UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MILLING ON TITANIUM ALLOY USING HEXAGONAL BORON NITRIDE (hBn) NANOFLUID AS A COOLANT

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

by

MAISARAH BINTI KURSUS @ OTHMAN
B051520032
951016-01-5914

FACULTY OF MANUFACTURING ENGINEERING
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Alamat Tetap:
NO 38, JALAN JELATANG 7,
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Tarikh: 8.1.2019

Cop Rasmi:
DR. LIEW PAY JUN
Senior Lecturer
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

Tarikh: 8/1/2019

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Date : 8.1.2019

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.). The member of the supervisory committee is as follow:

....

(Dr. Liew Pay Jun)

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(Dr. Liew Pay Jun)

ABSTRAK

Titanium telah digunakan di pelbagai bidang seperti mata pisau kipas pesawat, :i bahan bakar, perkakasan marin dan implan pembedahan. Titanium aloi Ti-6A1-4V ıh salah satu bahan yang sukar untuk dimesinkan kerana sifatnya yang sangat keras. ah konvensional akan membawa kepada kekasaran permukaan kasar, daya ›tongan yang tinggi dan jangka hayat alat pemotong juga menjadi lebih pendek. amat kajian ini adalah untuk mengkaji kesan kepekatan cecair nano boron nitrida ıgon yang berbeza pada kekasaran permukaan, kerosakan mata alat dan daya ›tongan aloi titanium semasa proses penggilingan. Dalam kajian ini, empat kepekatan r nano boron nitrida heksagon yang berlainan telah digunakan iaitu 0.00% berat, ⁄o berat, 0.06% berat dan 0.1% berat dan impak pengilangan aloi titanium ;gunakan cecair pemotong konvensional(0.00% berat) dan cecair nano boron nitrida ıgon telah dibezakan. Cecair nano boron nitrida heksagon telah disediakan dengan :ampurkan boron nitrida heksagon dengan air dinyah-ion dan PVP K30 sebagai ktan. Parameter lain seperti kadar suapan, kelajuan pemotongan dan kedalaman ›tongan tetap malar. Penggunaan cecair nano boron nitrida heksagon menyebabkan saran permukaan yang lebih rendah, daya pemotongan yang lebih rendah dan sakan mata alat yang lebih rendah semasa penggilingan aloi titanium.

ABSTRACT

Recently, titanium has been used for many areas such as aircraft turbine blade, fuel tanks, marine hardware and surgical implant. Titanium alloy Ti-6A1-4V is one of the materials that difficult to machine due to its hardness. The conventional method will lead to rough surface roughness, high cutting force and the tool life is shorter. The aim of this study is to investigate the effect of different concentration of hexagonal boron nitride (hBn) nanofluid on the surface roughness, tool wear and cutting force of titanium alloy using milling process. In this research, four different concentrations of hBn nanofluid were used which are 0.00 wt%, 0.02 wt%, 0.06 wt% and 0.1 wt% and the milling performance between conventional cutting fluid (0.00 wt%) and nanofluid were compared. HBn nanofluid was prepared by mixing the hBn with deionized water and PVP K30 as a surfactant. The other parameters such feed rate, cutting speed and depth of cut were remained constant. The used of hBn nanofluid cause lower surface roughness, lower cutting force and lower tool wear during the milling of titanium alloy.

DEDICATION

Only

my appreciated father, Kursus @ Othman

my beloved mother, Dayang Salwa

my adored brothers and sisters

my beloved friends

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

Thank You So Much

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ASTM	-	American Society for Testing and Materials
SEM	-	Scanning Electron Microscope
ISO	-	International Organization for Standardization
CFRP	-	Carbon Fiber Reinforced Polymer
HR	-	Rockwell Hardness
ANOVA		Analysis Of Variance

LIST OF SYMBOLS

wt %	-	Weight percentage
R_a	-	Surface roughness
F	-	Force
V_c	-	Cutting speed
D	-	Cutter diameter
f_{zt}	-	Tangential feed per tooth
a_p	-	Axial cutting depth
F_x	-	Force on x-axis
F_y	-	Force on y-axis
F_z	-	Force on z-axis
%	-	Percentage
mm	-	millimeter
^oC	-	Degree Celsius
RPM	-	Revolution Per Minute
µm	-	Micrometer
nm	-	Nanometer

CHAPTER 1

INTRODUCTION

This research emphasized in the milling process by using a different concentration of nanofluid. This chapter also includes the problem statement, objective and scope respectively.

1.1 Research Background

Titanium alloy Ti-6A1-4V is one of the materials that difficult to machine because of its extremely high hardness (Hong *et al.*, 1999). Recently, titanium has been used for many areas such as aircraft turbine blade, fuel tanks, marine hardware (Asyby and Johnson, 2009). Other than that, titanium also has been used for surgical implant and any biomedical application.

The usage of titanium alloy is rapidly increasing nowadays due to the outstanding properties such as high compressive and tensile strength, low density but high fatigue resistance in air and in the water (Zhang *et al., 2008*). Common operation for titanium alloy including drilling, grinding, milling and turning because all of these machining methods are required in order to cut hard material like titanium alloy.

Milling is the process that used to produce different profile and curved. High-speed steels or carbide inserts usually used to make a tools for end milling or face milling. The cutter commonly rotates on an axis perpendicular to the work piece surface, and it also can be tilted to conform to machine tapered or curved surfaces. Milling operation commonly involving feed rate, cutting speed, depth of cut which those all the parameters need to be conducted well in order to get the optimization of cutting process. Due to the relative motion between the cutter teeth and the workpiece, face milling leaves feed marks on the machined surface (Kalpakjian and Schmid, 2010). Feed rate and cutting speed increase resulting the rising of cutting force value due to the high correlation between cutting force and cutting area (Gariani *et al.*, 2017). Thus, cooling technique should be introduced in order to minimize the cutting force and tool wear.

Cooling technique is used to reduce the heat and smooth the surface finish of workpiece. The cooling techniques that commonly used in the milling operation are dry machining, wet machining, Minimum Quantity Lubricant (MQL) and cryogenic cooling. Dry machining is a machining procedure that carried out without the assistance of cutting fluids (Goindi and Sarkar, 2017). This technique become very popular and many manufacturers that use metal on their product find it is very useful nowadays because it is cost saving, environmental sustainability and can increase tool life. Meanwhile, wet machining is one of the most efficient techniques to reduce heat on the hard material machining operation. This technique able to smooth the operation so that it will decrease the cutting force (Razak *et al.*, 2017). MQL is a method that has been used widely in a various industry. MQL usually are found on the machining of high speed machining such as turning, face milling and boring because it is more economical compared to low speed machining. MQL technique can reduce tool wear, cutting force, surface roughness and machining zone temperature (Singh *et al.,* 2017). Besides, cryogenic cooling that commonly used liquid nitrogen as the cooling media is considered as a sustainable alternative to conventional flood cooling application in the machining process (Tao *et al.*, 2018). This method is very useful because it can lower the cutting temperature significantly.

Recently, nanofluid has been widely used in machining for cooling purpose. Nanofluid is a fluid which contains nanometer-sized solid particles (Choi and Eastman, 1995). Even the use of nanofluid is very famous in different industry but the use of Hexagonal Boron Nitride (hBn) as nanofluid as the nanomaterial is hardly found form the previous research. hBn is one of the recycled materials that contain large amount of silica. Silica is one of the materials that have high thermal conductivity. Thus, this research is a part of treasure that need to be discussed in detail to analyse the use of hBn as the nanoparticles in the nanofluid as a coolant during a milling process on the titanium alloy.

1.2 Problem Statement

Titanium is well known as materials that have a very strong characteristic, but it has been categorized as a material that difficult to cut. When machining the titanium, the heat will not dissipate and tend to concentrate at the cutting edge and lead cutting tool failure in a short time. Titanium also has strong chemical reactivity with the cutting material which also leads to rapid tool wear (Hartung *et al.*, 1982).

In milling process, many types of cooling techniques have been exposed. In order to reduce the temperature of insert, lubricate the cutting tool, and to remove the chip optimally, cooling technique is very important to be included in the machining operation. There are five cooling techniques regularly used in milling which are dry machining, wet machining, MQL cryogenic cooling and nanofluid. Nanofluid is a dispersion of nanoparticles in the base fluid. Since it has an anomalous thermal conductivity, it has an important role in order to reduce the heat in cutting during milling and finally increase the tool life.

Previous research showed that hBn commonly used as a lubricant for bearing industry due to the properties contain. None of the research so far used hBn as nanoparticles in nanofluid as coolant in milling process. Thus, this research focuses on the effect of hBn nanofluid as coolant on the machining performance of titanium alloy.

1.3 Objectives

The objectives are as follows:

(a) To investigate the effect of different concentration of Hexagonal Boron Nitride (hBn) nanofluid on the surface roughness, tool wear and cutting force of the milling of titanium alloy.

(b) To compare the effect of conventional cutting fluid and nanofluid on the machining performances.

1.3 Scopes of the Research

This research will focus on the different concentrations of hBn nanofluid in the milling operations. The cutting tool that will be used is coated carbide insert with diameter of 20 mm. To prepare the nanofluid, deionized water will be used as a base fluid. There are four different nanofluid concentrations which are 0.0 wt%, 0.02 wt%, 0.06 wt% and 0.1 wt% will be used in this research. Meanwhile, the others parameters involve in this research including cutting speed, feed rate and depth of cut will be remaining constant during experiment. The result of the surface roughness, cutting force and tool wear by using conventional cutting fluid and nanofluid will be collected and compared.

CHAPTER 2

LITERATURE REVIEW

This chapter described the theory and research which have been defined and done by various researcher years ago. Related information of previous studies is extracted as references and discussion based on their research about milling, titanium alloy, nanofluid, and cooling fluid. Further explanation will be elaborated in this chapter.

2.1 Milling

One of the machining processes that include a number of highly versatile machining operations is milling process. This process has a variation of configuration by using a milling cutter. In other word, milling cutter also known as multitooth tool that produces number of chips in one revolution (Kalpakjian and Schmid, 2010)

2.1.1 End Milling

End milling is very common machining operation and important because of its versatility and capability to produce many different profiles and curved surfaces. The cutter, called an end mill has either a straight shank (for small cutter sizes) or a tapered shank (for larger sizes) and is mounted into the spindle of the milling machine. The tools for end milling usually made of high-speed steels or with carbide inserts, similar to those for face milling. The cutter commonly rotates on an axis perpendicular to the work piece surface, and it also can be tilted to conform to machine tapered or curved surfaces.

Noted that end mill also can produce a variety of surface at any depth, such as curve, stepped and pocketed (Kalpakjian and Schmid, 2010).

Milling is the common operation used in many experiment. For example Li *et al.* (2017) studied about milling performance optimization of DD5 Ni-based single-crystal super alloy. Moreover, Kim *et al.* (2017) have done the experimental characterization on micro-end milling of titanium alloy using nanofluid minimum quantity lubrication by using nanodiamond as a nanofluid with vegetable oil as a based fluid.

2.1.2 Application of Milling

Milling is suitable for the hard material machining. For instance, aerospace industry (Wang *et al.,* 2015; Whinnem *et al.,* 2009), automotive (Zhao *et al.*, 2015; Ishida et *al.*, 2014) and other industry for boreholes that required high accuracy. Generally, the materials that machining by helical milling including carbon fiber reinforced plastics (CFRP) (Liu *et al.*, 2014) aluminum alloys (Eguti *et al.*,2014), Die Steel Cr12 (Qin *et al.*,2014), titanium alloy also included (Olvera *et al.,*2012) and others. Notes that helical milling is highly used for cut this material based on different machines, tools, and lubricant condition.

2.2 Insert

There are many types of milling are used in the industry. For the face or end milling operations, insert has been used in order to cut the materials. There are several types of insert, which are coated or coated and those with several of angle such as corner radius, corner flat and wiper. The wear mechanism, mechanical fatigue, impact stress, and the formation of thermal cracks can be different from those associated if using fully loaded cutter (Chandrasekaran and Thoors, 1994: Tlusty, 1984).

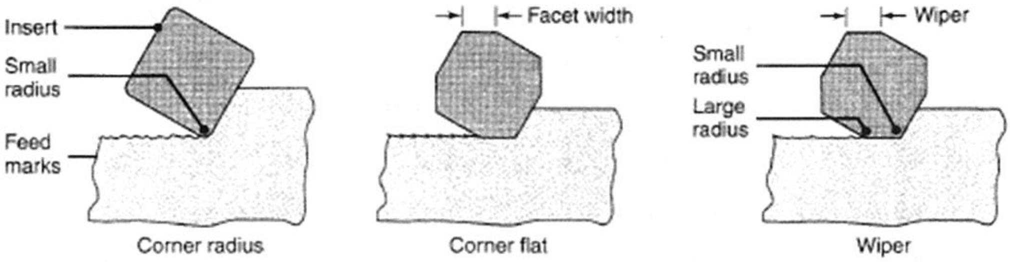

Figure 2.1: Cutting operations using different radius (Kalpakjian and Schmid, 2010)

Figure 2.1 shows various angle of face mill insert. From the different angle of insert, noted that surface roughness of the workpiece is depends on the corner geometry of the insert and the feed per tooth. Due to the relative motion between the cutter teeth and the workpiece, face milling leaves feed marks on the machined surface (Kalpakjian and Schmid, 2010). From the previous research done by Minh *et al.* (2017), they used uncoated cemented carbide insert with flank angle, 11^0 and nose radius, 0.66 mm in order to cut the hard material such as $60Si_2$ Mn steels. Meanwhile, Songmei *et al.* (2017) used two teeth inserts ACM300 and diameter of 16 mm as a cutting tool milling of Ti-6Al-4V.

2.3 Titanium Alloy (Ti-6AL-4V)

Titanium alloy Ti-6A1-4V is one of the materials that difficult to machine (Hong *et al.*, 1999). Titanium Alloy has poor conductivity. Thus, when machining titanium alloy, the heat cannot dissipate quickly and concentrated on the cutting edge and tool face (Machado *et al.*, 1990). Titanium also has a strong alloying tendency or chemical reactivity that will cause galling and smearing, along with rapid wear or cutting tool failure (Hartung *et al.*, 1982).

During machining, titanium alloys regularly exhibit thermal plastic instability which leads to unique characteristics of chip formation (Donachie *et al.*, 1982).