OPTIMIZATION OF PROCESS PARAMETERS ON SURFACE ROUGHNESS AND MATERIAL REMOVAL RATE OF STAINLESS STEEL AISI 316 IN CNC MILLING PROCESS

by

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LIST OF ABBREVIATIONS

CNC	Computer Numerical Control
DOE	Design of Experiment
WRW	Work piece Removal Weight
WRV	Work piece Removal Volume
ANOVA	Analysis of variance
MRR	Material Removal Rate
MS	Mean Squarer
MSD	Mean Square Deviation
S/N	Signal to Noise Ratio
OA	Orthogonal Array
QC	Quality Characteristic
TW	Tool Work Time
TWR	Tool Wear Rate
AA	Arithmetic Average

LIST OF SYMBOLS

N, A	Spindle speed (rev/min)
vc, B	Cutting speed (m/min)
vf, *F*	Feed rate (mm/min)
ap,c	Axial depth of cut (mm)
ae	Radial depth of cut (mm)
T	Cutting Time
ρ	Work Piece Density
SR	Surface Roughness
Q,MRR	Material Removal Rate
B	Bigger is better
S	Smaller is better
N	Nominal is the better
SA	Sum of Square of factor A
PA	Per cent Deviation of factor A
SB	Sum of Square of factor B
PB	Percentage Deviation of factor B
SC	Sum of Square of factor C
ST	Sum of all observation
$\sum Y_i^2$	Sum of Square Deviation
μs	Micro Second
μin	Micro Inches
μm	Micro Meter
Δ	Weight Difference

g	Gram
L9	Each level have nine experiments
PCBN	Poly Crystalline cubic Boron Nitride
GA	Genetic Algorithm
PVD	physical vapour deposition
RSM	Response Surface Methodology

LIST OF EQUATION

$vc = \frac{\pi.D.n}{1000}$ (m/min)

$Q = \frac{ap.ae.vf}{1000}$ (cm^3/min)

$MRR = \frac{WRW}{T}$ (g/min)

$MRR = \frac{WRV}{T}$ (mm^3/min)

MSD= $\frac{(Y1-Y0)^2 + (Y2-Y0)^2 + \cdots + Yn-Y0^2}{n}$ MSD for QC = N (Nominal is the best)

MSD= $\frac{(Y1)^2 + (Y1)^2 + \cdots + (Yn)^2}{n}$ MSD for QC = S (Smaller is the better)

MSD= $\frac{\left(\frac{1}{Y1}\right)^2 + \left(\frac{1}{Y2}\right)^2 + \cdots + \left(\frac{1}{Yn}\right)^2}{n}$ MSD for QC = B (Bigger is the better)

S/N= -10 $\log_{10}$MSD

Kesan parameter proses pada kekasaran permukaan dan bahan pengoptimuman kadar penyingkiran daripada keluli tahan karat (AISI 316) DALAM proses pengilangan CNC.

ABSTRAK

Dalam kajian ini, mesin pengisar CNC telah digunakan bagi memesin spesimen-spesimen diperbuat daripada keluli tahan karat AISI316 berdasarkan tetapan parameter-parameter yang dipilih. Spesimen-spesimen dengan ketebalan 6 mm telah digunakan. Kadar pembuangan bahan (MRR) telah dihitung dengan menisbahkan perbezaan berat spesimen sebelum dan selepas pemesinan kepada masa pemesinan. Prestasi pemesinan kedua adalah kekasaran permukaan (SR) dan ia diukur menggunakan peralatan MITUTOYO CS-3100. Kaedah Taguchi telah digunakan untuk menyusun atur ujikaji bagi mencari nilai optimum MRR dan SR. Telah didapati bahawa nilai ramalan maksimum MRR adalah 4.86 mm^3/s di bawah tetapan kelajuan gelendong; 2500 m/min, kadar suapan; 250 mm/min, dan kedalaman pemotongan; 0.1 mm. Sebaliknya, nilai ramalan minimum SR adalah 2.85 μm di bawah tetapan kelajuan gelendong; 500 m/min, kadar suapan; 250 mm/min, dan kedalaman pemotongan; 0.2 mm. Ujian pengesahan telah dijalankan untuk kepastian. Telah didapati nilai sebenar ujikaji MRR dan SR yang telah diukur berada dalam lingkungan 10% nilai ramalan.

Effect of process parameters on surface roughness and material removal rate optimization of stainless steel (AISI 316) in CNC milling process.

ABSTRACT

In this study, the CNC milling machine was used to machine the specimens made from stainless steel AISI 316 based on the selected parameters setting. Specimens with 6 mm in thickness obtaining was used. The material removal rate (MRR) was calculated by dividing machine time the weight of the specimen weight before and after the cutting process. The second performance surface roughness (SR) and it was measured by MITUTOYO CS-3100 device. Taguchi Method was utilized as in layout the experimental to optimize MRR, SR. It was found that prediction maximum value MRR was 4.86 mm^3/s under setting spindle speed 2500 m/min , feed rate 250 mm/min , and depth of cut 0.1 mm . On the other hand the prediction minimum SR value 2.85 μm, was under setting spindle speed 500 m/min , feed rate 250 mm/min , and depth of cut 0.2 mm. Confirmation tests were run to verify. The prediction it was found the experimental results of MRR and SR for within 10% percentage of the prediction value.

CHAPTER 1

INTRODUCTION

1.1 Background

Manufacturing technology, specifically machine tools, are used to create the products and goods on which modern economies are based. Over time, different types of machines with different purposes were developed in 1818 during the industrial revolution. Eli Whitney is credited with building the first milling machine (Youssef, & El-Hofy, 2008). Since then, it has been constantly improved, and with the application of CNC technology, it is arguably the most versatile machine tool available today. Part of the evolution of the milling machine has been its miniaturization. The miniaturization of the CNC milling machine has reached a point where a machine can be placed on a desktop, enabling low cost machines to become widely available to educators, inventors, and hobbyists. A milling machine is a machine defined by a rotating tool with cutting edges, which is used to mechanically remove materials, in the form of chips, via the rotating move cutting between tool and the (workpiece). The relational motion sample, unlike drilling, of the milling process, is capable of relative motion between the rotating, a tool, and the work piece in directions other than the axis of the tool's rotation. A large variety of milling machine configurations and sizes have been developed and are usually distinguished by the orientation of the cutting tool, the number of linear and or rotational motion axes, and the working volume of the machine (Drozda & Wick, 1983).

1.2 Problem Statement

Although the CNC milling machine is one of the more precise process of machining, it is not without its problems. The cutting parameters selection for realizing higher precision and efficiency in cutting in CNC milling machine has not been fully established. The problem of current method improvement in this experimental investigation is to evaluate the effects of the process parameters on AISI 316 stainless steel work piece's surface roughness and material removal rate by employing the design of experiment using L27 array and Analysis of Variance (ANOVA) using carbide End Milling (774L-B) tool on CNC milling. The contribution to the body of knowledge in this thesis is to the investigation and predict the optimal values for machining parameters, which are value guidelines satisfying the CNC machine in milling for manufacturing industries.

1.3 Objectives

The objectives of the study are:

1. To identify the quality characteristics of machining by measuring surface roughness and material removal rate for optimization during the cutting operation.
2. To evaluate the effect of input machining parameters on output response, surface roughness, and metal removal rate.
3. To experimentally validate the optimum parameters for CNC milling machining application for alloy material and confirm the best conditions parameters for CNC milling machine.

1.4 Scope of Dissertation

The scope of this work are:

1. Research is focused on the effect of process parameter in CNC milling.
2. The Taguchi technique DOE layout will be used for machining parameters, accounting for depth of cut, feed rate, and cutting speed. Constant feed rate and depth of cut were set based on literature.
3. The cutting speed were varied from 500, 1500, and 2500 m/min, the feed range varied from 100, 200, 250 mm/min, and the axial depth ranges are 0.1, 0.2, 0.3 mm.

1.5 Report Structure

This thesis is made up of 5 chapters, which are:

1. Chapter 1 will introduce the background of the study and the principle of CNC milling machine, detail the problem statement, objectives, and scopes. The background study will discuss the cutting process in CNC milling machine, which is the main manufacturing process in this work, followed by the problem statement.

2. Chapter 2 will highlight literature survey on CNC milling cutting principle, structure, material used (AISI 316), and the (Taguchi technique). The division will discuss details pertaining to the previous process, methods, and application related to this work, and the evidence gathered that will be used in this work.

3. Chapter 3 will discuss the thesis methodology, and will be made up of flow chart pertaining to the study. It will also encompass the materials and machines used in this work.

4. Chapter 4 will detail the Taguchi process using DOE (design of experiments) to analyze the results of this work from experiments with help from the CNC milling machine.

5. Chapter 5 will conclude and summarize the work objectives, future work recommendation, and commercialization of the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Many researchers investigated steel AISI 304, XW42, and En 31 on CNC milling. However, there are currently no work being done on SS316, despite the fact that it is the most commonly used steel in the manufacturing industries due to its better corrosion resistance. Only a few researchers utilized the ANOVA technique to analyze the results due to the lack of experimental design. Without using ANOVA, no significant parameters and individual contribution of input parameter to the response can be calculated (Rose, 1996).

The highlight of experimental papers incorporated into this part is the CNC processing parameters, such as speed, feed rate, and depth of cut. This section contains a percentage of the exploration concentrating on identifying the CNC processing process. The influence of parameter machine process of SR on MRR will be discussed as well.

2.2 Literature Survey of Machinability

2.2.1 Numerical Control Advantages and Concepts

Numerical control have been used in manufacturing for more than 40 years. The CNC milling machine (numerical control) is a process of automatically operating a manufacture machine setup on a letters, code, numbers, and special particles. When the group complete coded instructions for an operation, it is called a program. The program is translated into conformable electrical signals as inputs to motor for setup in the machine. Numerical control machines have been manually programmed. If a computer is used to create a program, the method is known as computer-aided programming. The process taken in this text is in the form of manual programming. Traditionally, numerical control systems is composed of the following combination: a tape punch and change written instructions into a symmetric hole pattern. The cavity pattern is punched into tape. Much older units used a typewriter device called a Flex writer, while later devices consist of a microcomputer coupled to a tape punch unit.

- Bar reader: The hole pattern reads to translate the type to a consistent electrical signal symbol.
- Control: The tape reader then link an electrical signal symbol for the NC machine to respond.

NC machine: Responds to automatic signals of the controller. Accordingly, the machine implement the required motions to manufacture a part (spindle rotation on/off, table, and or spindle motion along the direction of the programmed axis)

2.2.2 History of CNC Milling Machine

The story of numerical control (NC) began when the automation of machine tools first incorporated abstract programmable logic, and it survives today in the form of the ongoing development of computer numerical control (CNC) technology. In many manufacturing companies, milling is used as a versatile processing method due to its ability to produce complex shapes with high smoothness and accuracy. Attention has turned towards dynamic milling techniques due to the potential advantages in arterial removal rate and tool lifetime compared to conventional milling. The first NC machines were built in the 1940s and 1950s based on existing tools that were modified with motors that moved the controls to follow points fed into the system on a punched tape. These early servomechanisms were rapidly augmented with analog and digital computers, creating the modern CNC machine tools that have revolutionized the machining processes. Certain tool manufacturing companies have tested and determined that this can be the case, especially when machining hard materials.

2.2.3 Working Principle of CNC Milling Machine

The milling machine is based on a work piece being fed to a milling cutter. This is done by developing relative motion with precise control between work piece and rotating milling cutter. The work piece was given to the feed motion. The cutting machine of the sample in milling operations is similar to that of the operation on the lathe. The cutting that takes place was via plastic deformation of the metal by the cutting tool. The milling machine can hold more than one cutter at a time. The holding device is supported by its own mechanism. The work piece can be milled selectively. One example include indexing. Milling cutters are cutting tools that are typically used in milling machines or machining centres to perform milling operations (and occasionally in other machine tools). They remove material by movement within the machine (e.g., a ball nose mill) or directly from the cutter's shape (e.g., a form tool such as a hobbing cutter).

2.3 Milling

2.3.1 Up-and Down Milling

The cutting process in milling is inherently intermittent, which means that each tooth of the tool is only cutting up to half of a revolution of the cutter. Hence, the cutting edges on the tool are making periodic impacts on the work-piece, as opposed to continuous machining operations e.g. drilling and turning. (Roymech, 2013).

There are two different types of milling: up-and down-(climb) milling. The principles of these are shown in Figure (2.1) (Roymech, 2013)

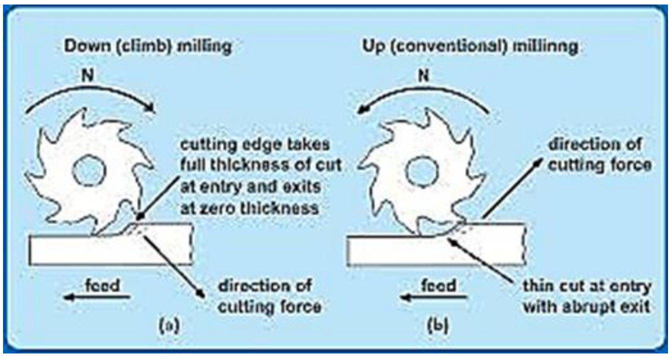

Figure 2.1: Up- and down-milling

In up-milling, the work-piece is fed opposite to the tool's rotation, resulting in a chip thickness of zero in the beginning of the cutting process, which then increases in thickness towards the end of the procedure. The high cutting forces in up-milling tend to press the milling tool and the work-piece away from each other, which tend to lift the workpiece from the machine table. It is thus important that the work-piece is secure. In down-milling, the samples is fed-up in the same trend the tool's rotation giving a large chip thickness at the beginning of the cutting process, which eventually becomes zero at the end of the procedure. Due to this, the pressing effect that occurs in up-milling is not obtained in down-milling. The cutting forces in down-milling instead strive to pull the work-piece towards the cutter, which keeps the insert engaged (Jarfors, Anders 2006). Additionally, in down-milling, a better surface finish is usually obtained compared to up milling due to the reduced recutting of the chips. In up-milling, the chips are ejected in front of the cutter, which may cause re-cutting, and eventually tool breakage (Sveriges Mekanförb. 1980).

2.3.2 Dynamic Milling

When a cutter passes a corner, the tool engagement will increase, which increases the load on the cutter in the manner shown in Figure (2.2), (Zelinski, 2010). As the tool engagement increases, the time each cutting edge (flute) is in contact with air decreases, and consequently, the chance the tool releasing heat will be reduced.