Faculty of Manufacturing Engineering

THE EFFECT OF FLY ASH SUSPENSION AS COOLANT IN MILLING PROCESS

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THE EFFECT OF FLY ASH SUSPENSION AS COOLANT IN MILLING PROCESS

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DECLARATION

I declare that this thesis entitled "The Effect of Fly Ash Suspension as Coolant in Milling Process" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : FINIKS ANAK KANIS

Date : 16 August 2023

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Industrial Engineering in Manufacturing Engineering.

Signature : ....

Supervisor Name: ASSOCIATE PROFESSOR DR. LIEW PAY JUN

Date : 16/8/2023

DEDICATION

Dedicated to my beloved and beautiful wife Brenda Brenjah Anak Hinly, my lovely daughter Cherish Rivka Anak Finiks, my father, Kanis Anak Kayat, my appreciated mother, Margaret Anak Jagan, my adored siblings, Vanassa Anak Kanis, and Vinceson Anak Kanis, for giving me moral support, cooperation, encouragement and understandings.

Thank You So Much & Love You All Forever!

ABSTRACT

The removal of material from the workpiece as well as the alteration of its surface are both components of the milling process, which is a series of procedures. When working with metal, almost all of the available energy is converted into heat during the cutting process. During the milling process, the area where the cutting tool and the workpiece come into contact generates a zone of extremely high temperatures. This happens because the milling process involves the removal of material. As a direct consequence of this, the surface quality of the workpiece suffers as a whole. Consequently, the utilisation of a coolant is necessary to resolve this issue. This research project, evaluated how the machining of mild steel is affected by the use of a variety of different cooling techniques. Experiments were conducted using a standard milling setup, comparing the performance of palm oil with and without fly ash as an additive on surface roughness and cutting forces during machining processes. Various cutting parameters including cutting speed, feed rate, and depth of cut were investigated using the Taguchi method. The results demonstrated that the addition of fly ash to palm oil significantly improves surface roughness and reduces cutting forces compared to pure palm oil. The optimum parameters for surface roughness are A2 (palm oil with fly ash), B1 (feed rate 600 mm/min), C3 (cutting speed 1800rpm) and D2 (depth of cut 0.3mm). whereas the optimum parameters for cutting force are A2 (palm oil with fly ash), B1(feed rate 600 mm/min), C1 (cutting speed 1000rpm) and D1 (depth of cut 0.2mm). The findings of this study contribute to the development of environmentally friendly lubrication strategies in the manufacturing industry, utilizing waste materials to improve machining performance and sustainability.

KESAN ABU TERBANG SEBAGAI PENYEJUK DALAM PROSES PENGISAR

ABSTRAK

Penyingkiran bahan daripada bahan kerja serta pengubahsuaian permukaannya adalah kedua-dua komponen proses pengisar, yang merupakan satu siri prosedur. Apabila bekerja dengan logam, hampir semua tenaga yang ada ditukar kepada haba semasa proses pemotongan. Semasa proses pengisar, kawasan di mana alat pemotong dan bahan kerja bersentuhan mewujudkan zon suhu yang sangat tinggi. Ini berlaku kerana proses pengisar melibatkan penyingkiran bahan. Akibat langsung daripada ini, kualiti permukaan bahan kerja terjejas secara keseluruhan. Oleh itu, penggunaan penyejuk adalah perlu untuk menyelesaikan masalah ini. Projek penyelidikan ini, menilai bagaimana pemesinan keluli lembut dipengaruhi oleh penggunaan pelbagai teknik penyejukan yang berbeza. Eksperimen telah dijalankan menggunakan persediaan pengilangan standard, membandingkan prestasi minyak sawit dengan dan tanpa abu terbang sebagai bahan tambahan pada kekasaran permukaan dan daya pemotongan semasa proses pemesinan. Pelbagai parameter pemotongan termasuk kelajuan pemotongan, kadar suapan, dan kedalaman pemotongan telah disiasat menggunakan kaedah Taguchi. Hasil kajian menunjukkan bahawa penambahan abu terbang ke dalam minyak sawit secara signifikan meningkatkan kekasaran permukaan dan mengurangkan daya pemotongan berbanding minyak sawit tulen. Parameter optimum untuk kekasaran permukaan ialah A2 (minyak sawit dengan abu terbang), B1 (kadar suapan 600 mm/min), C3 (kelajuan pemotongan 1800rpm) dan D2 (kedalaman pemotongan 0.3mm). manakala parameter optimum untuk daya pemotongan ialah A2 (minyak sawit dengan abu terbang), B1 (kadar suapan 600 mm/min), C1 (kelajuan pemotongan 1000rpm) dan D1 (kedalaman pemotongan 0.2mm). Dapatan kajian ini menyumbang kepada pembangunan strategi pelinciran mesra alam dalam industri pembuatan, menggunakan bahan buangan untuk meningkatkan prestasi pemesinan dan kemampanan.

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LIST OF ABBREVIATIONS

MQL	-	Minimum Quantity Lubricant
CNC	-	Computer numerical control
AISI	-	American Iron Steel Institute
CVD	-	Chemical Vapor Deposition
MWFs	-	Metal Working Fluids

LIST OF SYMBOLS

m	-	Meter
mm	-	Millimeter
min	-	Minutes
rpm	-	Revolution per minutes
wt %	-	Weight Percentage
°C	-	Degree Celsius
N	-	Newton
kg	-	Kilograms
µm	-	Micrometer
nm	-	Nanometer
K	-	Kelvin
s	-	Seconds
g	-	Gram
%	-	Percentage

CHAPTER 1

INTRODUCTION

This chapter includes the background, problem statements, objective, scopes and significance of the research.

1.1 Research Background

In order to decrease the amount of friction that occurs during the machining process at the point where the tool chip and the tool work come into contact with one another, cutting fluid is frequently utilised. According to Khor et al. (2022), cutting fluid also helps in reducing the temperature of the machining process. This can happen either through the vaporisation (heat absorption) of coolants or by the wet stability of the fluid. When introducing cutting fluid to the machining process, there is less of a splashing action, and as a result, there is a larger chance that the heat will disperse. The wettability of machining fluids is directly correlated to this splashing activity.

Figure 1.1 depicts the classification of cutting fluid as oil-based, aqueous-based, or gas-based. According to Vishal et al. (2022), vegetable cutting oils assist minimise tool wear and friction by forming a high-strength lubricant film between tool-chip surfaces. This film helps prevent tool wear. In addition to this, the inclusion of particles in vegetable oil can increase the temperature reduction, oxidative stability, and capacity to keep the workpiece at a steady temperature. This is significant when working to close tolerances since it allows for more accurate results. As a result of this, the milling process for mild steel will utilize a cutting fluid that is comprised of vegetable oil that has fly ash added to it as part of this research project. Roughness of the surface and cutting force during the milling process were investigated, and the effect of milling parameters on the machining responses were investigated by using the Taguchi method as well.

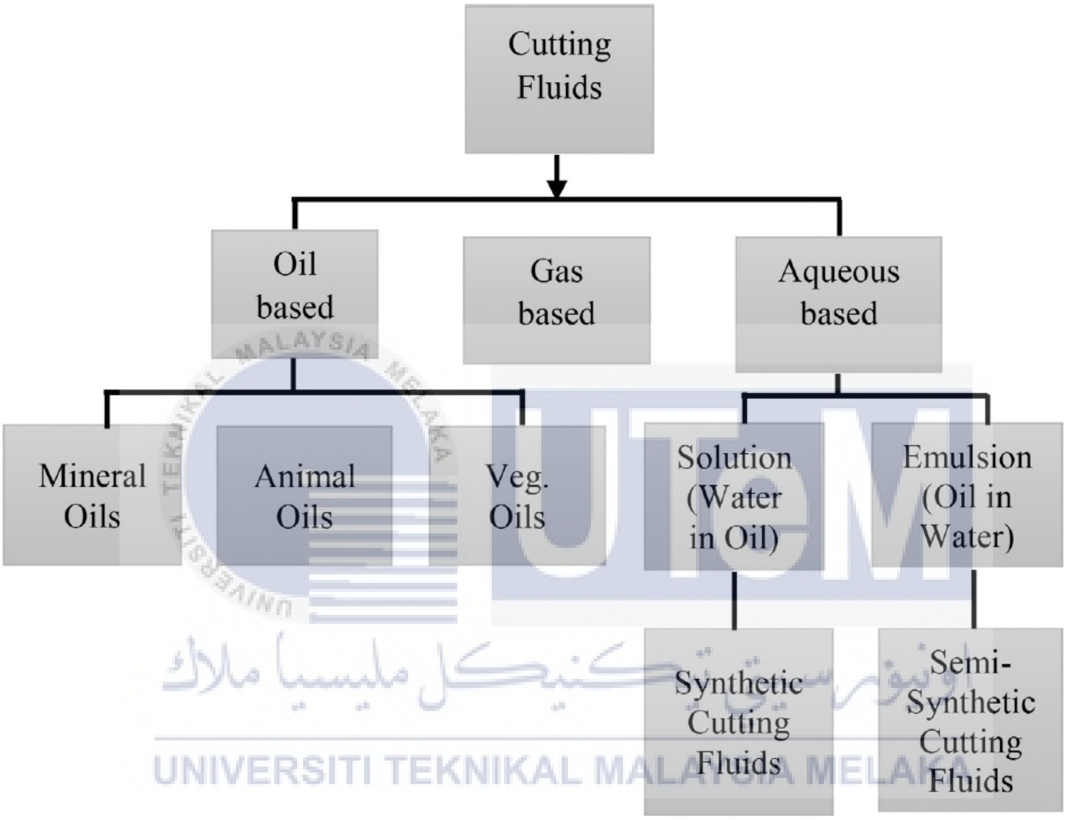

Figure 1.1: Classification of cutting fluid (Vishal et al., 2022)

1.2 Problem Statement

High temperatures are produced during the milling process as a result of friction between the material and the cutting tool. This causes the operation to become inefficient in terms of the tool life, the rate of material removal, and the quality of the workpiece surface. Because these formations are harmful to tools, workpieces, and machines, it is clear why cutting temperature is such an essential factor in determining the surface quality of workpieces and the accuracy of machine tools. According to Ogedengbe et al. (2019), coolants play a pivotal role in reducing the rate of heat generation in machining.

In order to reduce the temperature in the cutting zone, mineral oil is normally applied in the machining zone. However, according to a comprehensive review of the literature carried by Kazeem et al. (2022), mineral oil-based cutting fluids have a lot of disadvantages, in term of health and the environment. Workers in manufacturing run the risk of developing autoimmune illnesses and allergy conditions. Therefore, vegetable oils are extensively employed due to their high flash points and biodegradability when compared to mineral oils. However, palm oils include unsaturated fatty acids, which poses some challenges in terms of corrosiveness and life of the cooling oil, because of high temperature rise in the machining process (Venkatesh et al. 2018). It is common for there to be a desired characteristic provided by the free production of fatty acids in vegetable oils, which is used in the lubricant.

Hence, in the case of fly ash with palm oil is a vegetable oil, the addition of fly ash particles changes the mechanical properties of the mixture, resulting in decreased surface roughness and cutting force compared to pure palm oil. Fly ash is a fine powder obtained from power plants, typically consisting of small spherical particles. These particles act as filler material, creating a modified composite when mixed with palm oil. In this study, the effectiveness of using fly ash additive in vegetable oil as a coolant on the performance of milling machining was investigated using Taguchi method.

1.3 Objectives

The objectives of this research are as follows:

i. To investigate the effect of the surface roughness and cutting force during milling process of mild steel.

ii. To investigate the effect of machining parameters (palm oil, palm oil with fly ash, cutting speed, feed rate, and depth of cut) to the mild steel by using the Taguchi method.

1.4 Scopes

The scope of this research includes the following:

1. The cutting fluid used in this study was pure palm oil and palm oil mix with fly ash as suspension additives.
2. The surface roughness and cutting forces were investigated in the milling process of mild steel.
3. Evaluate the impact of the surface roughness and cutting forces by using pure palm oil and palm oil with fly ash as suspension coolant on the milling performance.
4. To measure parameters such as the depth of cut, feed rate, cutting speed, and the types of cutting fluids to determine the suitability of the suspension in achieving desired milling outcomes.

5. The Taguchi method was used to design the experiment by using Taguchi L18 $(2^1 \text{x } 3^2)$ orthogonal array was selected as the best option.

1.5 Significant of Study

This study is valuable because the machining of mild steel is a challenging process because of its properties. Therefore, research into an efficient cooling mechanism is required in order to lower the temperature that exists between the end of the tool and the workpiece in order to further improve the surface integrity of the product. Using palm oil as a lubricant is an effective approach to cut down on waste while also lowering the risk of potential health problems because it is both non-hazardous and biodegradable. Fly ash utilization offers several environmental advantages. It reduces the amount of waste sent to landfills, as fly ash is commonly disposed of in these facilities. By finding productive uses for fly ash, such as in the mixture with palm oil, we can minimize the environmental impact of its disposal. The combination of fly ash and palm oil aligns with principles of sustainability. By reusing waste materials and optimizing their properties through mixing with palm oil, we can reduce the need for new resource extraction and minimize waste generation. This contributes to the conservation of resources, reduces energy consumption, and helps create a more sustainable and eco-friendly approach to material utilization. As a result, the effectiveness of vegetable oil with fly ash additive reduces surface roughness and cutting force during milling on a mild steel workpiece.

CHAPTER 2

LITERATURE REVIEW

The literature review is the summary taken from journals, reference books, or articles that are related to the current study. The main focus of this chapter is to study the conventional milling process with different types of cutting fluids.

2.1 Milling Process

Milling process is the most prevalent type of material removal or machining process, which can remove undesirable material from a product to generate a variety of characteristics. According to Feilong et al. (2022), the process of reducing surplus material on the workpiece into chips using tools in order to achieve the required geometry and surface quality of the workpiece is referred to as cutting. Workpieces, fixtures, cutters, and milling machines are needed for the milling process.

In the milling process, the tool bit or end mill is a high-speed rotating cutting tool with pointed teeth that is also positioned as a grinder to remove workpiece materials such as steel or aluminum. According to Amin et al. (2020), the effectiveness of the milling process was judged based on the results of measurements taken of tool wear, temperature, cutting forces, and surface roughness. Due to the occurrence of high-speed cutting, the cooling method is important in order to produce the desired shape well.

2.2 Milling Parameters

The three primary process parameters in milling operation are cutting speed, feed rate, and depth of cut.

2.2.1 Cutting speed

Cutting speed is the most important cutting parameter that provides necessary cutting motion. According to Naife (2010), the cutting speed is calculated from rotating speed for any machining operation as shown in equation 2.1.

$$V_C = \frac{\pi DN}{1000} \qquad (2.1)$$

Where,

N: spindle speed (r.p.m)

V_C: cutting Speed (m/min)

D: work diameter (mm), π: 3.14

Table 2.1 shows the range of cutting speed used by previous researchers in the milling process. According to Ahmed (2015), cutting tools have a cutting speed that is defined as the linear speed of their periphery that is produced by the operation. If the cutting speed was increased, the surface quality would be improved.

Table 2.1: Range of cutting speed used in previous researches

Cutting Speed	Workpiece	References
50 – 120m/min	Mild Steel	Metal cutting (2023)
66.88 m/mm	Tungsten carbide	Naife (2010)
100–800 m/min	13 Cr Steel	Hideaki et al. (2015)
60 m/mm	Ti 6Al-4V	Masakazu et al. (2014)

2.2.2 Feed rate

The primary purpose of the feed rate is to advance the cutter in relation to the workpiece in order to remove material from a larger surface area. According to the findings of Ameer et al. (2022), the feed rate had the most significant impact on surface roughness for both coated and uncoated tools, but the cutting speed had a considerable impact on the temperature of the cutting process. According to Shakir et al. (2020), the spindle speed, which is measured in revolutions per minute (rpm), the depth of cut, which is measured in millimeters (mm), and the feed rate, which is measured in millimeters per revolution (mm/rev), are all considered to be input variables for process optimization. The experiments were carried out on mild steel grade 60. It was determined that the combination of a spindle speed of 800 revolutions per minute (rpm), a feed rate of 10 millimeters per revolution (mm/rev), and a depth of cut of 0.5 millimeters produced the lowest surface roughness that resulted in goods that were environmentally friendly.

2.2.3 Depth of cut

The tertiary cutting motion provides the necessary depth within the work material that is intended to be removed by machining. According to Tertsegha et al. (2017), when keeping the depth of cut and feed rate constant, the material of the cutting tool had a direct impact on the cutting forces. It is applied in the third perpendicular direction, and the removal of superfluous material from the workpiece is the consequence of the simultaneous action of three cutting parameters. The depth of cut usually varies between 0.1 to 1.0 mm. Parameters affect the performance and efficiency of the precision machining process.

2.3 Types of Cutting Fluid

Cutting fluids are fluids that are frequently used during machining operations. The main purpose of the cutting fluid is to remove the heat generated during metal cutting and other machining operations. According to Fazle et al. (2015), the removal of heat from the process is the primary function of the cutting fluid during the operation. As demonstrated by Ameer et al. (2022), the machining difficulties associated with difficult-to-cut metal alloys, such as hardened steel, nickel-based alloys, titanium alloys, and other materials, were conquered with the help of a variety of coolants and coolant delivery systems, as shown in Figure 2.1. These innovations were necessary to achieve the desired results.

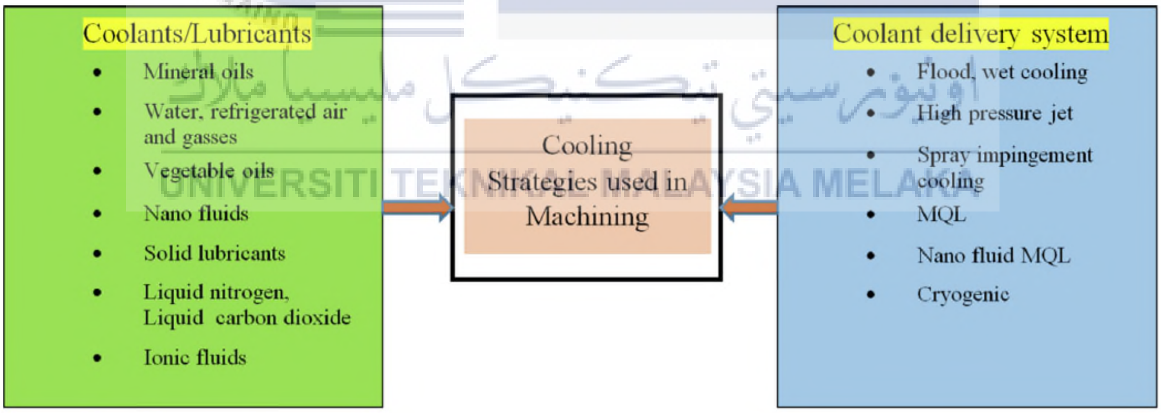

Figure 2.1: List of different types of coolants and coolant delivery systems (Ameer et al., 2022)

The three primary cutting fluids that will be focused on are vegetables oil, mineral oils, and solid lubricant.