Faculty of Manufacturing Engineering

# OPTIMIZATION ON MILLING MACHINING PERFORMANCES OF AISI D2 STEEL USING TAGUCHI METHOD



Riduan bin Ismail

Master of Manufacturing Engineering
(Quality System Engineering)

2020

# OPTIMIZATION ON MILLING MACHINING PERFORMANCES OF AISI D2 STEEL USING TAGUCHI METHOD

**RIDUAN BIN ISMAIL**

**A dissertation submitted in fulfilment of the requirement for the degree of Master of Manufacturing Engineering (Quality System Engineering)**



**Faculty of Manufacturing Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

**2020**

# DECLARATION

I declare that this dissertation entitled "Optimization On Milling Machining Performances of AISI D2 Steel Using Taguchi Method" is the result of my own research except as cited in the references. The dissertation has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....................................

Name : Riduan bin Ismail

Date : 28/01/2020

# 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 (Quality System Engineering).

Signature : ..................................................

Supervisor Name : PM Ir. Ts. Dr. Mohd Shukor bin Salleh

Date : 28/01/2020

**DEDICATION**

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

## ABSTRACT

Surface integrity and tool wear is important to determine the quality of machine surface in order to achieve optimum cutting parameter. This project was conducted to study the optimum of cutting parameters on tool wear and surface roughness using AISI D2 steel under dry milling process. The cutting tool that has been selected was uncoated carbides end mill and the size of the AISI D2 steel is 100 mm x 60 mm x 20 mm. Deckel Maho DMU 60 CNC Milling machine was utilized in this project to remove the surface of material. The main controllable milling parameters that have been investigated in this project were cutting speed, feed rate and depth of cut. The machining parameters used in this experiment were cutting speed (50 m/min, 70 m/min and 90 m/min), feed rate (0.05 mm/rev, 0.075 mm/rev and 0.1 mm/rev) and depth of cut (0.1mm, 0.3mm and 0.5 mm). In this experiment, Taguchi method is used to obtain the optimum parameters via Minitab 17 software. Mitutoyo surface roughness tester was used to determine the average of surface roughness. The tool wear rate of the cutting tool is analysed using the stereo microscope. Analysis was performed using experimental result and ANOVA. The effect of dry machining condition on surface roughness and tool wear of the workpiece is also analysed. Based on the analysis, the optimum cutting parameter to get the minimum surface roughness were cutting speed (70 m/min), feed rate (0.05 mm/rev) and depth of cut (0.5 mm), while the optimum cutting parameter to get the minimum tool wear were cutting speed (50 m/min), feed rate (0.05 mm/rev) and depth of cut (0.1 mm). It shows that the cutting speed is the most influence parameter that contributed to the highest effect of surface roughness and tool wear followed by the feed rate and depth of cut.

## *ABSTRAK*

*Keutuhan permukaan dan kehausan mata alat merupakan perkara yang penting dalam menentukan kualiti permukaan sesuatu komponen yang dimesin untuk mencapai parameter pemotongan yang optimum. Projek ini mengkaji kesan parameter pemotongan pada kekasaran permukaan dan kehausan mata alat menggunakan keluli AISI D2 dalam proses kisaran kering. Alat pemotongan yang dipertimbangkan adalah kisar rata karbida tanpa salut dan saiz bahan kerja adalah 100 mm x 60 mm x 20 mm. Mesin kisar CNC Deckel Maho DMU 60 telah digunakan dalam projek ini untuk membuang permukaan bahan. Parameter-parameter yang dipertimbangkan ialah kelajuan pemotongan (50 m/min, 70 m/min dan 90 m/min), kadar suapan (0.05 mm/rev, 0.075 mm/rev dan 0.1 mm/rev) dan kedalaman pemotongan (0.1mm, 0.3mm dan 0.5 mm). Reka bentuk eksperimen dalam projek akan menggunakan kaedah Taguchi dalam perisian Minitab 17. Kemudian, dengan menggunakan penguji kekasaran permukaan Mitutoyo, purata kekasaran permukaan diukur. Kadar kehausan mata alat pemotongan telah dianalisis menggunakan mikroskop stereo. Analisa yang dilakukan adalah menggunakan keputusan eksperimen, carta dan juga ANOVA. Projek ini menerangkan kesan pemotongan kisar kering ke atas kekasaran permukaan dan haus mata alat. Daripada analisis, parameter pemotongan yang optimum untuk mendapatkan kekasaran permukaan minimum adalah kelajuan pemotongan 70 m/min, kadar suapan adalah 0.05 mm/rev dan kedalaman pemotongan ialah 0.5 mm, manakala parameter pemotongan yang optimum untuk meminimumkan kehausan mata alat adalah pada kelajuan pemotongan 50 m/min, kadar suapan adalah 0.05 mm/rev dan kedalaman pemotongan ialah 0.1 mm Ia menunjukkan bahawa kelajuan pemotongan adalah parameter yang paling menyumbang kesan paling tinggi pada kekasaran permukaan dan kehausan mata alat, diikuti dengan kadar suapan dan kedalaman pemotongan. Ini menunjukkan bahawa kelajuan pemotongan adalah merupakan parameter paling mempengaruhi yang memberi kesan kepada kekasaran permukaan dan kehausan mata alat, diikuti dengan kadar suapan dan kedalaman pemotongan.*

# ACKNOWLEDGEMENTS

Alhamdulillah, I would like to thank to Allah S.W.T, the Most Merciful, and all praises to Allah for His blessing in completing this dissertation. Special acknowledgement to my supervisor, Associate Professor Ir. Ts. Dr. Mohd Shukor bin Salleh for his essential supervision, support and encouragement towards the completion of this dissertation. Highly appreciate to Associate Professor Ir. Ts. Dr. Mohd Amran bin Md Ali for his advice and suggestions in analyzing the collection of data in this project.

Special thanks to everybody who help me especially IKTBN Pagoh staff to accomplish this dissertation. For all helpful lecturers and assistant engineer, thank for supporting me everything regarding this project, teaching me some new and valuable knowledge while conducting this experiment.

Last but not least, I would like to thank my family for trusting me and my friends that encouraged, supported and helped me in completing this dissertation successfully. I am also obliged to everyone who had directly or indirectly involved through the contributions of ideas, as well as materials and professional opinions.

## TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

## LIST OF FIGURES

# LIST OF APPENDICES

## LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| AISI | - | American Iron and Steel Institute |
| ANOVA | - | Analysis of Variance |
| ANSI | - | American National Standard Institute |
| C | - | Carbon |
| CBN | - | Cubic Boron Nitride |
| CNC | - | Computer Numerical Control |
| Co | - | Cobalt |
| Cr | - | Chromium |
| DOC | - | Depth of Cut |
| EDM | - | Electrical Discharge Machining |
| HRC | - | Rockwell Hardness Type C (unit) |
| HSS | - | High Speed Steel |
| ISO | - | International Organization for Standardization |
| JIS | - | Japanese Industrial Standards |
| Mn | - | Manganese |
| Mo | - | Molybdenum |
| MRR | - | Material Removal Rate |
| MQL | - | Minimum Quality of Lubrication |
| OA | - | Orthogonal Array |
| PCBN | - | Poly Cubic Boron Nitride |
| PCD | - | Polycrystalline Diamond |
| Ra | - | Mean Roughness |
| RSM | - | Response Surface Methodology |
| S/N | - | Signal-to-Noise |
| V | - | Vanadium |
| $V_B$ | - | Flank Wear |
| Vc | - | Cutting speed |
| VDA | - | German Association of the Automotive Industry |

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

Until now, technology of machining still an important technology in the mould and die manufacturing industry to acquire complex profiles in the design. Machining is also indispensable to produce high precision geometry. Based on the use and application of mould and dies in the manufacturing sector, the resulting geometry is different and depends on the condition it is used. Moulds and dies that used to produce high quality products are often applied to conditions such as high temperature conditions and high pressure conditions. This makes a mould or die, must be designed and fabricated from the material that can overcome the constraints arising from the application in such conditions. Normally, the materials that used to producing a mould or die are high strength of steel group. High strength steel is referring to the use of hardened steel, wherein this type of steel is also suitable for use in conditions such high temperature and high pressure conditions.

American Iron and Steel Institute (AISI) group D tool steel are widely used by tool maker in tool and die industrial sector. In mould and die manufacture, the AISI D2 steel is regularly used as material. The high hardness provides AISI D2 steel a greater opposition to abrasion and wear, which are common issues in die and mould industries. Even though high hardness provides AISI D2 steel some greatness features and made it the chosen raw material in the tool and die manufacturing industry, it also has limited use due to difficulties in machining. This material is usually machined under hardened conditions to avoid the any side effects to the surface undergoing heat treatment. Difference to the conventional procedure of machining hard materials that regularly machines within the annealed state taken after by heat treatment and finishing processes such as grinding, machining in hardened state gives critical advantage in context to reduce production time and decreased costs of machining (Hosseini et al., 2016). Based on literatures in similar conditions, there are shows that the significance of hard machining and needs more exploration to study the influence of dissimilar cutting parameters on the life of cutting tool, and surface texture of the workpiece.

## 1.2 Statement of the Problem

Using hardened steel as material could result better on the product durability, especially for die and mould making industries. But before that, the industries need to spend more in the manufacturing process to get good in finish hard surfaces. Today, according to the progresses in machine and cutter technologies, the hardened steel is able to cut rapidly and perfectly. Basically, the cutting process on a hard surface only can be carried out after the steel has undergone heat treatment process so that the required dimensions are obtained; either for roughing or finishing purpose. According to Takacs & Farkas (2014), the benefits of hard cutting implementation are the capability to obtain good surface roughness, difficult profiles, better material removal rates, reduce costs, reduce finishing time and compensate for environmental concerns with dry machining. However, hard cutting in technically will cause wear condition at the edge of tool cutter, and low quality on machined surface due to high impact touches and heat creation. Thus, the appropriate factors must be fix in purpose to improve tool cutter life and obtain the cutting surface quality (roughness). Therefore, the continuous research in this subject is need to be done to cover some of parts that not covered enough especially relationship between the cutting parameters and the effect on the surface integrity and wearability of the cutting tool.

## 1.3 Objectives

There are three main objectives by doing this project:

i. To identify an appropriate cutting tool parameters in milling machining using uncoated carbide flat end mill.

ii. To examine the effects on surface roughness and tool wear through a various combination of cutting speed, feed rate and depth of cut when machining under dry condition.

iii. To validate optimal cutting parameters that produces the lowest surface roughness and tool wear under dry machining.

## 1.4 Scope of Project

The study focuses on the effect of surface quality of AISI D2 tool steel and tool wear of cutting tools during machining under dry condition. The machining process is using high speed CNC Milling machine and uncoated carbide end mill as cutting tools. The surface roughness of machined AISI D2 Steel is measured by portable surface roughness and tool wear is measured by stereo microscope. The different effect of surface roughness and tool wear are based on three (3) different cutting speed, feed rate and depth of cut. The data's that collected form the set of experiment are analysed by commercial software, Minitab 17.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

AISI D2 steel is a universally used material in the tool and die making industry. AISI D2 steel has been commonly used in the tool and die manufacturing industry especially for the manufacture of automotive products. In the advanced industry, the machining process of producing tools and dies has been used to produce complex 3D profiles and shapes to meet the geometry required by part. Usually, tools and die will be used in different parameters depending on the type and the application. Technically, tools and die are commonly used under high temperature and pressure conditions. In order to survive under high temperatures and pressures, it has to have robust features, for example mechanical performance and chemical behavior.



Many previous studies on this matter indicate the importance of machining on hard materials and there is a need to continue the study in the future to see the effect of using different parameters on machining of this type on cutting tool life, cutting power, and the finished surface of the finished workpiece.

## 2.2 Previous Study

Hosseini et al. in 2016, have describing details about AISI D2 steel in their study because they saw that this material is regularly be chosen by manufacturer in tool and die making. They have done the research about hard machining on D2 steel to investigate the effects of several combinations of parameters on tool life, power of cutting and surface integrity. The parameters that involved in their study are such as depth of cut, feed rate and machining time. D2 steel as a material in hard machining process, they have studied the parameter that effects on the power of cutting, rate of tool wear, and surface condition. Their study has resulted that by increasing the depth of cut and feed rate in the turning operation, will quickens the tool wear rate in the same machining time. This indicates that the temperature should be reduced during the machining process with feed rates and high cutting depth which may cause the tool to cut out faster. The results of the study have shown that feed rate, cut of depth, cutting speed and cutting time are the dominant parameters and are important factors in determining the machining characteristics of D2 steel (Hosseini et al., 2016).

High consideration in surface integrity and wear of tool are very important in hard milling technology in order to attain optimal cutting parameters. The study about these two conditions after hard machining has done by Kundor et al. (2016) that using coated carbide tool to cut the AISI D2 steel by milling process. In the study, they are found that the mechanical wear is usually prevailing in the opening cutting. The machining in higher cutting speed result the thermal wear that caused by high temperature condition. The flank wear and chipping are frequently main wear types that happen on the tool especially at the edge of tool. The result also exposed the different combination of feed level and speed of cutting are not change the characteristic on the machined surface. The result based from Kundor studied concluded that surface roughness values were continuously increase with the evolution of the tool wear (flank wear) in all cutting parameters.

In term of decreased the production cost and reduce production time compare to conventional machining, milling machining on hardened material would offered that advantages. Differences temperature conditions is an important element in milling process that will affected the wear of cutter. The weakness in milling parameters determination may cause unnecessary tool wear and augment the roughness of machined surface. Therefore, Gaitonde et al. (2016) have studied the aspects of machinability in milling process on the hardened steel materials. They have investigating the effects of parameters such as depth of cut, feed rate and cutting speed against machining responses such as machining temperature, cutting force, and surface roughness by using response surface methodology (RSM) design. The analysis resulted the cutting temperature rises consistently with increase the speed of cutting, but the surface roughness values is decreasing while increasing the cutting speed. They also found that in higher feed level, increasing the cutting speed would decrease the force of cutting in various range of depth of cut (Gaitonde et al., 2016).

The selection of design of experiment is very important in determine the efficient method to run the experimental study. That's are closely related to the use of time, costs, manpower, equipment and materials. Kumar and Kaswan (2016) have describe in their paper that the Taguchi's method is an effective experiment method because of it capability in studying on variable responses, and less in number of experiment's runs than the full factorial design of experiment. With Taguchi method, the best parameters of cutting can be determined in terms to get the optimum response of machining process such as surface roughness and material removal rate (MRR) value. In Kumar studied, they have used Taguchi method to attain the optimum value in combination of parameters that running experiment by milling machining and carbide end mill. The collected data have analysed by Taguchi analysis on each input parameter to obtain the optimal response, where the signal-to-noise (S/N) ratios have been calculated before. The significant indicators for every parameter that have used to obtain the responses were determined and validated by using the analysis of variance (ANOVA) (Kumar & Kaswan, 2016).

Senthilkumar et al. (2010), also have used Taguchi technique to conduct their experiments by manipulating the input parameters in machining such as cutting speed, cutting depth and feed rate for determining the finish condition of machined surface and wear on cutter with carbide tool inserts (uncoated) in dry condition. By using Inconel 718 as a material, they have investigated the impacts of the cutting parameters on the surface finished and tool sharpness. Based on the Taguchi's analysis, they found that the speed of cutting and cutting depth are the influence parameters in the turning process while in the facing machining performance of response is influenced by feed rate and speed of cut.

The type of cutting tool material also an important factor that will affect the performance measures in machining process. One of studies that described this was conducted by Junaidi Mir and Wani in 2018, where they are investigate the machinability on surface roughness and wear of tool, in hard machining of AISI D2 steel by using PCBN, ceramic and coated carbide inserts. They have used the response surface methodology (RSM) as design of experiment. Various combinations of parameters namely cutting speed, hardness of cutting tool, and cutting time was used to investigating the belongings on the two response, surface roughness and flank wear, additionally analyse by using analysis of variance (ANOVA). A quadratic regression model was used in their study to determine the relationship between the input and output parameters. As results, they found that the cutting time and hardness of cutting tool are mostly effecting the tool wear. But then the other side, the surface roughness was mainly affected by cutting time and cutting speed. End of the study, they are using the desirability function approach (DFA) to carry out the multiple response optimization on tool wear and surface roughness. (Junaidi Mir & Wani, 2018).

## 2.3 Machining

Kalpakjian (2013) specified the machining is the process of utilising cutting tools to expel overabundance or undesirable material from the workpiece surface as chips to acquire the last shape and size of the finished result. Gaitonde et al. (2016) express that machining is a method of removing material by utilizing power-driven machine instruments to shape it into a planned outline. Chips are framed amid machining because of the shear disfigurement of the work material. The development of the chip relies on upon the kind of material being machined, then after finished the machining operation, the cutting conditions were taken. There are four (4) essential sorts of chips that are by and large created amid cutting process.

They are continuous chips, continuous chips with built-up edge, discontinuous chips, and serrated chips. A chip-breaker geometry present on the cutting tool helps in maintaining a strategic distance from the era of continuous chips. A two-dimensional schematic diagram of metal cutting process demonstrating the fundamental terminology is shown in Figure 2.1 (Kalpakjian et al., 2013). Machining is a standout amongst the most vital manufacturing process and is most frequently applied to shape metals.

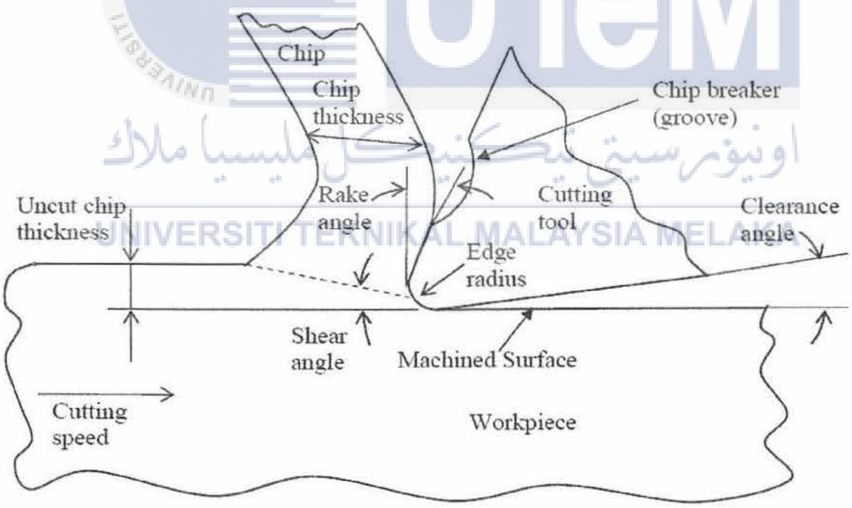


Figure 2.1: Metal cutting terminology

Material removal processes are extensively arranged into three categories which is conventional machining, non-conventional machining (also known as non-traditional machining), and abrasive processes. Conventional machining requires mechanical material removal using certain sharp tools to achieve the desired geometry. The milling, turning, facing, and drilling processes are some types of conventional machining processes. Abrasive processes require removal of material mechanically using hard and abrasive particles; such as grinding, honing and lapping process. Non-conventional machining uses different forms of energy dissimilar from those used by conventional machining and abrasive processes for the material removal; like Electrical Discharge Machining (EDM), laser cutting, plasma cutting, water jet, etc.

### 2.3.1 Dry machining

Dry machining is an alternative to implement ecological protection for occupational safety and health rules regarding conventional flooded cooling practice. Besides offering cost reduction in machining, the advantages of dry machining include allergy free and non-injurious to skin. 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.



The manufacturing taken a toll as lubricants and coolants utilized for machining shows to 16-20% of the manufacturing expenses (Sreejith, 2008). Nonetheless, the execution of dry machining can't be refined by solely cut off the supply of cutting liquid. It needs the hard usage, wear resistant, low thermal diffusivity tool materials and coatings that can hold their properties at higher machining temperatures.

### 2.3.2 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