



## **Faculty of Manufacturing Engineering**

# **THE EFFECT OF CUTTING PARAMETER, SURFACE INTEGRITY AND TOOL WEAR ON AISI D2 TOOL STEEL IN DRY MILLING PROCESS**

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WEAR ON AISI D2 TOOL STEEL IN DRY MILLING PROCESS**

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**TAJUK: The Effect of Cutting Parameter, Surface Integrity and Tool Wear On AISI D2 Tool Steel in Dry Milling Process**

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## APPROVAL

I hereby declare that I have read this dissertation and in my opinion this dissertation is sufficient in terms of scope and quality as a partial fulfilment of Master of Manufacturing Engineering (Manufacturing System Engineering).

**Signature** :  .....

**Supervisor Name** : **Dr. Mohd Shukor Bin Salleh**

**Date** : **25/03/2017**

## **DEDICATION**

This dissertation is dedicated to my beloved parents, my lovely wife, my son, family and friends.

## ABSTRACT

Surface integrity and tool wear has become a very significant consideration in order to achieve optimum cutting parameter along with the recent evolutions in hard milling technology. This project was conducted to study the effect of cutting parameters on tool wear and surface roughness using AISI D2 tool steel in dry milling process. HAAS CNC Milling Machine was utilized in this project to remove the material surface. The parameters that had been selected were cutting speed, feed rate and depth of cut. A dry milling process was conducted during the machining process. The cutting tool that had been selected was TiAlN coated carbide endmill. The diameter of the cutting tools is 10 mm. AISI D2 tool steel was selected as the work piece material. The size of the material is 50 mm x 40 mm with 30 mm thickness. The design of experiments in this project was using the Taguchi method with L9 of orthogonal array. Then, by using the Mitutoyo surface roughness tester with ten points tested, the average surface roughness were measured. The surface integrity of the workpiece and the tool wear rate of the cutting tool were later analysed using the stereo microscope. In order to determine the optimum machining parameter, Taguchi method was used by using Minitab 17 software. This analysis was conducted to identify which cutting parameter that significantly affected the surface roughness and the tool wear rate. From the analysis, the optimum cutting parameter to get the minimum surface roughness is cutting speed is 200 m/min, the feed rate is 0.015 mm/tooth and depth of cut is 0.1 mm. It shows that the feed rate is the most influence parameter that contributed the highest effect of surface roughness and followed by the cutting speed and depth of cut. The optimum cutting parameter that contributes to the lowest tool wear is cutting speed is 150 m/min, feed rate is 0.010 mm/tooth and depth of cut is 0.2 mm. The obtained results showed that the depth of cut has a significant influence on the tool wear rate. As for the surface integrity, the workpiece surface with lowest surface roughness shows the less existence of feed marks on the machined surfaced workpiece. The low value of depth of cut assists in obtaining a finer surface finish.

## ABSTRAK

*Integriti permukaan dan penggunaan alat telah menjadi satu pertimbangan yang amat penting untuk mencapai parameter pemotongan yang optimum selari dengan perkembangan terkini dalam teknologi pengilangan keras. Projek ini telah dijalankan untuk mengkaji kesan parameter pemotongan pada kehausan mata alat dan kekasaran permukaan menggunakan keluli AISI D2 dalam proses pengilangan kering. Mesin pengisar HAAS telah digunakan dalam projek ini untuk membuang permukaan bahan. Parameter yang telah terpilih adalah kelajuan pemotongan, kadar suapan dan kedalaman pemotongan. Proses pengisaran kering telah dijalankan semasa proses pemesinan. Alat pemotongan yang telah dipilih adalah mata pengisar karbida bersalut TiAlN. Diameter alat memotong adalah 10 mm. Keluli AISI D2 telah dipilih sebagai bahan benda kerja. Saiz bahan adalah 50 mm x 40 mm dengan 30 mm tebal. Reka bentuk eksperimen dalam projek ini telah menggunakan kaedah Taguchi dengan susunan L9 ortogon. Kemudian, dengan menggunakan penguji kekasaran permukaan Mitutoyo dengan sepuluh mata diuji, purata kekasaran permukaan diukur. Integriti permukaan bahan kerja dan kadar kehausan mata alat pemotongan kemudiannya dianalisis menggunakan mikroskop stereo. Seterusnya, untuk menentukan parameter pemesinan yang optimum, kaedah Taguchi digunakan dengan menggunakan perisian Minitab 17. Analisis ini dijalankan untuk mengenalpasti parameter pemotongan yang mempengaruhi kekasaran permukaan dan kadar kehausan mata alat. Daripada analisis, parameter pemotongan yang optimum untuk mendapatkan kekasaran permukaan minimum adalah kelajuan pemotongan 200 m/min, kadar suapan adalah 0.015 mm/gigi dan kedalaman pemotongan ialah 0.1 mm. Ia menunjukkan bahawa kadar suapan adalah parameter yang paling menyumbang kesan paling tinggi pada kekasaran permukaan dan diikuti dengan kelajuan pemotongan dan kedalaman pemotongan. Parameter pemotongan optimum yang menyumbang kepada kehausan mata alat yang paling rendah adalah kelajuan pemotongan 150 m/min, kadar suapan adalah 0.010 mm/gigi dan kedalaman pemotongan ialah 0.2 mm. Keputusan yang diperolehi menunjukkan bahawa kedalaman pemotongan mempunyai pengaruh yang besar ke atas kadar kehausan mata alat. Bagi integriti permukaan, permukaan bahan kerja dengan kekasaran permukaan yang rendah menunjukkan kewujudan tanda memakan mesin yang kurang timbul pada bahan kerja. Nilai kedalaman pemotongan yang rendah membantu mendapatkan kemas permukaan yang lebih halus.*



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## LIST OF ABBREVIATIONS

AISI	-	American Iron and Steel Institute
C	-	Carbon
CNC	-	Computer Numerical Control
Co	-	Cobalt
Cr	-	Chromium
HSS	-	High Speed Steel
Mn	-	Manganese
Mo	-	Molybdenum
Ra	-	Mean Roughness
RPM	-	Revolution per Minutes
TiAlN	-	Titanium Aluminium Nitride
V	-	Vanadium
Vb	-	Flank Wear
Vc	-	Crater Wear

# CHAPTER 1

## INTRODUCTION

### 1.0 Introduction

This study title is the effect of cutting parameter, surface integrity and tool wear on AISI D2 tool steel in the dry milling process. In this study, the optimal parameter in the dry milling process that produce the finest surface roughness and the minimum tool wear can be determined. This chapter explained about the introduction of the project, which consists of the project background, problem statement, objectives and the project scope.

### 1.1 Background of the study

Generally, many studies have been carried out to improve the machinability of hard-to-machine steel materials. Motorcu et al. (2013) defined machinability as the easiness or difficulty in a machining operation involving cutting conditions such as cutting speed, feed rate and depth of cut. Moreover, machinability of a material can be defined by measuring the tool life, surface roughness and cutting force. Machinability is an essential consideration in machining process. Therefore, the corresponding cutting conditions represent an important element in process planning for machining. Hence, this study conducted to see how cutting parameters affect the surface roughness and tool wear while identifying the suitable machining process that maintaining the quality of surface integrity and keeping longer tool life.

In this study, CNC machine is used to mill AISI D2 tool steel under dry milling condition. TiAlN coated carbide endmill with the diameter 10 mm is used. Taguchi method



design of experiment is used to determine the optimum cutting parameter for surface finish and tool wear of AISI D2 tool steel. The surface roughness of the workpiece will be tested using the Mitutoyo surface roughness measuring tester and stereo microscope will be used to analyse the tool wear of the cutting tool. Minitab 17 software is used for analyses and arranges the data of the experiment.

## **1.2 Problem Statement**

Hard milling is a machining process that allows machine shops to mill material with higher Rockwell hardness. Ability to produce complex shapes, fine surface roughness and higher material removal rate makes hard milling has broad application in mould and die industries. However, to fulfil the technology of hard milling requires the selection of proper tools and cutting conditions. Thus, further study should be conducted to see how cutting parameters affect the surface integrity and tool wear. This analysis can assist in identifying the suitable machining process that maintaining the quality of surface integrity and to keep longer tool life.

## **1.3 Objectives**

The objectives of this study are:

- a) To investigate the optimum cutting parameter for dry milling of AISI D2 tool steel.
- b) To analyse the effect of cutting parameter on surface roughness and tool wear regarding to the cutting speed, feed rate and depth of cut.
- c) To observe the tool wear characteristic and surface integrity.

## **1.4 Scope of the study**

The study focuses on the effect of cutting parameter on surface integrity and tool wear. AISI D2 tool steel with the dimension of 50 mm × 40 mm × 30 mm will be used as a workpiece material. The machining process will be used HAAS CNC Milling Machine and 10 mm diameter TiAlN coated carbide endmill. The surface roughness of AISI D2 tool steel will be analysed by Mitutoyo Surface Roughness Tester and the tool wear of TiAlN coated carbide endmill will be analysed by stereo microscope. This experiment will be run under dry milling condition with machine parameter which is cutting speed (150 m/min, 200 m/min, 250 m/min), depth of cut (0.1 mm, 0.2 mm, 0.3 mm) feed rate (0.005 mm/tooth, 0.010 mm/tooth, 0.015 mm/tooth) and radial depth of cut is 1 mm.

## **1.5 K-Chart**

Refer to Appendix A.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.0 Introduction

In the industries, several techniques are used to reduce the manufacturing costs and to protect the environment. In machining process, the used of cutting fluid could play an important role in different parameter such as tool life, cutting temperature, surface finish, chip formation and metallic particle emission. Islam et al. (2012) claimed that the surface roughness of different work materials is influenced differently by the cutting fluid supply strategies. Therefore, there is a scope for optimizing the cutting fluid supply strategy in terms of both method and the amount of cutting fluid. Because of that, the elimination of the use of cutting fluids, if possible, can be a significant incentive. Hence the implementation of dry machining will reduce manufacturing costs. However, it should also be noted that some of the benefits of cutting fluids are not going to be available for dry machining and also dry machining will be acceptable only whenever the part quality and machining times achieved in wet machining are equalled or surpassed. For this reason, technology has to be further improved if dry cutting is to be fully employed in industries.

#### 2.1 Milling Machine

Milling machines are tools designed to machine metal and other solid materials. Often automated, milling machines can be positioned in either vertical or horizontal orientation to carve out materials based on a pre-existing design. Milling is a widely employed material removal process for different materials. Milling process leads to high

friction between tool and workpiece, and can result high friction between tool and workpiece, and can result high temperatures, impairing the dimensional accuracy and surface quality of product (Shahrom et. al, 2013).

## 2.2 Wet Machining

Friction between workpiece and cutting tool cause high temperature on cutting tool during machining process. The effect of this generated heat decreases tool life and increases surface roughness. Therefore, the application of cutting fluids is to protect cutting tool from the generated heat. Besides that, cutting fluid significantly provides more efficient chip removal. As discussed by Najiha et al. (2012), metal working fluids or cutting fluids is used to minimize the thermal expansion of the worked metals, and thus aid in achieving a better surface finish on the finished product and a longer tool life.

Based on Debnath et. al (2016) result on experiments were carried out on mild steel bar using a TiCN + Al<sub>2</sub>O<sub>3</sub> + TiN coated carbide tool insert in the CNC turning process, cutting fluid also showed a significant contribution to surface roughness (33.1%) as well as to tool wear (13.7%). It showed that cutting fluids helps increase tool life and improve efficiency of the production systems by providing both cooling and lubricating during machining and remove chips from the work surface.

However, several negative effects causes by cutting fluid when handled inappropriately. Boubekri and Shaikh (2012) investigated that the exposure to such amounts of metal working fluid may contribute to adverse health effects and safety issues. This indicates that the operator may experience negative effects of the cutting fluids. Due to the issues of using cutting fluid in machining have many negative impacts in manufacturing, a detail study need to be done for an option to reduce their use.

### **2.3 Minimum Quality of Lubrication (MQL)**

In machining process, the function of the cutting fluid is to minimize the heat produced between the surface of the part and tool. Minimum Quantity of Lubrication (MQL) is an alternative in machining by using the minimal amount of cutting fluids. MQL can be used in order to provide cooling over the tool-workpiece interface and reduce the quantity of heat generated due to friction. Amini et al. (2015) stated that fluid flow rate, fluid frequency, nozzle position and distance are effective parameters in MQL machining.

From the experiments by Yazid et al. (2011) on the effects of Dry and Minimum Quantity Lubrication conditions on finish turning Inconel 718 using PVD coated TiAlN carbide tool showed that MQL produces better surface roughness than dry condition. Furthermore, it's supported by Vishwakarma et al. (2014) study that the cutting performance of MQL machining is better than that of dry and conventional machining and helps improve tool life and also gives better finished surface. Elmunafi et al. (2015) showed that, by using small amount of lubricant of 50 ml/h during turning process was able to produce better results compared to dry cutting, especially in terms of longer tool life. This proves that with flood cutting fluid supply MQL provides the benefits mainly by reducing the cutting temperature, which improves the chip-tool interaction and maintains sharpness of the cutting edges.

### **2.4 Dry Machining**

Dry machining is an alternative to enforce environmental protection laws for occupational safety and health regulations regarding conventional flooded cooling practice. Besides offering cost reduction in machining, the advantages of dry machining include non-injurious to skin and allergy free. Moreover, it reduced disposal and cleaning costs.

However, Wernsing and Büskens (2015) stated that dry machining is not established in mass production yet, since the maintenance of shape and functionality of the machined parts is not guaranteed. In terms of surface quality, operation time and tool life, dry machining processes need to give comparable results as conventional machining processes. For example, Sugihara et al. (2015) reported in the dry machining of aluminium alloys, aluminium chips strongly adhere to the surface of a cutting tool, which significantly deteriorates cutting performance.

Besides that, Sharma and Sidhu (2014) performed a research on effects of dry and near dry machining on AISI D2 steel using vegetable oil. Figure 2.1 showed the effect of dry and near dry machining on cutting temperatures for various cutting speeds and feed rates while Figure 2.2 showed the effect of dry and near dry machining on surface roughness (Ra) for various cutting speeds and feed rates. The chart explains that dry machining is showing a tremendous increase in cutting temperatures as compared to near dry machining when increasing cutting speed.

The temperature of the cutting zone rises quickly as rubbing of tool and workpiece produces heat at the interfaces and can damage the surface integrity of the work-piece and cause damage to the tool. The heat generated may cause workpiece softening as well as reduces the strength and hardness of the cutting tool. As expected, near dry machining has shown a great reduction in roughness as compared to dry machining.

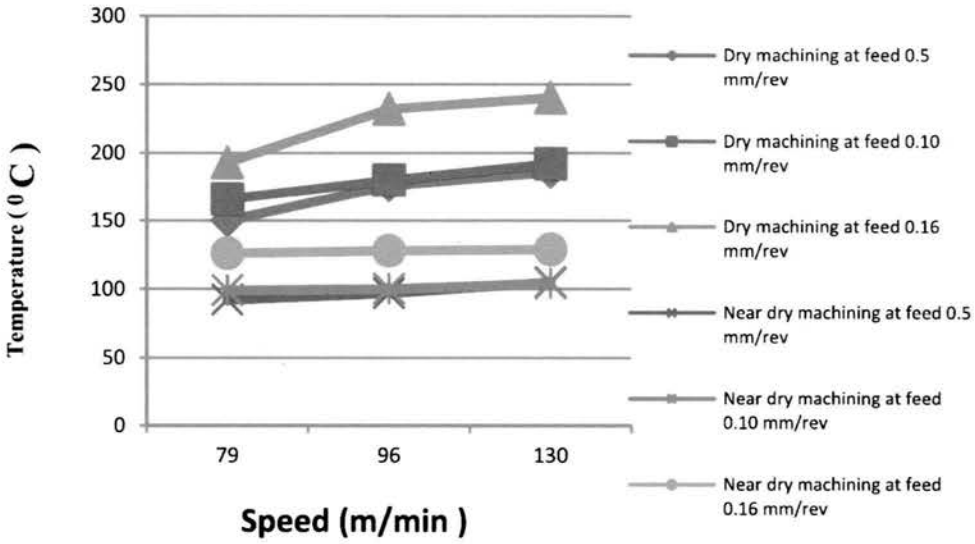


Figure 2.1 : Effect of near dry and dry machining on temperature at different feed rate and speeds. (Sharma and Sidhu, 2014)

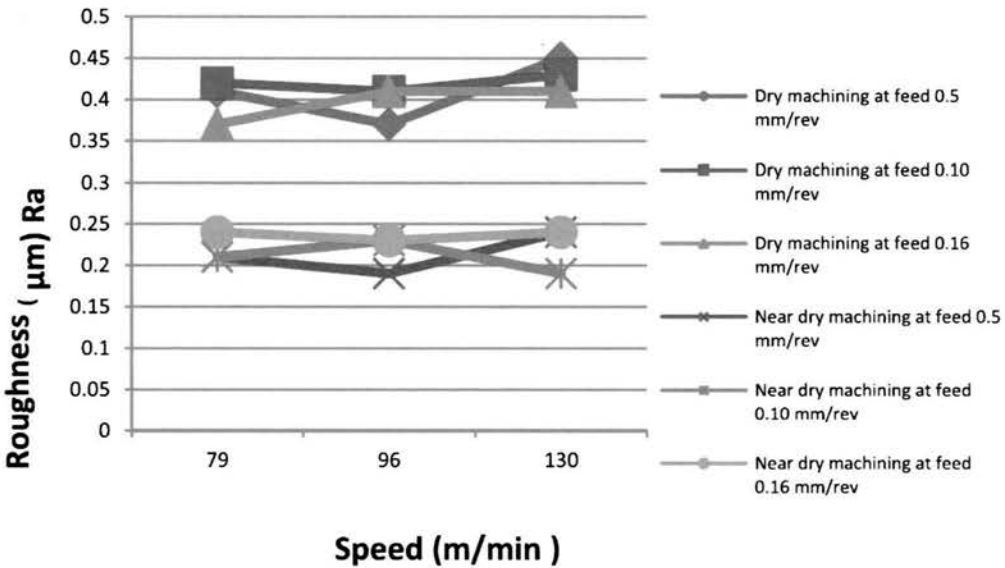


Figure 2.2 : Effect of near dry and dry machining on surface roughness at different feed rate and speeds. (Sharma and Sidhu, 2014)

## 2.5 Cutting Tool

Machining of materials is recognized as removing unwanted materials by using different cutting inserts with variable cutting parameters. The selection of cutting tool materials for a particular application is among the most important factors in machining operations, as is the selection of mould and die material for forming and shaping process. The cutting tool is subjected to high temperatures, high contact stress, and rubbing along the tool chip interface and along the machined surface. Consequently, the cutting tool material must possess the following characteristic like hot hardness, toughness and impact strength, thermal shock resistance, wear resistance, and chemical stability and inertness.

### 2.5.1 Cubic Boron Nitride (CBN)

Cubic Boron Nitride (CBN) is a high-performance tool material from a polycrystalline mass, that's similar to Polycrystalline Diamond (PCD) that produced in a high temperature-pressure process. Thamizhmanii et al. (2015) stated that machining of materials by super hard tools like Cubic Boron Nitride (CBN) and Poly Cubic Boron Nitride (PCBN) is to reduce tool wear in order to obtain dimensional accuracy, smooth surface and more number of parts per cutting edge. Wear of tools is inevitable due to rubbing action between work material and tool edge. CBN and PCBN cutting tools are used to machine difficult to cut materials like high strength alloy steels, stainless steel, Inconel 718, Titanium etc. The main application range is ferrous materials possessing hardness from approximately 45 HRC as well as grey cast iron, Cr-chilled cast iron and wear alloys on a cobalt, nickel or iron basis. CBN, its hardness only surpassed by a diamond, is suitable for the machining of materials that cannot be machined with PCD or monocrystalline diamond.