OPTIMIZING THE 3D MILLING MACHINE PARAMETER TO IMPROVE THE CUTTING ACCURACY

NUR ADILAH BINTI SAWARI

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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NUR ADILAH BINTI SAWARI

This report is submitted
in fulfilment of the requirement for degree of
Bachelor of Mechanical Engineering (Design and Innovation)

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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DECLARATION

I declare that this project report entitle “Optimizing the 3D milling machine parameter to improve the cutting accuracy” is the result of my own work except as cited in the references.

Signature :……………………..………………………………

Name :……………………..……………………………….……..

Date :………………………..……………………………

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in term of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Design and Innovation).

Signature :…………………………………………..……

Name of Supervisor :………………………………….……….……

Date :………………………………….……….……

DEDICATION

To my beloved mother and father

ABSTRACT

3D milling machine is a machine that use to cut workpiece in three Cartesian coordinate which are x-axis, y-axis and z-axis. As the technology develop, there are many techniques and software that been introduced to help controlling the system. In UTeM, the movement of the machine can be control by using NXT Intelligent Brick (I-Brick) which is a programmable brick of NXT. The brain of the Mindstorms robot can be controlled by installing the Lego Mindstorms NXT software. In order to optimize the milling machine, MATLAB/Simulink been use as the programming environment to design the machine movement. The programming model are designed and been tested to achieved the desired requirements of cutting pattern. The machine parameters that influence the cutting accuracy such as motor voltage, cutting speed and tool bit diameter also has been determined and analysed. To analysed the parameter, it will be tested on the machine itself and the method of optimization using MINITAB software is used as an approach to minimize the number of experiment in a systematic way. The results are analysed and presented in this report.

ABSTRAK

3 dimensi mesin miling merupakan satu mesin yang digunakan untuk memotong bahan kerja dalam tiga koordinat iaitu paksi x, paksi y dan paksi z. Semakin teknologi berkembang, terdapat banyak teknik dan perisian yang telah diperkenalkan untuk membantu pengawalan sistem. Di UTeM, pergerakan mesin tersebut boleh dikawal menggunakan 'NXT Intelligent Brick (I-Brick)' yang merupakan satu alat yang diprogramkan untuk mengawal NXT. 'NXT Intelligent Brick (I-Brick)' boleh dikawal dengan memuat turun perisian 'Lego Mindstorms NXT' di dalam komputer. Untuk mengoptimumkan penggunaan mesin tersebut, perisian MATLAB/Simulink digunakan untuk merekabentuk pergerakan mesin tersebut. Model tersebut di rekabentuk untuk mencapai keperluan yang dikehendaki mengikut bentuk potongan. Parameter mesin yang mempengaruhi ketepatan pemotongan seperti kuasa motor, kelajuan pemotongan dan diameter mata alat juga dikenalpasti dan dianalisis. Ia juga akan diuji pada mesin tersebut dan kaedah optimisasi menggunakan perisian MINITAB akan digunakan untuk mengoptimumkan pengawalan sistem. Keputusan dianalisis dan dibentangkan dalam laporan ini.

ACKNOWLEDGEMENT

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Furthermore, I would like to acknowledge with much appreciation the crucial role of post graduated students in Innovation Laboratory, who give the permission to use the requirement equipment and necessary materials to complete my experimentation on the 3D NXT milling machine.

A special thanks to my family who help me in fabricating and assembling parts and gave a lot of suggestion regarding to this project where I found it is difficult for me to solve. A special thanks also to my classmate and teammate who help me on giving some suggestion and encourage me in completing this final year project.

Last but not least, I would like to express my gratitude to any individual or group whom I have not mention that has gave me support and advices in order to complete this project especially to Design and Innovation's students and lecturers.

To conclude, I hope that this report of final year project can fulfil the conditions as requested for degree of Bachelor of Mechanical Engineering (Design and Innovation), UTeM.

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LIST OF ABBREVIATIONS

3D	Three Dimensional
BMCD	Bachelor in Mechanical Engineering (Design & Innovation)
DOE	Design of experiment
I-Brick	Intelligent Brick
MATLAB	Matrix Laboratory
PID	Proportional Integral Derivative
USB	Universal Serial Bus
UTeM	Universiti Teknikal Malaysia Melaka

LIST OF SYMBOL

L	Number of level
P	Number of parameter
π	Pi (3.14)
n	Number of experiment/observation
β_0	Overall means response
β_{ij}	Main effects for each factors
β_{ii}	Quadratic effect for the i^{th} factors
V	Cutting speed
S	Spindle speed
F	feed
f	Feed per tooth
N	Number of rotation
D	Diameter of tool bit

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Milling is a machinery process that use rotary cutter to remove or cut the material from work pieces. The 3-dimension (3D) milling machine means that it can cut the work piece using three Cartesian coordinates or axes which are x-coordinate, y-coordinate and z-coordinate. Technologies nowadays help us on controlling the milling machine by using various type of software available now such as Lego Mindstorms NXT and Simulink. This software is used to create a programmable control of the milling machine.

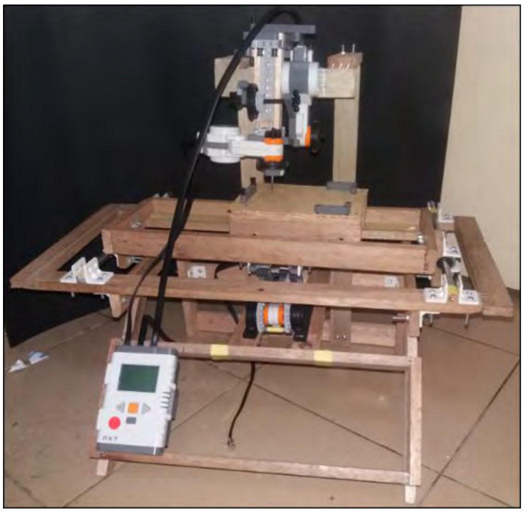


Figure 1.1: 3D NXT milling machine in UTeM

The existing 3D milling machine in UTeM is using the NXT intelligent brick (I-Brick). I-Brick is a programmable brick of NXT. The NXT is the brain of a Mindstorms robot. There are two type of communication that are used to download the programs which is by using Universal Serial Bus (USB) 2.0 port or by a wireless communication using Bluetooth function. A dot matrix display that supports 100x64 pixels can be found on the front of I-Brick. It can connect up to 3 different motor using different output port and can connect various types of Lego sensors devices at 4 different input ports. The basic NXT educational set usually came with 4 different type of sensor such as touch sensor, sound sensor, light sensor and ultrasonic sensor. The NXT servo motor can be control by adjust the direction of rotation between the range of power and degree of rotation. Each motor can be controlled separately. In order to move it to the right, the motor on the right side will turn in clockwise direction while the other motor will rotate counter clockwise. It also can synchronize the motor to move forward and backward. (Kim & Jeon, 2007). The Lego Mindstorms NXT's software is use to optimize the control and motion of the NXT. Before using the software, the code and symbols need to be understood first so it is easier to implant or determine which symbols or code should be used.

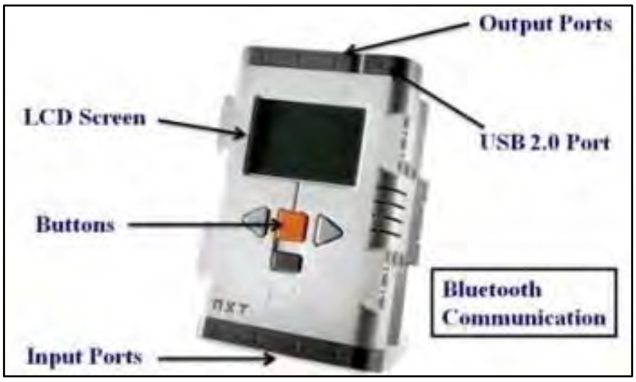


Figure 1.2: NXT Intelligent Brick (I-Brick)

Figure 1.3: Lego Mindstorms NXT's software

Simulink is a graphical programming environment that are used for creating model, simulate and analyse the multi-domain of the dynamic systems which been integrated with MATLAB. It is basically a graphical block diagram tool and can be customised using the block libraries. (The Mathworks Inc, 2016)

One of the method for optimization is by using the design of experiment approach. An optimal region usually can be determined after getting the result of the experiment between the influenced parameter and the response. Usually in engineering field, it is use to improve the response after conducting an experiment whether to minimize or maximize the response. (Engineering Statistics Handbook, 2013)

1.2 PROBLEM STATEMENT

There are some of problem occurs regarding to existing 3D milling machine which lead to inaccuracy and poor result to the work pieces. This problem occurs due to a few factors such as calibration of the machine, motor voltage and others. It is important to perform the calibrations on the prototype to obtain a better performance and reduce maintenance. The calibrations need to be done in the program and prototype itself so some improvement can be made and the precaution can be established.

Calibrations not only limits on changing the values of the code of the block diagram but also addition of other code such as loop into the block diagram to make a better program. Changing any dimension such as adding more height on the axes also means calibrating and known as physical calibrations.

1.3 OBJECTIVES

The objectives for this project are:

1.3.1 To design the 3D milling machine movement using MATLAB/SIMULINK software.

1.3.2 To analyse three machine parameters that influenced the cutting tool movement namely motor voltage, cutting speed and tool bit diameter.

1.3.3 To optimize the 3D milling machine parameter using MINITAB software.

1.4 SCOPE

The scopes of this project include:

1.4.1 The concept of the milling machine will only covers on the basic milling machine that is the vertical milling machine and will be implemented on the design.

1.4.2 The Lego Mindstorms NXT intelligent brick will be the brain of the milling machine's prototype which will first be demonstrated in a simple gearing system.

CHAPTER 2

LITERATURE REVIEW

2.1 MACHINE TOOLS IN REMOVAL PROCESS

According to encyclopaedia Britannica (Lopez et al, 2009), the description for machine tools is given as any stationary power driven machine that is used to shape or form parts made by metal or other materials. The shaping is accomplished in four general ways which are by cutting excess material in the form of chips from part, by shearing the material, by squeezing metallic parts to desired shape and by applying electricity, ultrasound or corrosive chemicals to materials. (Lopez et al, 2009)

The basic function of a machine tool for removal process is to move the cutting tool along a more or less complex trajectory with sufficient precision, withstanding the forces from the removal material process. This can be done to reach the precision and or material removal rate.

The input for machine tool designers is a user requirement which lead to the machine features. The requirement must follow a few aspects and one of them is to determine the maximum part size that need to be machine. The machine workspace must be larger than the work piece size. The material removal rate also needs to be determined in order to achieve the precision of the machine. Usually the machine needs to be suitable for its operation and requiring a sufficiently accurate and highly productive machine at lower price.

The most importance aspect that needs to be follow while designing a machine is precision. There are two different concepts that involves which is accuracy and repeatability. Accuracy is the capability of being on target with specification and desired result. Repeatability is the ability to reach the same value. Therefore, a machine may be repeatedly inaccurate in one extreme case or imprecise yet very accurate at the other extreme. So, in order to achieve a determined grade or accuracy, there are few guidelines that need to be considered such as the effect of assembly in machine components on tool position, the structure deformations under the action of cutting and inertial forces and dynamic behaviour of the system under certain cutting forces. (Lopez et al, 2009)

2.2 THE MILLING STRUCTURE OF MACHINE

The principle of machine structure is the machine tools must support all components in machine. At the same time, it also must bear up the forces that produce from the process and upholding sufficient toughness in order to preserve the essential precision. There are two main types of features which included in the structures which are the frame, bed and the structural components. The frame is categorized as the main body of the structure constitutes the machine frame while bed is where all the other components rest. The important components are the part where the mechanism being linked with relative motion between them. (Lopez et al, 2009)

2.2.1 TYPES OF MILLING MACHINE

Peripheral (slab) milling is where the milled surface was created by teeth that are located on the edge of the cutter body and the axis of cutter usually placed at a plane which parallel to the workpiece surface that need to be machine.

Another type of milling machine is face milling where the cutter was attached on the spindle which the axis of rotation is perpendicular to the workpiece surface. The result of the milled surface located on the periphery and face of the cutter.

End milling usually rotate the cutter on an axis perpendicular to the workpiece. It can be slanted to machine tapered surface and the cutting tooth is located on both end of pace and periphery of cutter body. (Manufacturing Education, n.d.)

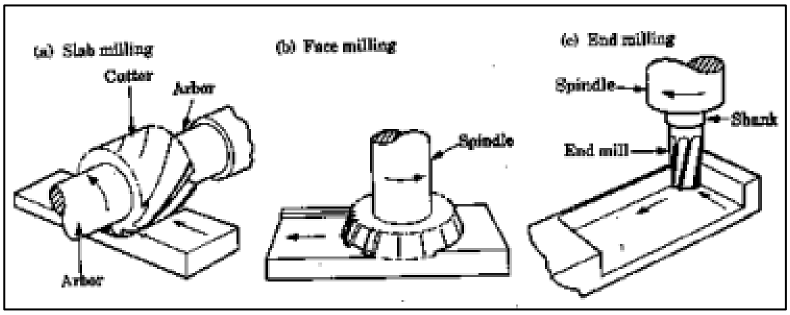
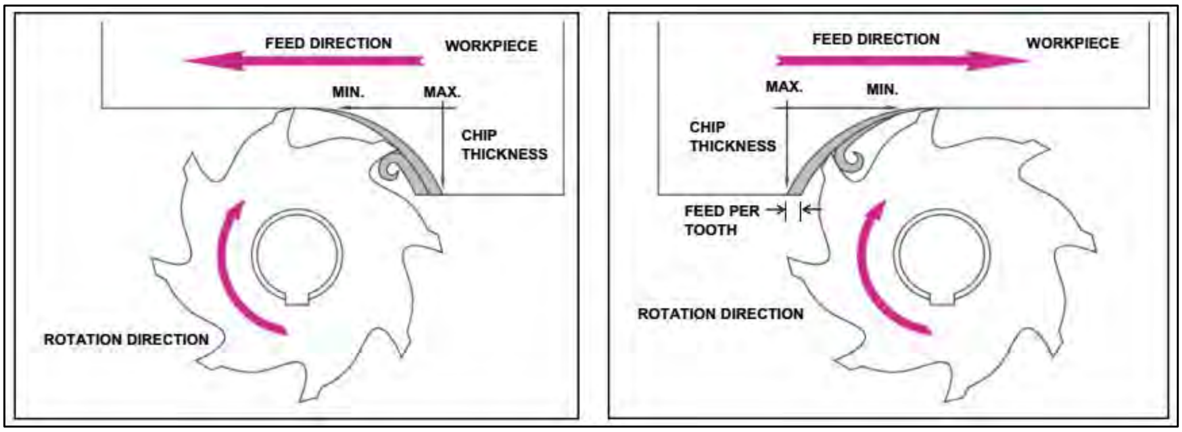


Figure 2.1: Type of milling operation

The common milling mode that been use in the industry are conventional milling and climb milling. (Nik et al, 2016). Up milling been categorize as a conventional milling where the direction of the rotation's cutter different from the feed motion but down milling been classified as a climb milling which the direction of cutter rotation is similar to the feed motion. The chip form in down milling is contrasting to the chip form in up milling where the cutter tooth is nearly parallel to the upper surface of the workpiece. It will start to mill the full chip thickness as the chip thickness is gradually reduced. (Milling Education, n.d)



a) Convectional (up) milling　　　　　b) Climb (down) milling

Figure 2.2: Machining process for different milling mode

2.3 MILLING CUTTER

The end milling cutters need to have teeth on the end and periphery. A larger end milling end cutter is mounted on arbor while the smaller ones have a shank for chuck or direct spindle mounting. The end milling cutter is used to creation of keyways, slots and recessed. It also can used to mill angles, edges and shoulders of work piece. (Milling machine operation, n.d). There are several types of end milling cutter are shown in Figure 2.3 above.

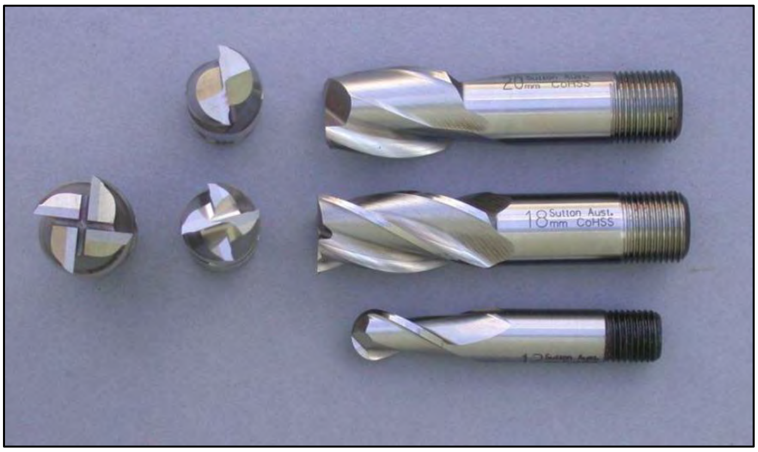


Figure 2.3: Several types of end milling cutter