DRILLING OF TITANIUM ALLOY USING HYBRID NANOFLUID COOLANT

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

by

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2019

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: **DRILLING OF TITANIUM ALLOY USING HYBRID NANOFLUID COOLANT**

Sesi Pengajian: **2018/2019 Semester 2**

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I hereby, declared this report entitled “Drilling of Titanium Alloy Using Hybrid Nanofluid Coolant” is the results of my own research except as cited in the reference.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee are as follow:

……

(Associate Professor Dr. Liew Pay Jun)

ABSTRAK

Penyelidikan ini fokus kepada kesan kepekatan cecair nano hibrid di antara '*graphene*' dan *'multiwall carbon nanotubes (MWCNTs)'* dengan air tulen sebagai penyejuk dalam proses penggerudian aloi titanium. Kekasaran permukaan, pembentukan *'burr'* dan juga daya tujahan terhadap lubang yang digerudi dengan menggunakan kepekatan cecair nano hibrid yang berbeza telah dikaji dalam penyelidikan ini. Pada masa yang sama, ciri-ciri haba cecair nano hibrid seperti kekonduksian terma dan kelikatan juga telah dikaji. Campuran cecair nano hibrid tersebut telah disedia menggunakan *'two step method'* di mana pertama sekali, kedua-dua zarah-zarah *'graphene'* dan *'MWCNTs'* dicampurkan dan selepas itu, air tulen dalam kandungan campuran zarah-zarah tersebut dicampurkan. Parameter pemesinan yang telah digunakan dalam penyelidikan ini adalah kadar suapan (0.09 mm/putaran), kelajuan pemotongan (22 m/min), kedalaman pemotongan (5 mm) dan juga empat kepekatan cecair nano hibrid yang berbeza iaitu 0.0wt%, 0.1wt%, 0.5wt% dan 1.0wt%. Selepas itu, prestasi kesemua parameter ini telah dinilai. Hasil daripada kajian menunjukkan gabungan antara 'graphene' dan '*MWCNTs'* zarah nano menghasilkan cecair nano hibrid yang telah dipertingkatkan kekonduksian terma dan juga kelikatannya. Di kepekatan optimum iaitu 0.5wt%, nilai yang boleh diperhatikan pada daya tujahan dan kekasaran permukaan adalah di bacaan yang paling rendah berbanding dengan kepekatan yang lain. Kepekatan ini juga menghasilkan ketinggian *'burr'* seragam yang paling rendah di bahagian luaran lubang yang digerudi.

ABSTRACT

This research focused on the effect of different concentrations of the hybridization between graphene and multiwall carbon nanotubes (MWCNTs) with deionized water as a coolant for the drilling of titanium alloy. Surface roughness, burr formation and thrust force of drilled holes against the volume concentration of hybrid nanofluid was studied. The thermal characteristics of hybrid nanofluid such as thermal conductivity and viscosity were investigated as well. The hybrid nanofluid was prepared by applying two step method which is firstly mixing both the graphene and MWCNTs nanoparticles and after that mixing both the mixture with deionized water and further stirring by ultrasonication process using ultrasonic homogenizer. The machining parameters that were used in this research are feed rate (0.09 mm/rev), cutting speed (20 m/min), depth of cut (5 mm) followed by four different concentrations of the graphene and MWCNTs hybrid nanofluid mixture which were 0.0wt%, 0.1wt%, 0.5wt% and 1.0wt%. The experiment results showed the combination of both graphene and MWCNTs nanoparticles have produced a hybrid nanofluid with enhanced thermal conductivity and also its viscosity. At optimum concentration of 0.5wt%, it can be observed the value of both thrust force and surface roughness were at the lowest reading compared to other concentrations. This concentration also produced the lowest height of uniform burr formation at exit of the hole.

DEDICATION

To my only
beloved father, Sonny Heng
appreciated mother, Chhoa Eng Gim
adored brother, Bobby Heng
and all my helpful friends
for giving me so much supports physically, mentally, financially, full cooperation, encouragement and also understandings towards completing a part of this project.
Thank You So Much & Love You All Forever

ACKNOWLEDGEMENT

This project could not have been completed without the contribution and help from the people that name may not all be mentioned. I am sincerely appreciated all their contributions and being so grateful to acknowledge their presence and giving part of their contribution in completing my research. Nevertheless, I am really very grateful and appreciate everything particularly to the following:

Dr. Liew Pay Jun, who is my project's supervisor, for all the endless support, kind and understanding spirit during the time I am doing this project together with her PhD and Master students for always willing to lend their hands to help us during the period of completing my final year project with patience and understanding.

To all my lovely and supporting family members, relatives, friends and whoever in have shared their support, either morally, mentally, and financially, thank you very much. Truly appreciated all of your supports.

Finally, I would also like to thank everyone who are very important in helping me to accomplish this report and expressing my deep apology for not mentioning each of you.

Above everyone else, to God the Almighty, the author who provides us wisdom and knowledge, for his countless blessings to us.

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LIST OF ABBREVIATIONS

Ag	-	Silver
AISI	-	American Iron and Steel Institute
Al	-	Aluminum
Al_2O_3	-	Aluminum Oxide
C	-	Carbon
CFRP	-	Carbon Fiber Reinforced Polymer
CNF	-	Carbon Nanofiber
Cu	-	Copper
CuO	-	Copper Oxide
CVD	-	Chemical Vapor Deposition
DI	-	Deionized
Fe	-	Iron
Fe_3O_4	-	Iron Oxide
GO	-	Graphene Oxide
HSS	-	High Speed Steel
LN_2	-	Liquid Nitrogen
MQL	-	Minimum Quantity Lubrication
MWCNT	-	Multiwall Carbon Nanotube
N	-	Nitrogen
NiTi	-	Nic
O_2	-	Oxygen
OM	-	Optical Microscope
SiC	-	Silicon Carbide
SiO_2	-	Silicon Dioxide
Ti	-	Titanium
Ti-6Al-4V	-	Titanium Alloy
TiN	-	Titanium Nitride

TiO_2	-	Titanium Dioxide
ZnO	-	Zinc Oxide

LIST OF SYMBOLS

%	-	Percent
°	-	Degree
°C	-	Degree Celsius
µm	-	Micrometer
D	-	Diameter of the cutter
f	-	Feed rate
F_m	-	Maximum force
M_m	-	Maximum torque
HV	-	Vickers Hardness
m/min	-	Meter per minute
ml	-	Milliliter
mm	-	Millimeter
mm/rev	-	Millimeter per revolution
mm/rev	-	Millimeter per revolution
MPa	-	Mega Pascal
N	-	Newton
N	-	Rotational speed of the cutter
nm	-	Nanometer
pH	-	Potential of Hydrogen
Ra	-	Roughness average
RPM	-	Revolution per minute
V	-	Cutting speed
vol%	-	Volume percentage
wt%	-	Weight Percent
W/m·K	-	Thermal conductivity

CHAPTER 1
INTRODUCTION

This study is set to introduce the research on hybrid nanofluid as a coolant for the drilling process which involved titanium alloy as the workpiece. Further investigation onto this study has been explained in the report organization.

1.1 Background

Nanotechnology has done its part to the technological advances in different bio-materials industries and renewable energy creation in the course of the most recent decade. Nowadays, a transformed interest emerges the utilization of nanotechnology for the petroleum industry, for example like drilling and also manufacturing field. Specifically, addition of nanoparticles into injection fluids may radically favor improved oil recovery, for example, changing the properties of the fluid, wettability variation of rocks, diminishing the interfacial tension etc. (Cheraghian, 2016).

Lately, the traditional heat transfer fluid was replaced by a more advanced fluid such as nanofluid because of its better heat exchange and flow characteristics. The utilization of nanofluids in the system of thermal management brings out not just the better heat exchange and furthermore it lessens size of the heat exchangers. Currently, a portion of the creators examined the execution of warmth exchangers by the use of nanofluids. The warm conductivity of nanofluids is one reason for the upgrade of warmth exchange (Madhesh and Kalaiselvam, 2014).

Conducted investigations on the nanofluids have been expanded quickly all these times. Regardless of some irregularity in the revealed findings and lack of thoughts of how heat transfer works in nanofluids, it has been risen as a favorable heat exchange liquid. In the extension of nanofluids studies, the specialists have additionally attempted to utilize hybrid nanofluid, which in other words, by mixing different nanoparticles either in blend or composite form. The main usage of hybrid nanofluids is to improve the heat transfer in any heat exchanging applications and also machining (Sarkar *et al*., 2015).

Sidik *et al*., (2016) stated that hybrid nanofluids are possible liquids that provide a more enhanced heat exchange performance and thermophysical characteristics than traditional heat exchange fluids such as oil, water and nanofluids with single nanoparticles. Hybrid nanofluid is another nanotechnology fluid that is being produced by the dispersing process with two dissimilar nanoparticles into ordinary heat exchange liquid. In recently conducted research, analysts have demonstrated that hybrid nanofluids can adequately substitute the conventional coolant particularly those working at high temperatures.

A machining operation involves making round holes in metallic and nonmetallic materials which is known as drilling is a most common machining process in manufacturing world. Approximately 75% of all metal-cutting process is of the drilling operation. Drilling process is capable of producing deep hole because the drills have a high length to diameter ratio, however due to its flexibility, necessary precaution need to be taken to maintain accuracy and prevent drill from breaking. Operations related to drilling are such as reaming, tapping, counterboring, countersinking, centering and spot facing. Various cutting conditions in drilling are being taken into consideration before starting the drilling process. These parameters are such as the cutting speed, feed rate, feed, machining time, work thickness and approach allowance.. (Melorose *et al*., 2015).

Palanisamy *et al*. (2009) stated that in drilling, coolants are utilized in eliminating heat produced at the workpiece and interface of tool during machining. These liquids can be utilized as both a coolant to lessen tool temperature and furthermore as a lubricant. Poor delivering of coolant and low pressure can prompt various unfriendly impacts while machining hard to machine materials, for example, titanium and its alloys. There are various cooling techniques

that can be used to reduce the high temperature generated from machining such as the cryogenic, nanofluid, minimum quantity lubrication, dry machining and flood coolant.

The main objective of this study was to investigate the surface roughness, burr formation and thrust force against the volume concentration of hybrid nanofluid as coolant during the drilling process of titanium alloy. Before the experiment, the thermal characteristics of hybrid nanofluid such as thermal conductivity and viscosity were investigated. The optimum concentration of the hybrid nanofluid for drilling of titanium alloy were determined.

1.2 Problem Statement

Titanium alloy is a hard material and thus machining will deteriorate the surface quality of workpiece. During machining, high temperatures are generated due to the friction between cutting tool and workpiece, causing the process becomes inefficient in terms of tool life, material removal rate and workpiece's surface quality. This problem is more pronounced when drilling process is used to drill holes on hardened and difficult-to-cut materials such as titanium alloy. Nowadays, many operators are using fluid coolant such as MQL, flood coolant, nanofluid or even the latest invention, hybrid nanofluid to reduce the high temperature during the drilling process. Hybrid nanofluid is a dispersion of two or more nanoparticles whether in solid particles or in fluid form combining with a single base fluid. From the previous research, it shows that the used of hybrid nanofluid as coolant in machining are still lacking although it has a better thermal conductivity characteristic which can reduce the heat generated during machining. Therefore, the main objective of this study was to investigate the effect of different concentration of hybrid nanofluid as coolant in the drilling of titanium alloy. Surface roughness, burr formation and thrust force during hole drilling has been determined.

1.3 Objective

The objectives of this study are as follows:

i. To investigate the thermal characteristics of hybrid nanofluid such as thermal conductivity and viscosity.

ii. To investigate the surface roughness, burr formation and thrust force of drilled holes against the volume concentration of hybrid nanofluid as coolant during the drilling process of titanium alloy.

1.4 Research Scopes

In this study, the focus was on the investigation of drilling process via CNC milling machine using hybrid nanofluid as coolant on the titanium alloy as a workpiece. Four different concentration (0 wt%, 0.1 wt%, 0.5 wt% and 1.0 wt%) of Graphene-MWCNT hybrid nanofluid with deionized water as the base fluid has been used. The drill bit used in the machining process was high speed Cobalt. Surface roughness, burr formation and thrust force of drilled holes has been determined. During the drilling process, parameters such as feed rate, cutting speed and depth of cut were kept constant.

1.5 Report Organization

In Chapter 1 Introduction, this study was to set and introduced the hybrid nanofluid which was particularly being used in machining such as drilling, milling or turning. As mentioned earlier, hybrid nanofluids are potential liquids that offer better heat exchange performance and thermophysical properties than conventional heat exchange fluids such as oil,

water and ethylene glycol and nanofluids with single nanoparticles. Objective and scope were also prepared in this chapter.

In Chapter 2 Literature Review, the history of nanofluid, hybrid nanofluid, coolant, drilling process and etc. has been discussed. Previous researches used nanofluid in many types of machining and since hybrid nanofluid is a new invention in past few years ago, it is currently being used mostly as heat exchanger and not much in machining. Thus, this study was focusing on drilling process on a titanium alloy using hybrid nanofluid as coolant. The previous researches that utilized the hybrid nanofluid as coolant has been reviewed and summarized.

In Chapter 3 Methodology, the procedures to carry out the dispersion process to produce a hybrid nanofluid and method to carry out the experiments has been explained. The common methods to produce hybrid nanofluid were one-step method or two-step method with two or more nanoparticles combining with a base fluid. Other than that, this study has also discussed the method for obtaining the data such as burr formation, thrust force and surface roughness against the volumetric concentration of hybrid nanofluid being used on each experiment.

In Chapter 4 Results and Discussion, all the data that have been collected from the experiments were analyzed. From the data obtained, critical discussion has been done with the comparison with the previous study.

Finally, in Chapter 5 conclusion and recommendation for improving the experiments were included.