STUDY OF THERMAL EFFECT ON VISCOSITY AND SURFACE TENSION OF METALWORKING FLUIDS

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

by

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DECLARATION

I hereby declared this report entitled “Study of Thermal Effect on Viscosity and Surface Tension of Metalworking Fluids” is the results of my own research except as cited in reference.

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Date	: 9TH JANUARY 2019

APPROVAL

This report is submitted to the faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for the degree of Bachelor of Manufacturing Engineering (Hons.). The members of the supervisory committee are as follows:

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ABSTRAK

Cecair kerja logam bagi kelikatan dan ketegangan permukaan sangat dipengaruhi oleh suhu kerjanya. Perubahan dalam suhu kerja telah menjejaskan cecair kerja logam bagi kelikatan dan ketegangan permukaan maka keupayaannya melindungi alat dan memelihara sesuatu produk berkualiti tinggi. Kajian ini telah meneliti suhu bendalir kerja logam daripada pelbagai kelajuan spindel kawalan berangka terkomputer (CNC) pengumpar dengan menggunakan penyejuk separuh sintetik. Suhu telah direkodkan dengan menggunakan termogandingan di kelajuan gelendong yang terpilih. Bahan kerja yang telah digunakan untuk kajian ini ialah Inconel 718. Respons yang diukur dalam kajian ini ialah kekasaran permukaan, haus rusuk alat potong, suhu, kelikatan dan ketegangan permukaan. Cecair kerja logam kelikatan dan ketegangan permukaan telah diukur menggunakan meter likat Haake Viscotester 2 Plus dan Du Nouy teknik pengukuran ketegangan permukaan pada suhu yang telah direkodkan sebelumnya. Terdapat lima kepekatan yang telah dijalankan dalam kajian ini iaitu kepekatan 100%, 90%, 80%, 70% dan 60%. Data yang dikumpul dipindahkan ke perisian "Design Expert" untuk menganalisis data dengan menggunakan analisis varians (ANOVA). Didapati bahawa suhu adalah faktor penting yang telah dipengaruhi oleh kelikatan dan ketegangan permukaan. Keputusan yang diperolehi menunjukkan peningkatan suhu pada kelikatan akan berkurang dengan penigkatan ketegangan permukaan. Tahap hubungan antara parameter input terhadap sambutan telah dianalisis. Dengan menuggunakan dua tahap reka bentuk factorial dalam eksperimen, didapati bahawa nilai mengoptimumkan untuk kelikatan adalah 2.9639 dPas manakala ketegangan permukaan adalah 68.691mN/m pada 820 RPM untuk kederasan memotong dan 0.2mm/rev untuk kadar penghuluran.

ABSTRACT

The metalworking fluids viscosity and surface tension are highly influenced by its working temperature. Changes in the working temperature had been affected the metalworking fluids viscosity and surface tension hence its ability to protect tool and maintaining a high quality product. This study had been looked into the metalworking fluid temperature at various spindle speed of computer numerical control (CNC) turning using semi-synthetic coolant. The temperature had been recorded using the thermocouple at the selected spindle speed. Workpiece material that had been used for this study is Inconel 718. The measured response of this study was surface roughness, tool flank wear, temperature, viscosity and surface tension. The metalworking fluids viscosity and surface tension had been measured using the Haake Viscotester 2 Plus and Du Nouy surface tension measuring technique at temperature recorded previously. There were five concentrations that had been conducted in this study which is concentration of 100%, 90%, 80%, 70% and 60%. The data collected was transferred to the software which is Design Expert to analyse the result using analysis of variance (ANOVA). It was observed that the temperature was the important factor which has been influenced the viscosity and surface tension. The result was as temperature increase the viscosity decrease and surface tension had been raise. The degree of relationship between the input parameter against the response had been analysed. Applying the two level factorial design in the experiment, it is observed that the optimize value for viscosity was 2.9639 dPas while surface tension was 68.691 mN/m at 820 RPM for cutting speed and 0.2 mm/rev for feed rate.

DEDICATION

Only

my beloved father, Basri bin Bahador

my appreciated mother, Nurul Aznam binti Ahmad

my adored sister and brother, Shahrul Bazli, Ainee Balqis and Syahrul Zhafran

for giving me moral support, money, cooperation, encouragement and also understandings

Thank You So Much & Love You All Forever

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In the name of ALLAH, the most gracious, the most merciful, with the highest praise to Allah that I manage to complete this final year project successfully without difficulty.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

The wide uses of metalworking fluids in manufacturing processes like forming and cutting have become important role in industry. These processes produce heat generation in metalworking processes. Moreover, it will reduce friction between tool and workpiece. Metalworking fluids can cause the prevention from the thermal deterioration of the workpiece material. Hence, it will reduce tool wear by their lubricating properties. In metalworking fluid, they are important for the generation and the quality of the surface integrity.

According to Brinksmeier E. *et. al.*, 2015, applying special coatings, it can affect the environmental in cutting processes included undertake which is to change the metalworking fluids. The author's had given the excellent review towards the oil-based of metalworking fluids which it can increase productivity of different forming processes. The chemical working mechanisms will be influence of the varied metalworking fluids composition. The process performances also remained untouched although the lubrication has effect on emulsions are briefly presented.

From 1990 to 2008, the total energy used in Malaysia increased at a rate of 7.2% annually. This is because of increasing industrialization, modernization and development. The European Union stated that there were 320000 tonnes per year approximately in petroleum consumption. The applications of metalworking that used in mineral oil-based fluids can be known as a coolant. It was a high quality manufacturing processes and act as a lubricant for metal cutting whereas it can increase productivity (Syahrullail *et el.*, 2013).

1.2 Problem Statement

The cooling and lubricating the contact zone between tool and workpiece are the ability of metalworking fluids. In the previous studies, stainless steel and low alloyed steels were investigated with a wear resistance experiment by applying metalworking fluids with described various concentrations of additives (Huesmann-Cordes, 2014; Brinksmeier, 2015; Meyer and Wagner, 2016). The chemical properties of the metals was assessed and correlated by the wear resistance.

The rate of heat extraction is an important factor which in viscometer based on two things. Firstly, the type of apparatus which in the test liquid that permanently contained within the apparatus while the other one is test liquid that flows through and out of the apparatus. For example in cuts, to give some of the heat away in the first case, the liquid will flow itself. However, the conduction of heat to the surfaces is the only significant heat transfer process in instruments like the concentric cylinder and cone-and-plate viscometers.

In machining sector, the continuously usage of metalworking fluid in machining have been improved the production and quality of parts. During machining operations, it will be required effect to obtain performance and properties of machined components. This will cause deterioration of metal cutting tools. Hence, there will be required to avoid damage of the produced component by changing tools before a critical level of wear is reached (Hoier *et al.*, 2018). The workpiece interface which causes the failure of cutting tools, formation of micro cracks and surface roughness of workpiece will be compromised at high temperature (Amrita *et al.*, 2014)..

(Sanjeev *et al.*, 2012) investigated that the requirement for minimising the surface roughness was due to combination of less machining time, high cutting speed and low feed rate. The tool wears increases with increase in machining time for a specified value of cutting speed or feed rate. They also found that the roughness values were varying non-linearly with increase variation of feed, yet surface roughness values will be increased as the speed increases. Roughness values usually were not influence by the depth of cut. The surface roughness highly influence by the feed rate due to cutting speed and depth of cut.

1.3 Objectives

The objectives are as follows:

i. To determine coolant temperature at various spindle speed.

ii. To measure coolant viscosity and surface tension at various temperature.

iii. To determine correlation between coolant temperature against workpiece surface finish and tool wear.

1.4 Scopes of the Research

This study will be carried out in Computer Numerical Control (CNC) Laboratory of Faculty Manufacturing Engineering in Universiti Teknikal Malaysia Melaka. The manufacturing process that will be conducted is turning process. The material for the workpiece is Inconel 718 steel in rod shape. The type of tool wear to be studied is flank wear which will be produced by turning process. In this study, the type of coolant that will be used is semi-synthetic coolant oil. Then, the used of thermocouple is important because it can measure the temperature at the selected spindle speed. For the surface tension, it will be measured by Du Nouy Tensiometer and Haake Viscotester 2 Plus is for measuring viscosity. The surface roughness will be conducted in this study by using the Surftest SJ-301 profilometer.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is mainly described about the theory and research which had been done by various researcher years ago. The previous study of related information is extracted as references and discussion based on their research about metalworking fluids viscosity, surface roughness, tool wear and surface tension.

2.2 Metalworking Fluids

K.Weinert (2004) describes that metalworking fluids play an important role in manufacturing processes such as cutting, grinding and forming. Dissipating and conducting the generated heat can be achieved by cooling. Metalworking fluids assist the prevention from the thermal damage of the workpiece material and reduce tool wear by their lubricating and cooling properties (Huesmann-Cordes, 2014). The surface integrity in metalworking, they are high important for the generation and knowledge. The researchers, (Brinksmeier *et al.*, 2004), stated that the development of the performance certain manufacturing processes by metalworking fluids had a few energy was made to analyze their mechanism of action.

According to (Bay, 2010), the environmental aspects of lubricants in cutting processes will change when the metalworking fluids applying special coatings on structured tool surfaces and workpiece. The researchers gave good analysis with regard to the potential of oil based metalworking fluids which to improve productivity at different cutting processes. The chemical working mechanisms of metalworking fluid compositions on the process performance remained unconsumed although the lubrication effect of emulsions were shortly showed.

As stated by (K. Weinert *et al.*, 2004), they investigated that both dry machining and minimum quantity lubricant for cutting processes in general summary of the potential to reduce metalworking fluids. The established of tool life were made by comparing the demands regarding to coatings and tool materials.

As stated by (Liew *et al.*, 2017), metalworking fluid performance in the machining operation was important to increase the usefullness of the machining process. The main purpose of metalworking fluid was for cooling and lubrication but it also helps in increasing the dimensional accuracy of the workpiece, increasing life span of the cutting tool and improving surface finish. Other than that, metalworking fliuid was used to increase the corrosion resistance of the workpiece and machine, avoid formation of build-up edge and remove the chips from the cutting zone.

2.3 Type of Metalworking Fluids

The coolant is used for cool down the cutting zone and reduces heat and friction between workpiece and cutting tool. Basically, a function metalworking fluid in machining is act as lubricant. When friction is reduces and then heat will be reduced. The causes of friction of heat cannot be fully reduce and eliminate. Besides that, cutting fluid should be act as the efficiency coolant. The performance of metalworking fluid is act as lubricating to solve the problem of get rid from the cutting tool, chip and minimizing of work. The most important function of metalworking fluid is cooling. This function should be performing effectively to influence the high thermal conductivity and the maximum heat which will be takes and eliminated per unit fluid per volume.

2.3.1 Straight Metalworking Oils

Straight metalworking oils were mineral oil based which has no contain of water. The process of straight metalworking oils will improved by different additives such as fatty oils for better wettability or sulphur for extra pressure conditions and better lubrication.

These fluids usually used in low speed applications such as stainless steels and other poorly machinable metals (Kopeliovich, 2012).

Table 2.1: Advantages and disadvantages of straight metalworking oils (Kopeliovich, 2012)

Advantages	Disadvantages
Excellent lubrication	Poor heat removal
Good corrosion protection	Expensive
Easy maintenance	High viscosity
	Flammable

2.3.2 Emulsifiable Metalworking Oils

Emulsifiable metalworking oils were water soluble oils which contain emulsifiers, extra pressure and other additives. It was included with stable finely dispersed oil emulsion in water since the emulsifiers reduce interfacial tension between water and oil droplets. The concentration was 2-10% that mixed with water (Kopeliovich, 2012).

Table 2.2: Advantages and disadvantages of emulsifiable metalworking oils (Kopeliovich, 2012)

Advantages	Disadvantages
Good lubrication	Anti-bacteria additives
Good cooling capability	Toxic mist
Corrosion protection	Hardly to maintain
Low cost	Exposed to hard water

2.3.3 Synthetic Metalworking Fluids

It was mixed with water based solutions that contain synthetic lubricants, water softeners, anti-bacteria additives, glycols, extra pressure, corrosion inhibitors and other additives. Synthetic metalworking fluids widely used in variety of metalworking operation such as heavy duty grinding, poorly machinable alloys and high speed cutting (Kopeliovich, 2012).

Table 2.3: Advantages and disadvantages of synthetic metalworking fluids (Kopeliovich, 2012)

Advantages	Disadvantages
Good lubrication	Some toxicity
Good cooling capability	Easily contaminated
Corrosion protection	High cost
Easily handling, cleaning and maintenance	

2.3.4 Semi-synthetic Metalworking Fluids

It was water based mixture that contains solution and emulsion of additives, emulsifiers, synthetic lubricants and some amount of mineral oils (Kopeliovich, 2012).

Table 2.4: Advantages and disadvantages of semi-synthetic metalworking fluids (Kopeliovich, 2012)

Advantages	Disadvantages
Better cooling and wetting capability	Poor stability in hard water
Good cooling capability	Some toxicity
Corrosion protection	Contaminated by foreign oils
Easy to handle and maintenance	

2.4 Tool Wear

The rubbing process is extremely will be controlled in the cutting tool. This is happen when contact between metal and metal, workpiece and chip under high temperature and very high stress condition. Based on the huge range of applications, the uses of hard coated cemented carbide cutting tools are wide used. During machining operation, there is the degeneration of metal cutting tools which has direct impact on the achieve properties and performance of machined components. Therefore, it is required to change tools before a cutting level of wear is reached in order to prevent damage of the produced product.

As indicated by (M'Saoubi *et al.*, 2015), the tool wear must be in comprehension and expectation particularly applicable when cutting materials like Ni-based superalloys. The same trend was shown that occupying high pressure cooling and conventional during turning. When machining superalloys, it must be essentially influenced by workpiece qualities because the flank wear was frequently of the tool life in deciding wear form (Polvorosa *et al*., 2017).

Zhu (2013) stated that the flank wear was occurred when combination of several mechanisms such as diffusion, abrasion, plastic deformation and adhesion of the tool material. An observation had been reviewed towards the input of hard workpiece causes on the flank of metal cutting tools. Figure 2.1 summarized about the wear causes, wear mechanisms, wear types and consequences of the wear.

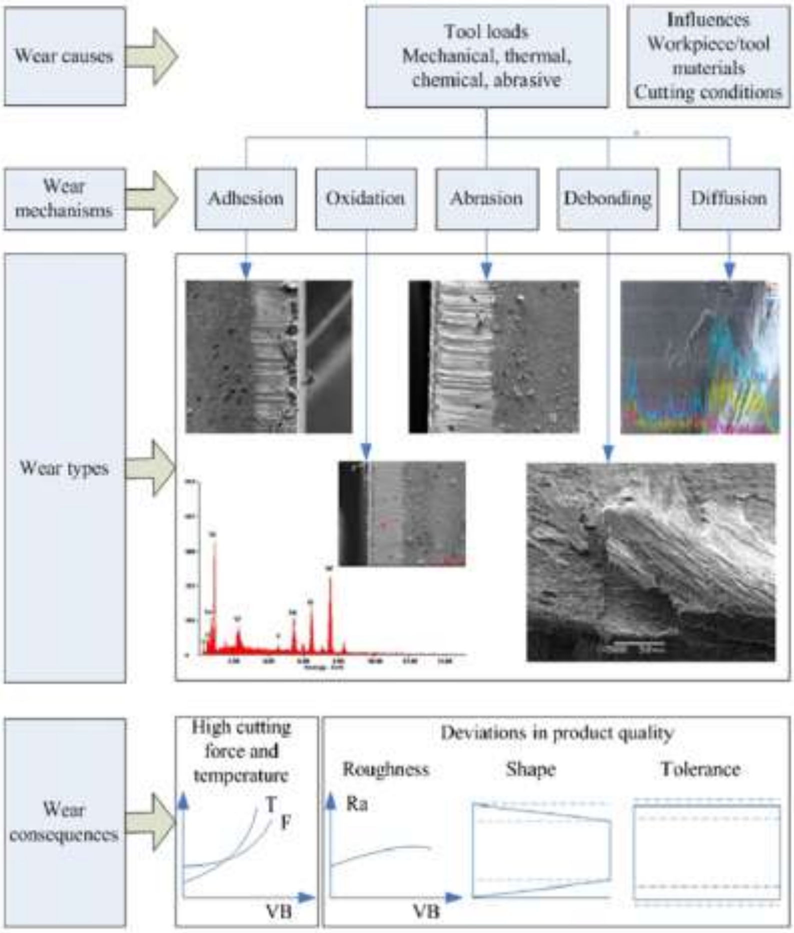

Figure 2.1: An overview of the wear causes, wear mechanism, types of wear and consequences of tool wear (Zhu *et al.*, 2013).

Olovsjö and Nyborg (2012) was compared the flank wear progression of uncoated cemented tungsten carbide tools when machining two different superalloys which is Waspaloy and Alloy 718. They have been studied that the higher flank wears rates when machining was Alloy 718 as compared to the Waspaloy. The uncoated cemented tungsten carbide was used for the cutting tool. A stereo optical microscope which Zeiss Discovery V20 was used to measure the width of flank wear land (VB) after each interval the machine stopped. The result from the experiment, the graph shows that the flank wears with different time of cutting operation as shown in Figure 2.2. From the graph, the progression with machining of Alloy 718 was faster than machining Wasploy. This is because Alloy 718 has larger spread of the resulting flank wear (Hoier *et al.*, 2018).

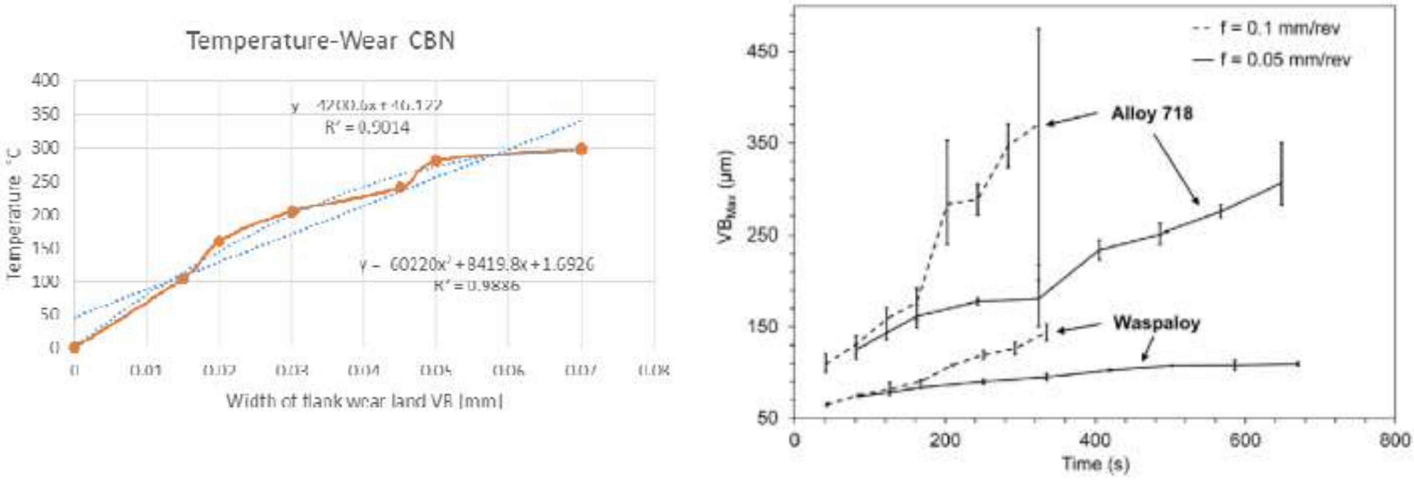

Figure 2.2: The tool wear and cutting time with two feed rates (Hoier *et al*., 2018).

2.4.1 Tool's Wear Dependent on Temperature

According to (M.Tarić *et al*., 2017), they had studied about the temperature of turning tool's wear by using cubic boron nitrade (CBN) and hard metal (HM). The wear rate of CBN and HM increases as the temperature increases which was up to 360℃ as shown in Figure 2.3. This is because HM insert wear process is much faster than the CNB insert at constant cutting conditions. This was due to the properties of HM which had the wear resistance at high temperature. However, the wear rate of CBN decreases below 350℃ because it had wear resistance at low temperature.

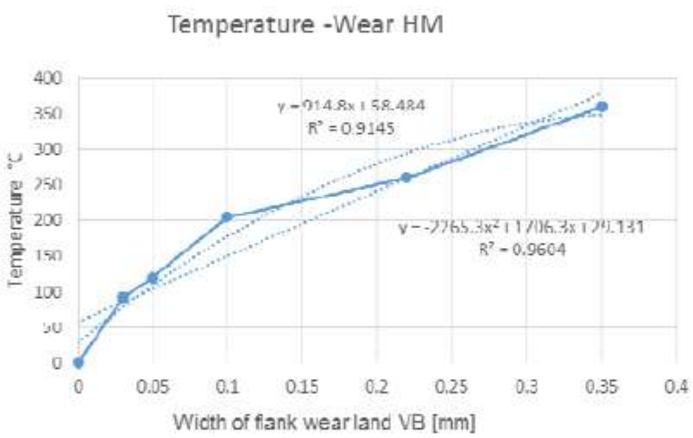

Figure 2.3: Graph of wear rate on different temperature (M.Tarić *et al*., 2017).