ANALYSIS ON CUTTING TOOL PERFORMANCE IN MILLING INCONEL 718 UNDER MINIMUM QUANTITY LUBRICATION (MQL) AND PULSATION LUBRICATION SYSTEM (PLS)

Submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

By

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Signature	:………………………………………..
Author's Name	: MOHAMAD NOREZWAN BIN ZUNAIDE
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APPROVAL

This is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.). The members of supervisory committee are as follow:

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ABSTRAK

Sistem Pelinciran Kuantiti Minima (MQL) dan Sistem Pelinciran Denyutan (PLS) adalah kaedah alternatif untuk membekalkan cecair pemotongan dalam pembentukan kabus dan denyutan. MQL dan PLS telah terbukti meningkatkan prestasi pemesinan dan mengurangkan kos pemesinan. Walau bagaimanapun, keberkesanan dan prinsip kerja MQL dan PLS masih dipersoalkan dengan terhad penjelasan yang diberikan. Kajian ini dijalankan untuk mengkaji kesan Lebar Potong (WoC) pada prestasi alat pemotong dalam penggilingan Inconel 718 di bawah MQL dan PLS. WoC yang digunakan untuk percubaan ini ialah 10%, 20% dan 30%. Parameter permotongan seperti kelajuan gelendong, kedalaman pemotongan dan kadar suapan masing-masing dimalarkan pada 2984 rpm, 0.2mm dan 447mm/min. Data prestasi alat pemotong dibandingkan dengan mengukur kekasaran permukaan dan kadar haus mata alat. Hasil kajian menunjukkan pemesinan di bawah WoC = 10%, PLS mencatatkan kadar haus mata alat terendah dengan 0.1251mm. Untuk WoC = 20%, kadar haus mata alat terendah adalah 0.4032mm untuk MQL dan terakhir, untuk WoC = 30% kadar haus mata alat yang direkodkan ialah 0.6895mm untuk PLS. Untuk kekasaran permukaan purata, sistem MQL mencatatkan nilai terendah untuk WoC = 10%, 20% dan 30%. Secara kesimpulannya, pemesinan di bawah MQL telah menghasilkan kekasaran muka yang lebih baik disebabkan kebolehan kabus untuk menembusi lebih dalam ke zon pemotongan, membolehkan penyejukan yang lebih baik. Selain daripada itu, pemesinan di bawah PLS dapat menggurangkan kadar haus mata alat dengan denyutan cecair sejuk yang bertindak menghapuskan pembentukan BUE semasa pemesinan.

ABSTRACT

Minimum Quantity Lubrication (MQL) and Pulsation Lubrication System (PLS) are an alternative method to supply the cutting fluid in the formation of mist and pulse respectively. MQL and PLS have proven to increase the machining performance and reduce the machining cost. However, the effectiveness and the working principle of MQL and PLS are still questionable due to limited number of studies currently available. The present study is conducted to investigate the effect of width of cut (WoC) on the cutting tool performance in milling Inconel 718 under MQL and PLS. The WoC used for this experiment is 10%, 20% and 30% while the spindle speed, depth of cut and feed are constant at 2984 rpm, 0.2mm and 447mm/min respectively. The data of cutting tool performance is compared in term of surface roughness and tool wear. The result shows that machining under PLS with 10% of WOC resulted in the lowest tool wear rate with 0.1251mm. For WoC = 20%, the lowest tool wear rate is 0.4032mm for MQL and lastly, for WoC = 30% the lowest tool wear rate recorded is 0.6895mm for PLS. For the average surface roughness, the MQL system recorded the lowest for the WoC = 10%, 20% and 30%. It concluded that applying MQL in machining produced a better surface roughness due to the capability of mist to penetrate deeper at the cutting zone, allowing better cooling during machining. Meanwhile, machining under PLS decreased the tool wear as the pulse flow acts to remove the formation of Build-In-Edge (BUE) during machining.

DEDICATION

To my beloved parents and siblings

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First and foremost, I would like to express my greatest gratitude to Almighty God for giving me strength and courage to finally complete my bachelor degree project with the best I could. Indeed, without His Help and Well, nothing will be accomplished.

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MQL	-	Minimum Quantity Lubrication
PLS	-	Pulsation Lubrication System
CNC	-	Computer Numerical Control
WC	-	Tungsten Carbide
MMAD	-	Mass Median Aerodynamic Diameter
SLM	-	Selective Laser Melting
PCD	-	Polycrystalline Diamond
UHPC	-	Ultra High Pressure Coolant
CBN	-	Cubic Boron Nitride
DOE	-	Design of Experiment
BUE	-	Build in Edge

LIST OF SYMBOL

n	-	Spindle speed (rpm)
V_f	-	Feed (mm/min)
V_c	-	Cutting speed
D	-	Diameter of cut

CHAPTER 1

INTRODUCTION

1.1 Background

Machining is a process to produce the parts by removing the material into the required shape. This process applied in major industrial practices such as automotive, aerospace, medical, oil and gas and nuclear. There are three major factors contributed to the efficiency of machining which is cutting tools, workpiece material and cutting parameters. In the manufacturing field today, machining of material is getting leading as there are various advancements of new alloys and engineered material which ultimately causes these materials to have high strength, toughness, and other material properties. In manufacturing operations, it is imperative to view the machining operation as a system, comprises the workpiece, machine tools, cutting tool and also production personnel. Machining cannot be carried out efficiently or economically and also meet stringent part specifications without detailed knowledge of the interactions between these four components (Kalpakjian & Schmid, 2013).

Inconel 718 is one of the strongest steel in the metal family and it is widely used around the world in the industry sectors including aerospace, automotive, aircraft, and chemical. Inconel 718 is a superalloy with high strength which makes it resistant to corrosion, extreme temperature, and high pressure. Due to such mechanical properties, the Inconel 718 is suitable making turbojet components such as fan blades, disc and compressor casing. Furthermore, the high resistance in Inconel 718 also is applicable in the production of rocket engine and die making. The high strength of Inconel 718 comes from the annealing process during the making of Inconel 718 where metal is exposed to high temperature and followed rapid cooling.

In the manufacturing industry, milling is the most common process used and it is an engineering machining process that is used to produce parts by cutting away unwanted material. Milling can be done manually, which frequently requires continuous supervision by the operator. Nowadays, the industrial sector is increasing with the new technologies which use an automated system called computer numerical control, better known as CNC. By using CNC machining, the process is more precise than manual machining and can be repeated in the same manner over and over again. In this process, it is vital to select input (cutting) parameters with great precision for achieving high cutting performance (A. Qasim et al, 2015).

There are few criteria we can consider when determining the cutting tool performance during machinings such as surface integrity, tool wear, and temperature. There are two important points under surface integrity which are surface topography and surface metallurgy. To produce a better surface finish, the surface roughness must be lower. For the tool wear, there are two types of tool wear which are flank and nose wear. Tool wear very importantly to determine the tool life. The higher tool life, the shorter the tool life. Temperature produce between workpiece and cutting tool is very important to determine the cutting tool performance. The high-speed machining, the greater the temperature produced. So, it can affect the cutting tool in terms of tool wear and workpiece in terms of surface roughness.

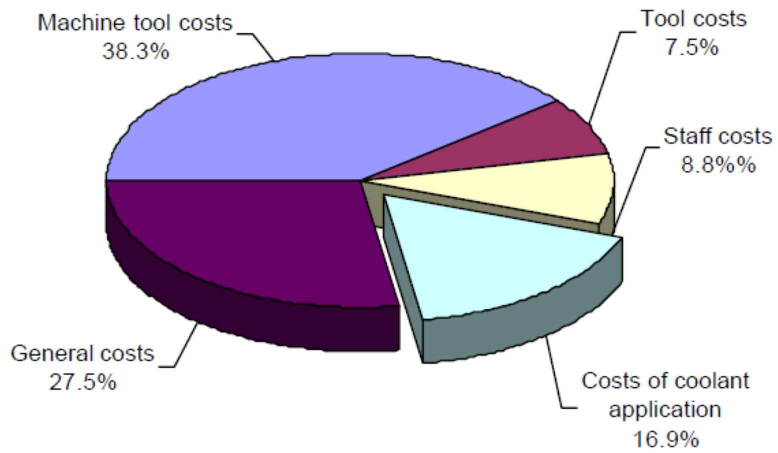
Machining under different coolant techniques such as MQL and PLS gives different impacts on machining performance. The type materials also play an important role when machining under MQL and PLS. All types of steel can be used as a workpiece when machining under MQL and PLS because both coolant techniques have the same function as the conventional coolant which is to remove heat generated during machining. But the outcome under MQL and PLS much better than the conventional technique.

1.2 Problem Statement

As we know, to remove the heat generated at the cutting tool, the conventional coolant is used during machining. A lot of heat generated during machining especially for very hard materials because of a lot of energy needed to machine the workpiece. The friction between the cutting tool and workpiece generated during machining can cause the tool wear and reduce surface roughness. To overcome this problem, coolant was used during machining in industries.

There are a few problems that occur when using conventional coolant during machining and one of the problems is the coolant does not reach cutting area. This is because the coolant evaporates before it can reach the cutting area due to the high temperature between the cutter and the workpiece. Next, the high cost of coolant due to the large quantity used for machining and its disposal. Figure 1.1 showed the cost of production of the camshaft in the European automotive industry. Approximately, about fifteen percent of machining cost is incurred by coolant and its disposal. Next, machining under flood coolant can cause harm to the safety of the operators due to the chemical substance of cutting fluid. Flood coolant can cause a skins problem when the operators stay in contact with coolant for a long time.

Lastly, the effect on the environment. The chips produced after machining are mixed with cutting fluid cannot be disposed of directly as regular trash. At the same time, the coolant used should be filtered before being reused and after several uses, it needs to be disposed of. The chips and the used coolant are disposed of as hazardous waste-a practice that is costly to any industry. Hence, using the coolant in large quantities is a costly proposition that is not user-friendly nor environmentally friendly. The alternative solution to solve this problem is to a machine with minimum quantity lubricant (MQL) and pulsation lubrication system (PLS).



a)

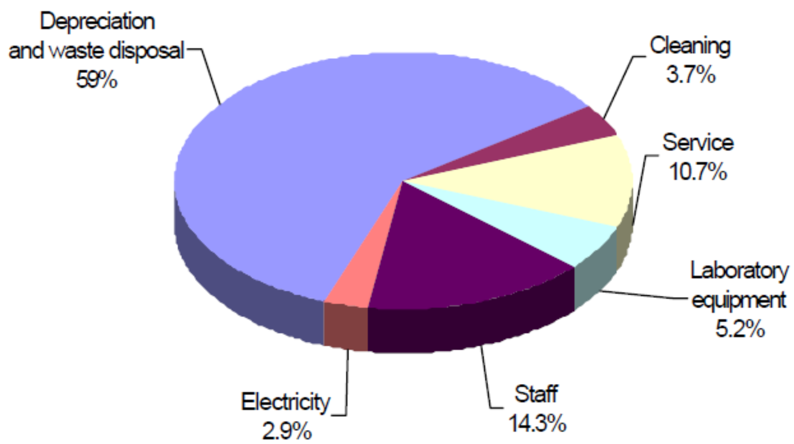


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Figure 1.1: Pie-chart representing of: a) manufacturing cost at German automotive industry; b) structure of coolant cost

1.3 Objectives

The objectives for this project are:

i. To study the effect of width of cut (WoC) on the cutting tool performance under Minimum Quantity Lubrication (MQL) and Pulsation Lubrication System (PLS).
ii. To compare the cutting tool performance between Minimum Quantity Lubrication (MQL) and Pulsation Lubrication System (PLS) by using the dry machining as a reference.

1.4 Scope

This study is to investigate the cutting tool performance under Minimum Quantity Lubrication (MQL) and Pulsation Lubrication System (PLS). Milling operation will be run using the CNC milling machine under these conditions by using Inconel 718 as the workpiece. The varying parameter is cutting speed while the depth of cut and feed rate is the constant variable. After milling operation, the analysis of surface integrity, tool wear will do to determine the cutting tool performance. To find the percent of increases of surface integrity, tool wear and force of MQL and PLS, dry machining will be run under the same cutting parameter. The dry machining will be a reference to determine the cutting tool performances. Lastly, we will compare the data of surface integrity, tool wear and force between MQL, PLS, and dry machining.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses the literature of the coolant system in the manufacturing system, chronological of the coolant system in industries through time and type of coolant system. An overview of minimum quantity lubrication (MQL) and pulsation lubrication system, covers theory for both coolant systems, the type of lubricant used in MQL and the factors that affect the cutting performance under MQL and pulsation lubrication system for milling process. An overview of Inconel 718 properties and applications in industries is also explained in detail here. The explanation and theory about the WoC also stated in this chapter.

2.2 Coolant System in the Manufacturing Process.

In the early 20th century, the machining process started to grow around the world and for the first time water was used as a coolant and it showed that water increased tool life and surface roughness. From there, manufacturers started to use a large variety of cutting fluid for cooling purposes to increases there production and qualities of the product produced. Nonetheless, these cutting have given a more disadvantage that their benefit likes increases in manufacturing cost, environment issue, human health, and others. So, due to that a lot has been done aiming to restrict the use of cutting fluid in the production (Heisel & Schaal, 2009).

Coolant system plays an important role in the machining process because it increases cutting tool life, increases cooling and lubricity and enhanced surface quality. In the milling process, the coolant system is needed to cool down the generated from the cutting tool and workpiece. Traditionally, coolants have been used since long, a study was reported which achieved 40%increase in cutting speed while machining steel with high-speed steel tool and water as a coolant (Shaikh & Sidhu, 2014). Coolant system or cutting fluid also used to flush away the chips from the tool-workpiece interface. A conventional coolant system or flood coolant was widely used in industries such as automation, aerospace, high precision part and etc. Flood coolant used a large quantity of lubricant during machining.

2.2.1 Flood coolant

The conventional coolant machine used in industry is flood coolant. The flood coolant means the cutting fluid flows in large quantities to the cutting tool and workpiece. The main function of flood coolant is to act as lubrication during machining and reducing friction created between the cutting tool and workpiece. This friction will produce heat that can cause the tool to wear. The cutting fluid commonly used in flood coolant is synthetic coolant.

During machining, the performance of cutting fluid can be determined by analyzing the characteristics of lubricant to penetrate on the chip-tool interface and form a thin barrier in the shortest time. This barrier must have lower shearing resistance than the resistance of the material in the interface and it can be formed in two ways either by physical adsorption or chemical reaction. So, this thin barrier will act indirectly as a coolant and reduce heat generation and cutting temperature during machining.

2.2.2 Minimum Quality Lubricant (MQL)

According to (Gunjal & Patil, 2018), MQL is widely used in turning, milling and drilling. The MQL system flow in the mist form. The mist generated by air pressure supply into MQL device and causes the coolant to aerosolize. This coolant flow at high speed toward cutting tool and workpiece. The MQL is also called an almost dry lubrication system (Cayli, Klocke, & Döbbeler, 2018).

Based on the report, the amount of lubricant used during machining under MQL was lower than 20 l/min than the flood lubrication system which is MQL only used in the range of 5-100 ml/h. The MQL system has an adjusted nozzle that can manually adjust in order to get the optimum flow rate and fully used up the droplets during machining. Due to micron-size, the droplets can be rinsed off after machining (W. A. Khan, Hoang, Tai, & Hung, 2018).