EXPERIMENTAL STUDY OF MILLING PROCESS USING SOLID LUBRICANT

FAREZ AMSYAR BIN ZULKIFLI

B051810136

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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EXPERIMENTAL STUDY OF MILLING PROCESS USING SOLID LUBRICANT

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

By

FAREZ AMSYAR BIN ZULKIFLI

B051810136

971206-08-5305

FACULTY OF MANUFACTURING ENGINEERING

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Cop Rasmi: ASSOC. PROF. DR. LIEW PAY JUN
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.). The supervisor as follow:

....

PROFESOR DR LIEW PAY JUN

ABSTRACT

Milling process is a conventional cutting process which involves the use of physical cutting tool to remove the workpiece material. Involvement of physical cutting tool will lead to heat generation due to friction, which led to increase the thrust force, shorter cutting tool life due to wear and deformation, poor surface finish, and dimensional inaccuracy of the machined surface. Thus, lubrication is applied at the contact point of the cutting tool and workpiece during the process to reduce the friction. Though, conventional petroleum-based cutting fluid has always been known due to its not environmentally friendly as well as harmful to human. Solid lubricant is one of the alternatives due to its ecological properties. Solid lubricant of 90 nm sized molybdenum disulfide (MoS_2) powder is mixed with palm oil at 0.02 wt%. The machining responses such as surface roughness, and thrust force during the milling process on mild steel plate is investigated. The control parameters are cutting speed, feed rate, and cooling condition. The applied cooling conditions are dry, minimum quantity lubrication (MQL) of only palm oil as base fluid, and solid lubricant minimum quantity lubrication (SLMQL) of MoS_2 mixed with palm oil. Applying the Taguchi method, it was found that most influential parameter is cooling condition. Linear ANOVA from regression analysis found that increase of cutting speed improved the surface roughness and thrust force, meanwhile higher feed rate reduces surface roughness but increase the thrust force. As expected, SLMQL performs the best, followed by MQL, and dry.

ABSTRAK

Proses pengilangan adalah proses pemotongan konvensional yang melibatkan penggunaan alat pemotong fizikal untuk membuang bahan dari bahan kerja. Penglibatan alat pemotong fizikal ini akan menyebabkan penjanaan haba akibat daripada geseran, lalu meningkatkan daya pemotongan, memendekkan jangka hayat alat pemotong akibat daripada haus dan ubah bentuk, kemasan permukaan bahan kerja yang tidak baik, dan ketidaktepatan dimensi permukaan bahan kerja yang dimesin. Oleh itu, pelincir diaplikasikan pada kawasan sentuhan alat pemotong dan bahan kerja semasa proses pemotongan untuk mengurangkan geseran. Namun, cecair pemotongan konvesional yang berasaskan petroleum adalah tidak mesra alam serta berbahaya kepada manusia. Pelincir pepejal adalah salah satu alternatif kerana sifat ekologinya yang baik. Pelincir pepejal serbuk *molybdenum disulfide* (MoS_2) bersaiz 90 nm dicampur dengan minyak sawit pada 0.02 wt%. Tindak balas pemesinan seperti kekasaran permukaan, dan daya tujah semasa proses pengilangan pada plat keluli lembut akan dikaji. Parameter boleh ubah adalah kadar suapan, kelajuan pemotongan, dan keadaan penyejukan. Keadaan penyejukan yang digunakan ialah pemotongan kering, pelinciran kuantiti minimum (MQL) iaitu minyak sawit sahaja sebagai cecair asas, dan pelinciran kuantiti minimum pelincir pepejal (SLMQL) iaitu minyak sawit sebagai cecair asas dicampur dengan MoS_2. Menggunakan kaedah Taguchi, didapati bahawa parameter yang paling berpengaruh adalah keadaan penyejukan. ANOVA linear daripada analisis regresi mendapati peningkatan kelajuan pemotongan meningkatkan kekasaran permukaan dan daya tujah, manakala kadar suapan yang lebih tinggi mengurangkan kekasaran permukaan tetapi meningkatkan daya tujah. Seperti yang dijangka, SLMQL berprestasi yang terbaik, diikuti oleh MQL, dan pemotongan kering.

DEDICATION

This report is dedicated to

my beloved parents, brother, sisters, and friends

for giving me moral support, cooperation, encouragement also understanding.

Thank you so much

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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 project bachelor’s degree 2 successfully without difficulty.

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LIST OF ABBREVIATIONS

ANOVA	-	Analysis of Variance
BA	-	Boric Acid
BUE	-	Built-Up Edge
CaF_2	-	Calcium Fluoride
CNC	-	Computer numerical control
CoF	-	Coefficient of Friction
CVD	-	Chemical Vapor Deposition
DF	-	Degree of Freedom
DOE	-	Design of Experiment
F_c	-	Cutting Force
F_f	-	Feed Force
F_p	-	Thrust Force
FKP	-	Faculty of Manufacturing Engineering
FKM	-	Faculty of Mechanical Engineering
Fy	-	Thrust Force
Gr	-	Graphite
hBN	-	Hexaboron Nitride
LCL	-	Lower Control Limit
MoS_2	-	Molybdenum Disulfide
MQL	-	Minimum Quantity Lubrication
MRR	-	Material Removal Rate

MS	-	Mean Square
PVD	-	Physical Vapor Deposition
Ra	-	Surface Roughness
RSM	-	Response Surface Methodology
SD	-	Standard Deviation
SLMQL	-	Solid Lubricant Minimum Quantity Lubrication
S/N	-	Signal-to-Noise
SS	-	Sum of Squares
T1	-	Take 1
T10	-	Take 10
Ti6Al4V	-	Titanium Alloy
UCL	-	Upper Control Limit
UTeM	-	Universiti Teknikal Malaysia Melaka
WS_2	-	Tungsten Disulfide

LIST OF SYMBOLS

%	-	Percentage
°C	-	Degree Celsius
α	-	Alpha
Δ	-	Delta
µ	-	Micron
µm	-	Micrometer
2σ	-	2-Sigma
dB	-	Decibels
Hz	-	Hertz
mm	-	Millimeter
mm/rev	-	Millimeter per Revolution
mm/min	-	Millimeter per Minute
m/min	-	Meter per Minute
mL	-	Mililitre
mL/h	-	Millilitre per Hour
N	-	Newton
nm	-	Nanometer
rpm	-	Revolution per Minute
s	-	Second
wt%	-	Weight Percentage

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Machining has been around for centuries, which then keep evolving until present days. Machining is a process in which the material is cut and removed into the desired shape. The process, also commonly known as subtractive manufacturing requires two subjects which are cutting tools and workpiece where the cutting tools must require higher hardness than the workpiece. The cutting process usually involves a stationary and a rotating part, which either the workpiece or the cutting tool will rotate, and vice versa. Machining is usually used to manufacture metals products. There are several types of conventional machining, which are drilling, turning or lathe, and milling. The operation works almost similar, which for drilling and milling, the rotating part is the cutting tool. Meanwhile for turning, the rotating part is the workpiece itself. Milling machine has always been used in industry because of its capability of processing the complex shape of workpiece. Milling machine also provide a superior metal removal rate compared to other machining. It offers a good accuracy as well as better surface finish. The machine can be operated by three axes of traverse motion; x for left and right, y for up and down, and z for front and back. The flexibility of movement of the cutting tool leaves much less blind spot to operate the cutting process. The rotating cutting tool will traverse along the axis and contact the workpiece, where the rotation will provide a force which the cutter teeth will deform and remove the pieces of the workpiece into the desired shape (Saif, 2019). The cutting principle of milling cutting process is by shear deformation of the workpiece. The teeth of the cutter remove the material by providing many separate and small cuts against the workpiece.

However, the physical contact between the rotating cutter and the workpiece produces a friction, which possess a critical role in energy consumption, temperatures, cutting forces, cutting tool life, and machined surface quality, making the cutting process to be inefficient for certain circumstances if friction is uncontrolled or neglected (Gopalakrishna *et al.*, 2014). The importance of acknowledging friction in cutting process has been a major concern in industry ever since the early days. Friction limits the workpiece hardness that can be machined without dropping the quality of the result as well as increase the operating cost due to the needs of a harder cutting tool and increase the probability of non-conformance end product (Makhesana & Patel, 2020a). Thus, countermeasure of friction is a priority in enhancing the cutting process performance.

One of the most common ways of overcoming the friction issue is lubrication. Lubrication technique have been in used for thousands of years, as identified in the 1400 BC where calcium soaps is used for axles of chariots (Pirro *et al.*, 2016). The lubrication technology then evolved until present timeline, where the lubrication technique is also applied in worldwide machining industry to reduce the friction during the cutting process. The lubricant, for example a cutting fluid, is applied at the contact point of the cutting tool and workpiece, increasing the machining result of dimensional accuracy and good surface finish as well as extending the cutting tool life (Sloman, 2002). The two most important factors in an efficient and good machining are the cutting tool life, and the machining result: surface roughness of the workpiece.

Tool life is important because it manipulates the operating cost non-directly. The longer tool life would require less quantity of cutting tools to be used, hence, reducing the cost to provide cutting tool. Other than cost effecting, cutting tool condition immensely manipulates the workpiece quality. A bad condition cutting tool will results in a rougher surface of the workpiece (Krishna & Rao, 2008). Hence, the relationship of cutting tool quality and workpiece surface roughness highlights the importance in reducing the friction. This is where the lubrication is applied in machining.

The most common lubrication used is a conventional cutting fluid. Nevertheless, conventional cutting fluids or lubricants are not environmentally friendly. The one time use of lubricants create a large chunk of waste to dispose (Chattopadhyay, 2011; Kalpakjian & Schmid, 2017; Saha *et al.*, 2020). At high temperature, the cutting fluid chemicals will disassociate, which may cause health problems to the operators, as well as resulting in water pollution and soil contamination during disposal (Howes *et al.*, 1991). Hence, looking for a green alternative is a mission for the mankind. One of the alternatives is using solid lubricant. This study focuses on the application of solid lubricant to reduce the friction and increase the machining performance of mild steel by using milling process. The effect of molybdenum disulfide (MoS_2) solid lubricant on the surface roughness, and thrust force during the milling of mild steel will be investigated.

1.2 Problem Statements

In industry, friction has always caused the imperfection of machining practice. The friction in between the cutting tool and the workpiece causes the temperature to increase. The temperature of workpiece and cutting tool is one of the main factors of the imperfect result. It is believed that the increased and uncontrolled temperature results in the dimensional inaccuracy of the machined surface. Furthermore, it is believed that at high temperature, the workpiece and the cutting tool will soften and that may lead to the deformation. Also, the cutting tool wear is correlate directly to the cutting force during the machining where increase of cutting force will increase the temperature, which are then increase the cutting tool wear (Krishna & Rao, 2008). The rapid increase of temperature and cutting force between the cutting tool and workpiece after several minutes of machining has always been a major problem in machining industry because it affects the cutting tool wear and workpiece surface roughness. It also may lead to the cutting tool failure, such as breakage. Thus, it is vital to control the temperature of the workpiece and cutting tool during the entire cutting process.

1.3 Objectives of Study

The objective of the project is as follow:

i. To investigate the effect of cutting speed, feed rate and cooling conditions on surface roughness and thrust force during the milling of mild steel.
ii. To compare the machining performances under dry, minimum quantity lubricant (MQL) and solid lubricant MQL (SLMQL) conditions.

1.4 Scopes of Study

The scopes of study of the project are as follow:

i. The research of solid lubricant which revolve around the machining process specifically the milling machine on the mild steel as workpiece.
ii. The base fluid for the lubrication is palm oil and molybdenum disulfide nanoparticles will be used as the solid lubricant.
iii. Cutting parameters of cutting speed, feed rate, and cooling conditions will be varied throughout the whole study.
iv. The depth of cut, flow rate, type of solid lubricant will be kept constant throughout the whole study.
v. The study focuses on analysing the machining response which are surface roughness, and thrust force.
vi. The design of experiments will be done using Taguchi method.