DRILLING OF TITANIUM ALLOY USING HYBRID NANOFLUID IN MINIMUM QUANTITY LUBRICANT (MQL)

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DRILLING OF TITANIUM ALLOY BY USING HYBRID NANOFLUID IN MINIMUM QUANTITY LUBRICANT (MQL)

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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:

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ABSTRACT

Drilling is a machining process that used to make holes on workpiece or product. The process involves in rotary motion of cutting tool that penetrates the workpieces and remove the material. In this study, titanium alloy will be used as a workpiece in three cutting conditions which are dry, base fluid (MQL) and hybrid nanofluid (MQL). Combination of Molybdenum disulphide (MoS_2) and Titanium dioxide (TiO_2) nanoparticles will be used as hybrid nanofluid lubricant in this experiment. Both MoS_2 and TiO_2 will be dispersed into deionized water (DI) by using ultrasonic homogenizer. The surfactant that will be used in this mixture is Sodium dodecyl sulphate (SDS) to prevent the mixed solution from agglomeration. During the drilling experiment, 9 experiments will be run with 3 level conditions and 3 parameters by using Taguchi method. The input parameters such as cutting speeds, feed rates, and cutting conditions will be used in achieving the optimal condition for drilling process. Other machining parameters will be kept constant throughout the experiment. For the results and analysis, surface roughness and thrust force will be measured by using surface roughness tester, and dynamometer, respectively. At the end of the study, it is expected that by using hybrid nanofluid as lubricant, the lowest surface roughness and thrust force can be obtained.

ABSTRAK

Penggerudian adalah proses fabrikasi yang untuk membuat lubang pada bahan kerja atau produk menggunakan mesin. Proses ini melibatkan gerakan putaran pada mata alat yang menembusi bahan kerja dengan mengeluarkan sisa pemotongan. Dalam kajian ini, aloi titanium akan digunakan sebagai bahan kerja dengan tiga fasa pemotongan iaitu kering, cecair asas (MQL) dan cecair nano hibrid (MQL). Gabungan nanopartikel *Molibdenum disulfide* (MoS2) dan *Titanium dioxide* (TiO2) akan digunakan sebagai pelincir cecair nano hibrid dalam eksperimen ini. Kedua-dua MoS2 dan TiO2 akan diserakkan ke dalam air ternyahion (DI) dengan menggunakan *ultrasonic homogenize*. Surfaktan yang akan digunakan dalam campuran ini ialah *Sodium dodecyl sulphate* (SDS) untuk mengelakkan penggumpalan berlaku pada larutan tersebut. Di dalam kajian ini kaedah Taguchi digunakan untuk merancang stratergi experiment dan sebanyak 9 eksperimen akan dilakukan mengikut 3 fasa dan 3 parameter yang berlainan. Parameter input seperti kelajuan mesin pemotongan, kadar suapan, dan keadaan pemotongan akan digunakan dalam mencapai keadaan optimum untuk proses penggerudian. Parameter lain akan dikekalkan tanpa sebarang perubahan sepanjang kajian. Untuk keputusan dan analisis, kekasaran permukaan dan daya tujahan akan diukur dengan menggunakan penguji kekasaran permukaan dan dinamometer, masing-masing. Di akhir kajian, dijangkakan dengan menggunakan cecair nano hibrid sebagai pelincir, kekasaran permukaan bahan akan berada pada tahap paling rendah, penguranga N dan daya tujahan yang boleh diperolehi.

DEDICATION

This research is lovingly dedicated to

my beloved parent, sisters, and friends

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

Without them this project would not have been done

Thank you so much

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LIST OF ABBREVIATION

CNC	-	Minimum Quantity Lubrication
MQL	-	Solid Lubricant Minimum Quantity Lubrication
MoS_2	-	Molybdenum disulfide
UTeM	-	Universiti Teknikal Malaysia Melaka
TiCN	-	Titanium Carbonitride
TiAlN	-	Titanium Aluminium Nitride
TiN	-	Titanium Nitride
LNZ	-	Liquid nitrogen
CO_2	-	Carbon dioxide
LCO_2	-	Liquid Carbon dioxide
Gr	-	Graphite
MWCNTs	-	Multi-walled Carbon nanotubes
hBN	-	Hexaboron nitride
GO	-	Graphene Oxide
MMT	-	Montmorillonite
TiO_2	-	Titanium dioxide
GNPs	-	Garphene nanoplates
Cu	-	Copper
Ti6Al4V	-	Titanium alloy
BUE	-	Built-up edge
Ag	-	Silver

S/N	-	Signal-to-noise
RSM	-	Response Surface Methodology
SDS	-	Sodium dodecyl sulfate
mL/h	-	Millilitre per hour
SEM	-	Scanning Electron Microscope
ZnO	-	Zinc oxide
CuO	-	Copper
Al_2O_3	-	Aluminum oxide
GA	-	Gum Arabic
CTAB	-	Cetyltrimethylammonium bromide
NFMQL	-	Nanofluid with minimum quantity lubricant
DI	-	Deionized
SEM	-	Scanning Electron Microscope
MRR	-	Material removal rate
UCL	-	Upper Control Limit
LCL	-	Lower Control Limit
S/N	-	Signal-to-ratio
BFMQL	-	Base fluid with MQL
HNFMQL	-	Hybrid nanofluid with MQL
ANOVA	-	Analysis of variance
dB	-	Decibels

LIST OF SYMBOLS

°C	-	Degree Celsius
%	-	Percentage
°	-	Degree
wt%	-	Weight percent
mm	-	Millimetre
nm	-	Nanometer
N	-	Newton
mm/min	-	Millimeter per minute
m/min	-	Meter per minute
mm/rev	-	Milimeter per revolution
µm	-	Micrometre

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Over a decade, manufacturing process has been used in wide range of applications in the industries. For instance, machining process plays an important role in production field by completing the product into the desire shape which contribute to profit in the industry (Kumar *et al*., 2021). Machining processes are separated into two groups which are the conventional and non-conventional. Conventional machining process is defined as to have a physical contact between tool and workpieces. For example, turning, milling, and drilling application. On the other hand, the non-conventional machining process is a cutting process that does not have the physical contact between cutting tool and workpiece such as laser beam machining.

Drilling is a process where a rotating cutting tool removed parts from the workpiece by making a hole. In drilling, material removal occurs in the form of extrusion where high-thrust forces at the face of workpieces extrude the metal under drill bit edge due to the feeding motion. Along with the cutting speed, the contact experiences shear and metal deformation under the action of negative rake angle (Kumar *et al*., 2019). Nowadays, common drilling machine used in manufacturing holes is Computerize Numerical Control (CNC) machine where the results and data parameters are shown on screen with the setup of input data depend on the workpiece used. Common workpiece used in machining process are titanium, steel, and aluminium.

In drilling technology, workpiece such as titanium is identified as difficult-to-machined materials that have a wide variety of application such as in aerospace, construction, vehicles, and medical appliances. Titanium is widely used in modern technology due to its strength in mechanical properties (Madić *et al*., 2015). However, it requires high amount of cutting force and controlling parameter to smooth the operation. In addition, the frictional force between tool bit and titanium is higher than other metal alloy which can lead to the deformation of tool due to its strength properties (Xavier et al., 2017).

Tool life is an important factor that need to be controlled during the drilling process. This is because high cutting force will cause the temperature in the cutting zone between drill bit and workpiece to increase which will result in large amount of tool wear. Moreover, drilling process itself generates heat where it restrained in small area as the process focus at one cutting point (Jindal, 2012). In term of product quality, surface roughness is crucial because it determines the interaction of cutting surface and workpiece as it often used as an indicator of a mechanical component's performance. There are many factors that lead to surface roughness such as cutting-edge geometry, tool accuracy and tool wear. The surface roughness seems to increase as cutting speed and feed rate increase, whereas it decreases as point angles increase when using the same cutting parameters (Demir, 2018). This is shown when in dry cutting process, it results in low quality of product produced. Hence, this is the reason where lubricating system come in hand.

In order to improve tool life and surface finish, various cooling techniques have been used such as wet, minimum quantity lubrication (MQL), cryogenic and hybrid nanofluid MQL. Coolant plays an important role in the form of liquid to reduce the heat generated during cutting process and to smooth the contact surface between cutting tool and workpiece. Using of MQL technique has shown great impact in drilling performance especially cutting tool life (Rahim *et al*., 2015). New technology in drilling process with addition of nanoparticles in base fluid, which called as nanofluid with MQL as cooling technique helps to improve the drilling performance with high reduction percentage of surface roughness and tool wear (Kumar et al., 2020). Thus, in this study, hybrid nanofluid MQL will be used as coolant in the drilling process of titanium.

1.2 Problem Statements

Drilling of hardened and difficult-to-cut materials such as titanium alloy require big amount of force due to its high metal properties. Titanium alloy has high strength-to-weight ratio, fracture toughness and good anti corrosion. However, titanium will consume high cutting speed and thrust force to penetrate the material. High cutting speed and cutting force in drilling lead to high in temperature due to the friction contact between the cutting tool and workpiece. Increase of the cutting temperature in the cutting zone results in the plastic deformation of cutting tool which lead to tool failure and poor surface quality. In other words, this phenomenon creates the rough surface in the drilled hole and excess burr formation outside the drilled hole. This poor surface quality will affect the dimension tolerance in application industry and required rework process which result in excess cost production. Hence, increase of temperature has been major problem during the drilling process and solution need to be taken for better drilling performance.

1.3 Objectives of Study

The objectives of the project are as follows:

i) To investigate the surface roughness, burr formation and cutting force of titanium alloy with the present of hybrid nanofluid as lubrication in drilling process.

ii) To determine the optimum parameters for drilling of titanium alloy using Taguchi method.

1.4 Scope of Study

The scopes of the study are as follows:

i) The study focuses on hybrid nanofluid MQL as coolant in the drilling process.
ii) Analyse the performance of titanium alloy in drilling process with different cutting cooling conditions.
iii) Machining responses such as surface roughness, burr formation and thrust force will be analysed.
iv) Variation of cutting parameters such as cutting speed and feed rate are use.
v) Depth of cut on the workpiece are kept constant.
vi) Using Taguchi method as strategies in running the experiment.

1.5 Significance of Study

The significant of study are as follows.

i) Applying hybrid nanofluid MQL system improving drilling performance and reducing the overuse of conventional lubrication which can cause harmful to human behaviour and environment.

ii) Quality of product workpieces such as surface roughness is at the lowest point with the right cooling condition operation.

iii) Tool life is expected to be longer with the present of hybrid nanofluid which also can maximize the production process and reducing cost.