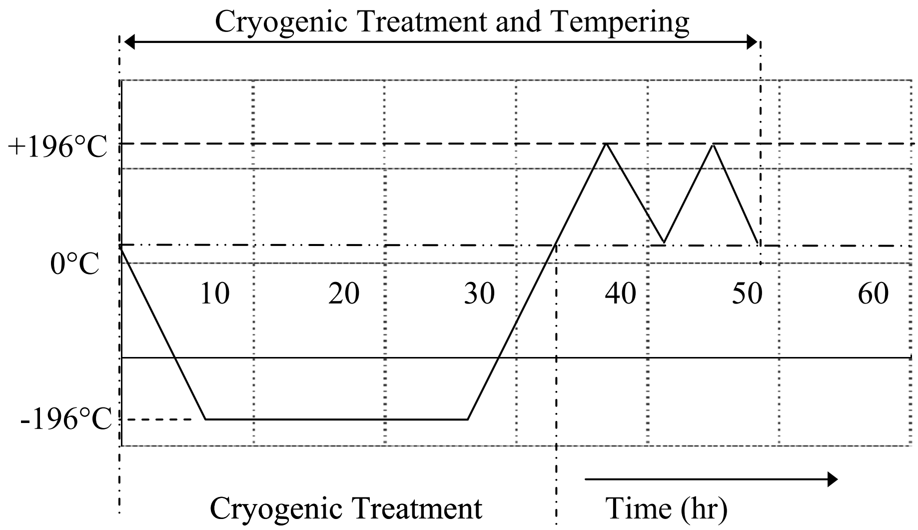

Figure 2.5: Details of cryogenic treatment process (Simranpreet, 2009)

2.5 Cryogenic System

The cryogenic treatment has been carried out using heat exchanger method. It is the condition where liquid nitrogen flow through a heat exchanger and the output cooled gas is diffused inside the chamber by a fan. There is no contact between nitrogen and samples.

KS Bal (2012) elaborate further that liquid nitrogen is allowed to flow from storage tank through inlet pipe and allowed to enter into cryogenic chamber which also called as Cyro-box. Temperature is controlled through computer programming software Delta T™ and desired cooling rate can be set. The cooling effect is provided by liquid nitrogen to the sample, but no direct contact is allowed between them. A fan is used to uniform distribution of temperature inside the chamber. After reaching the temperature set by the programmer, thermocouple send a signal to system controller through feedback mechanism, and hence, temperature controller regulates the flow of liquid nitrogen in the chamber and stop further cooling. The liquid nitrogen used to get converted and leaves the system as nitrogen gas.

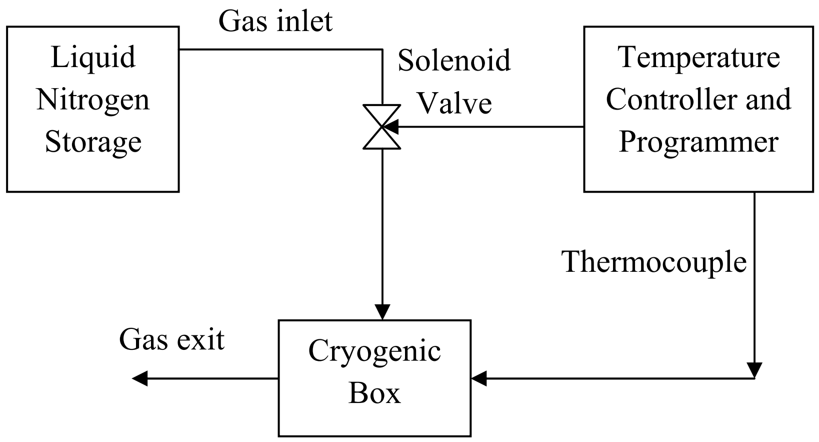

Figure 2.6: Schematic representation of Cyro-treatment set up (KS Bal, 2012)

2.6 Liquid Nitrogen

Liquid nitrogen is the condition of nitrogen in a liquid state which possessed the intensely low temperature. It has gone through the fractional distillation of liquid air. Liquid nitrogen is colourless clear liquid with density of 0.807 g/mL at its boiling point and a dielectric constant of 1.43. The pioneers who had successfully liquefied nitrogen gas at Jagiellonian University by Polish physicists, Zygmunt Wróblewski and Karol Olszewkion on 15 April 1883. The liquid nitrogen boils at -196°C at the atmospheric pressure with properties non-toxic, odourless, colourless and inflammable. Though it widely used as cryogenic fluid, but it can cause frostbite or cold burns upon contact of living tissue and produce asphyxia without any sensation or prior warning due to the insufficient of oxygen in air. It is due to Leiden frost effect occurred, as liquid nitrogen boils immediately once contact with a warmer object. It is known the expansion ratio of liquid nitrogen is 1:694 at 20°C with a enormous force or called explosion. So the liquid nitrogen can only be safely stored and transported in vacuum flasks (Dewar) which are appropriately insulated from external environment and perfectly sealed. Though the existence of the hazardous characteristic of liquid nitrogen. The application of liquid nitrogen has spread its wings in the field such as cryogenic engineering; as coolant for better machining, cryopreservation of biological sample, as coolant for CCD cameras, vacuum pump traps, and as an energy storage medium.

2.7 Review on Surface Roughness

Surface roughness is generally mentions about the measure about the texture about the surface of a material or objects. It is quantified by the vertical deviations of a real surface from its ideal form. If The surface is mention to be rough if the deviations are large and vice versa if the surface is smooth. Roughness of the surface is basically considered to be high frequency, short wavelength component of a measured surface.

Roughness of the surface has a significant influence to determine how the real object is going to interact with its environment. A general statement that a rough surface usually going to wear more quickly and ready with a higher friction coefficients that smooth surfaces. The state of roughness is often showing a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for the presence of cracks or corrosion to take place. Yet it will promote adhesion.

The aim for a quality surface from roughness has been an obstacle and expensive to control in machining process. The purpose to decrease the roughness of a surface is often giving an exponentially increase of cost in manufacturing practices.

Field (1989) mentioned the surface roughness and surface damage via machined surface have a significant influence on the surface sensitive properties such as fatigue, stress corrosion resistance and creep strength, which in turn affect the service-life of components. Hence high degree of surface integrity is playing a high role as the requirement for a better performance, reliability and longevity of machined parts during applications. Hence a review of surface roughness was discussed by Noaker (1993), showing the requirement to explore the function of the cutting parameters. So it is important to identify the machining parameters, which reduce the cutting forces and generate favourable surface characteristics.

While Thamizhmanii et al., (2007) elaborated that surface roughness decreased with the cutting speed was increased. In the experiment carried out, their observation was that roughness ceased rapidly at the increased of cutting velocity, feed rates, depth of cut, and increased of time. With the summary that surface roughness usually depends on cutting parameter and the interval time of applications.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, the information about the method that would be used in this experiment will be discussed with detail. The material, tools, equipment that used in this research will be discussed in this chapter. The parameter used for this research will be discussed as well to make sure the process function accordingly. With the flow chart, it will show how the process of the research runs from start till the final step executed.

3.2 Flow Chart

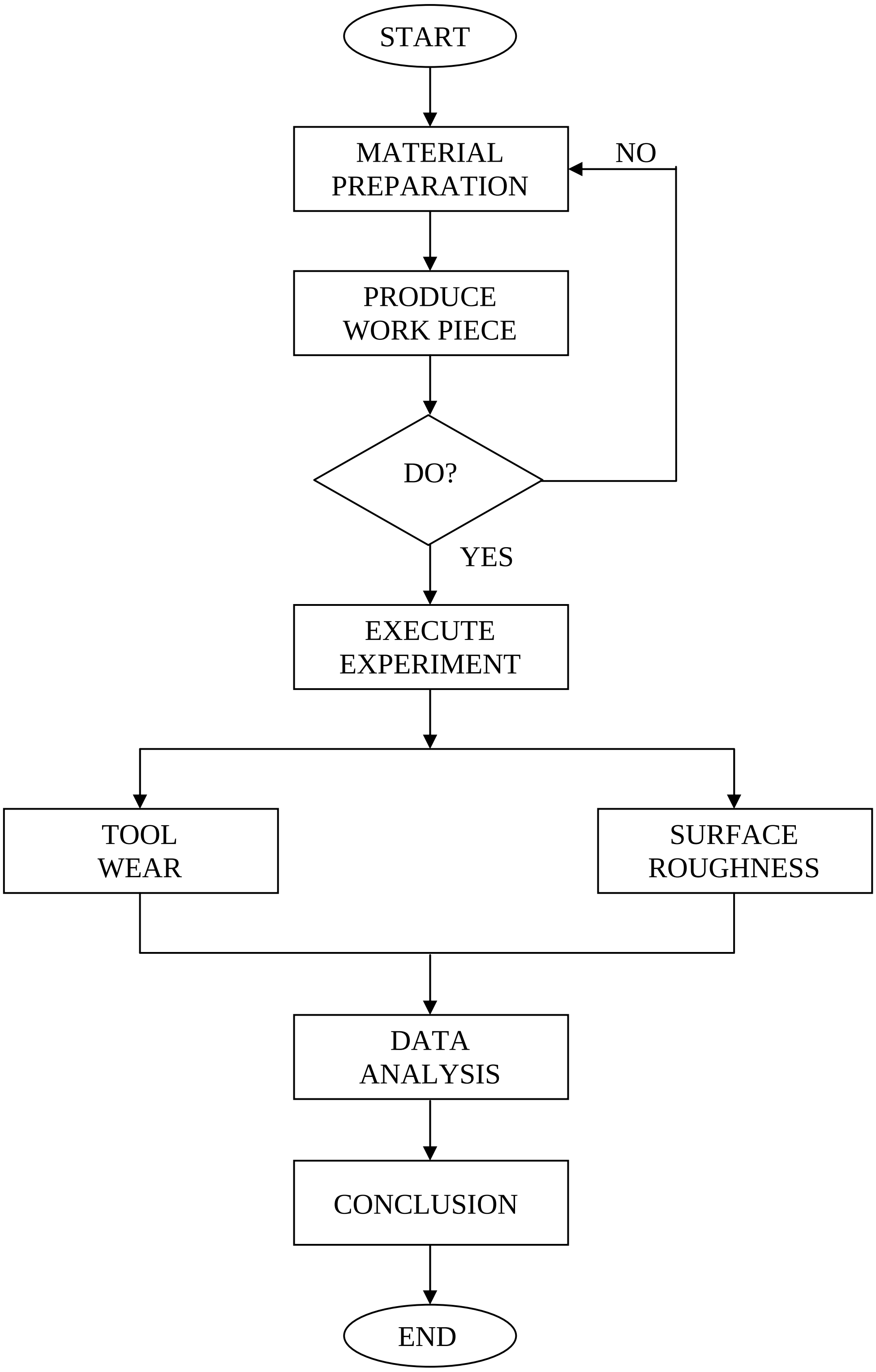

Figure 3.1: Methodology Flow Chart

3.3 Work piece Process

The work piece material that was used for this research was ASSAB 718HH as replacement to Inconel 718 for they had the same HRC value. The material received as 1000mm length and 35mm diameter. They were cut to 200mm length and skin turned to remove oxide formation. The work pieces were centred on both sides to accommodate in the lathe centres as shown in Figure 3.2.

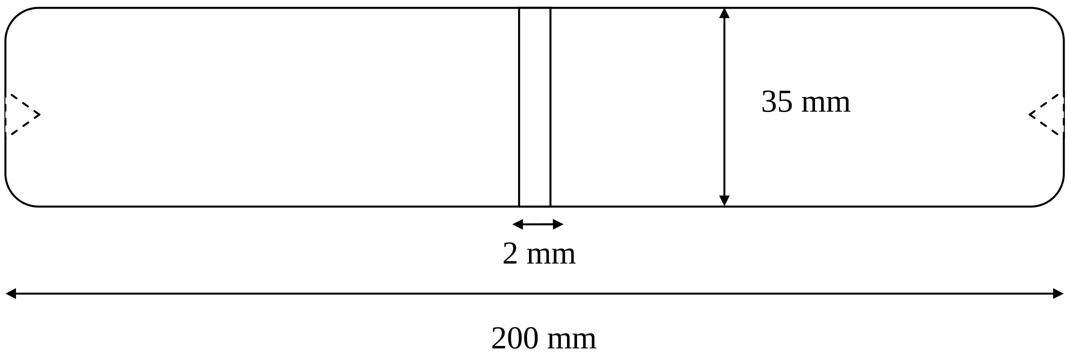

Figure 3.2: Layout of Work piece

The preparation of the work piece as shown in Figure 3.1 carried out using the conventional lathe machine, Model Harrison M300 as in Figure 3.3.

Figure 3.3: Conventional Lathe Machine

3.4 Experimental Procedure

After the work piece ready, the experiment was executed. CNC lathe machine Yamazaki Mazak Quick Turn Nexus 100-II MSY was used for this hard turning experiment.

Figure 3.4: Yamazaki Mazak Nexus 100 – II MSY

Table 3.1: Description of Yamazaki Mazak Nexus 100 – II MSY

Model	Quick Turn NEXUS 100 - II
Maximum machining diameter	Ø 280mm
Bar work capability	Ø51mm
Maximum machining length	309 mm
Travel (X/Z)	190 / 330 mm
Main Spindle (30min. rating)	6000 rpm
Tool storage capacity	12
Floor space requirement (For Europe)	1790 * 1630 mm

For this hard turning process, the material for the cutting tool was cemented carbide. The tool holder, PCLNR 2020 K12 was used to hold the cutting insert, CNMG120408R K10M. The machining process referred to Table 3.2. The same parameter was used for the non-treated insert and cryogenic treated inserts.

Figure 3.5: Tool Holder (PCLNR 2020 K12)

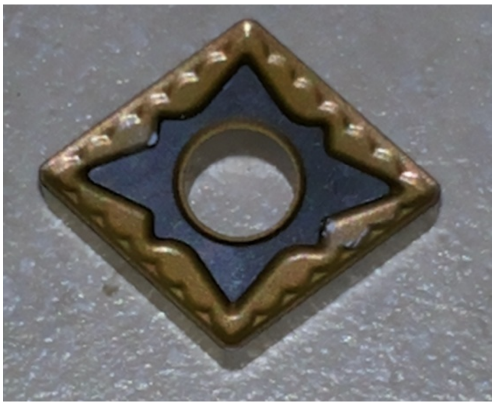

Figure 3.6: Cutting Insert (CNMG120408R K10M)

Table 3.2: Cutting parameters

Cutting Speed, V (m/min)	Feed rate, f (mm/rev)	Depth of cut, d (mm)
50	50, 70, 90	0.15, 0.75
70	50, 70, 90	0.15, 0.75
90	50, 70, 90	0.15, 0.75

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