3D MILLING MACHINE USING LEGO MINDSTORM

FERLAND KARSHIFF SIRINUS

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

3D MILLING MACHINE USING LEGO MINDSTORM

FERLAND KARSHIFF SIRINUS

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

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

JUNE 2016

DECLARATION

I declare that this project report entitled “3D Milling Machine Using LEGO Mindstorm” is the result of my own work except as cited in the references

Signature : .....

Name : FERLAND KARSHIFF SIRINUS

Date : .....

APPROVAL

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

Signature	:.	.....
Name of Supervisor	:	DR. FAIZ REDZA BIN RAMLI
Date	:	.....

DEDICATION

To my beloved mother and father

To my great supervisor and second examiner

To my fellow friends

To those who know me

ABSTRACT

Milling machine is a machine that can be operated in either manually or automatically which implemented by CNC system. The milling machine can drill, slot milling, end milling, face milling and bore milling any surfaces according to the designed motor power. The milling machine consist of a moving x and y axis table, milling arbor that holds the milling cutter and some more. For this project, a vertical milling machine prototype will be made by using LEGO Mindstorm NXT and the application of OpenStructure concept is applied. Investigation on the milled product and operational time is recorded. Several conceptual design is made at first, then continued with fabricating the machine and the Waterfall model is used to align with the objectives that established. Finally, the results of the milled product is recorded and shown with respect to theoretical drawing of product.

ABSTRAK

Mesin pengisar adalah mesin yang boleh beroperasi secara manual mahupun automatik menggunakan sistem CNC. Mesin pengisar boleh menggerudi, melakukan pengisaran slot, pengisaran hujung, pengisaran bidur, pengisaran permukaan dan pengisaran gerigi pada mana-mana bahagian permukaan mengikut kesesuaian kuasa motor. Mesin pengisar terdiri daripada meja yang boleh bergerak pada paksi x dan y axis, punjung pengisar yang memegang pemotong pengisar dan lain-lain. Untuk projek ini, mesin pengisar menegak dibina dengan menggunakan LEGO Mindstrom NXT dan konsep OpenStructure digunakan. Pada permulaan, beberapa rekabentuk konsep dijalankan, kemudian fabrikasi dilakukan dan konsep model Waterfall digunakan supaya selari dengan objektif-objektif yang telah disediakan. Akhir sekali, hasil keputusan daripada produk pengisaran direkodkan dan dibentangkan serta dibandingkan dengan lukisan teoritikal produk.

ACKNOWLEDGEMENT

I would like to express my deepest appreciation to my supervisor Dr. Faiz Redza Ramli for giving me this opportunity to do final year project with him. He never hesitated to give me advice and guidance whenever I confronted problems. I am thankful for his patience and advice while leading me in this project.

Secondly, I would like to thank my previous supervisor during internship named Mr. Roland Tinjau Rusulan for spending his time to guide me. They would share his knowledge in the field of machinist with me and guide me to do this project.

I would like to thank my course mates for giving me their support, patience and encouragement. Finally, I would like to thank my family for their support.

CONTENT

LIST OF FIGURES

LIST OF TABLE

LIST OF EQUATIONS

LIST OF ABBREVIATIONS

Abbreviations	Descriptions	Page
LEGO	“Leg Godt”	1
NXT	Next	1
CNC	Computer Numerical Control	12
SK	Steil Kegel	14
CAT	Computer Aided Translation	14
BT	Baron Taper	14
ISO	International Organization for Standardization	14
HSK	Hohl Shaft Kegel	15
NMTB	National Machine Tool Builders Association	15
USA	United State of America	15

CHAPTER 1

INTRODUCTION

1.0 BACKGROUND

The function of a milling machines are to machine flat surfaces and produce other irregular surfaces. Moreover, milling machines can also be used to bore, drill, and produce slots which make the milling machine a very versatile machine. The milling machine removes metal by using a rotating cutter that is fed into a moving work piece. Milling machine have a spindle that can be fed in z-axis with a quill feed lever on the machine head. Furthermore, the bed of the milling machine can be controlled manually which will move the work piece in x, y and z axes. The given material must match the cutting tool with a specific cutting forces and should be kept constant.

The LEGO Mindstorms are a series of kits which combines software and hardware which gives the LEGO Mindstorm the ability to produce or innovate a customizable and programmable robot with various kind of usage. The first generation of the LEGO Mindstorm kit are known as the Robotics Invention System (IRS) and then replaced by the new generation namely LEGO Mindstorm NeXT, which is then officially renamed as LEGO Mindstorm NXT in 2006. The LEGO Mindstorm NXT was created and developed at the Massachusetts Institute of Technology Media Lab along with a programmable brick called NXT Intelligent Brick. Since then, LEGO Mindstorms NXT are widely used at all educational level which is lead it to be divided into two version; Retail Version (set #8527) and Education Base Set (set #9797). The

Education Base Set was proven to be a good in producing intended result from students in the programming topic which is in the field of computer science. Students are able to learn easier in the basic programming through the visual element without having to face complicated problems and syntax errors.

The LabView Software for the LEGO Mindstorm NXT is free and downloadable from the official website of the LEGO Mindstorm. Each parts of the LEGO are connected by using joints provided and then the electrical power from the motor are converted into mechanical power that is transferable through a series of connection of mechanical system. In spite of that, the LEGO Mindstorm NXT also have other elements to be program at specific stimuli part such as light sensor and sound sensor. The combinations of stimuli parts and compiled program into the intelligent brick would be able to create a programmable robot. For instance, 3Xcavator as shown in Figure 1. The model of the LEGO are able to be controlled independently by the user through direct programming or even using third party tools such as Bluetooth connections.

Figure 1.0. *The early design of the 3D milling machine prototype.*

LEGO Mindstrom NXT able to be applied in our surrounding especially in the field of engineering. In this project, a 3D milling machine will be developed by using the LEGO Mindstorm NXT as the brain. A series of programming will be applied in the intelligent bricks to rotate the tool bit of the milling machine at certain rate of rotation per minute (RPM) which could be match to the RPM of the milling machine. An example of the applications of LEGO Mindstorm NXT in manufacturing a product is the Arthur Sacek's Milling Machine which use a tool bit to make a product base on a converted drawings. Another examples that applies the same principle are the

MakerLEGOBot. However, the MakerLEGOBot did not use the concept of 3D printing but rather only assemble a series of LEGO bricks into a product base on the script of programming inside the intelligent brick.

Also in this project, the design and concept of OpenStructures will be applied which will be the body of the milling machine. The OpenStructures is a project that explores the possibility to construct a model where anyone design are downloadable from the OpenStructures official website which the designs are based on a shared geometrical grid. The geometrical grid act as a medium to connect people throughout the world through simple designs. It initiates a collaborative responds which everyone can contribute in parts, components, design and structures. Furthermore, the OpenStructures is an ongoing experiments that to determine the possibility of sharing design projects according to a shared modular grid, which is the open standard that stimulates the exchange of parts, components and ideas.

1.2 PROBLEMS STATEMENT

The usage of LEGO Mindstorm NXT in the prototype of a milling machine would encounters its quantity and quality. The LEGO Mindstorm set of bricks contains a limited set and amounts of item for a package, and have a limited spaces for mechanical system, such as the gearing system. The intelligent bricks used battery as its life support which gives a limited amount of time. Moreover, as the battery slowly to become low, the quality of the product produced by the milling machine prototype would be also low. If the brick were charged during the operational time, it might lead to a short circuit of the inside circuit of the brick and damage it. Even though using the LEGO Mindstorm NXT could make the milling machine to be useful at anywhere and anytime, it still not as efficient as a fixed milling machine because of different surfaces of the working table. The OpenStructure are using a geometrical grid, which have a limited range from one grid to another. This could lead to the extension of the 3D milling machine part. To this date that this report was written, there are no 3D milling machine that used the concept of the OpenStructures.

1.3 OBJECTIVES

The list below are the objectives established as a guideline when working on this project:

1. To analyse the milling machine operational process.
2. To investigate and analyse the 3D milling machine using LEGO Mindstorm NXT.
3. To build a prototype of 3D milling machine using OpenStructures concept by applying data obtained from 3D milling machine of LEGO Mindstorm.

1.4 SCOPE OF PROJECT

The scope of this project are:

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.
2. The LEGO Mindstorm NXT intelligent brick will be the brain of the prototype of the milling machine which will first be demonstrated in a simple gearing system.
3. Only the OpenStructures geometrical grid concept are presented in this report.

CHAPTER 2

LITERATURE REVIEW

2.1 THE CHARACTERISTIC OF A MILLING MACHINE

The milling machine consists of base, overarm, spindle, column, table and knee. Each part have their own function that completed the characteristic of a basic and simple milling machine. Another important part are the tool bit, which is the milling machine cutter. The Xi'an Jiaotong University research team (Zhao et, 2008) states that; 'The precision and reliability of machine tools directly influence the processing quality, productivity and efficiency, and further the market competitiveness and the user's confidence'. This means that the tool bit plays an important role to produce a product with a good quality. The application of the milling machine in flexible and agile manufacturing, and remanufacturing of a product has steadily on the rise which a compaction of the whole structures would make it more economical (Xuxiao, 2010).

2.2 LEGO MINDSTORM NXT AS AN EDUCATIONAL METHOD

The choice of an appropriate platform of using educational robotics activities are important nowadays. Some requirements for the medium to be used in the educational robotics are the ability to program the medium at different level of complexity and supports programming paradigms, able to be exploited at any level of complexity and educational ages, and have a simple design but comes with possibilities of expansion through innovation (Kiss, G. 2010). The LEGO Mindstorm

NXT have all the requirements stated. Harel and Papart (1991) states that; 'The NXT complies very well with the constructionist learning approach and the robot is a public entity'. The LEGO Mindstorm NXT have their own advantages in the educational level and one of it is to move students to the second step of robotics and automation educational in a quick process.

2.3 SPEED FOR MILLING CUTTERS

The speed of milling is the distance at which the circumference of the cutter passes over the work piece. The RPM of the spindle is necessary to give a desired speed which depends on the size of the milling cutter. The speed is determined by the kind of material being cut and the size and type of the tool bit used, width and depth of the cut, finish required, type of cutting fluid and method of application, and power and speed available are factors need to be considered.

The speed computation for choosing the tool bit are show as follow.

$$\text{RPM} = \frac{\text{CS x 4}}{\text{D}}$$

Where,

RPM = Speed of the spindle (in revolutions per minute)

CS = cutting speed of milling cutter.

D = diameter of milling cutter.

For examples, the spindle speed for machining a piece of steel at a speed of 35 with a cutter 2 inches in diameter is calculated as follow.

$$\text{RPM} = \frac{\text{CS x 4}}{\text{D}} = \frac{35 \text{ x } 4}{2} = 70 \text{ RPM}$$

Therefore, the milling machine spindle would be set to 70 RPM as near as possible.

2.4 THE SERVO MOTOR OF LEGO MINDSTORM NXT

The servo motor of the LEGO Mindstorm NXT runs at 170 RPM with no load and draws 60 mA of power. This means that the increase of the power draw in turn provides more torque. However, when a load is put, the servo will run slower but draws more current. Therefore, a hypothesis is established that the intelligent bricks will run out of powers before it finished a work. **Figure 2.0** shows the internal structure of the LEGO Mindstorm.

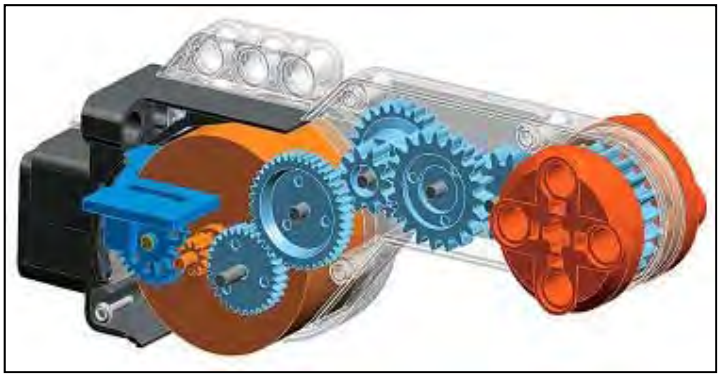

Figure 2.0. *The internal structure of LEGO Mindstorm NXT motor.*

Throughout the researches, the comparison of motors with different type of loads and power supplies are done. Figure 3 shows the result of the comparison.

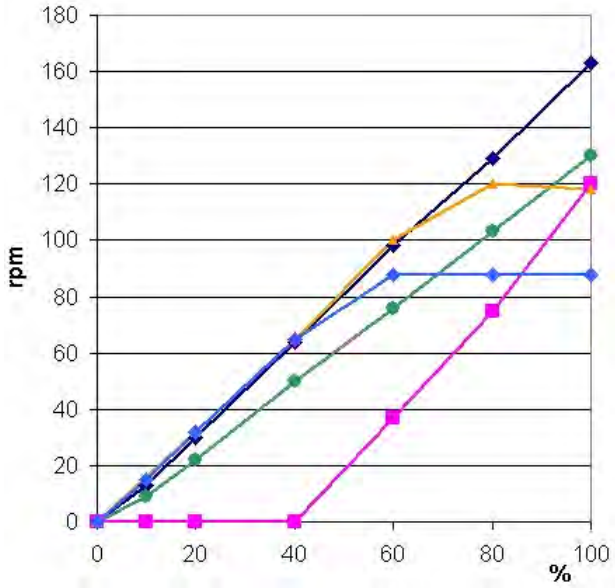

Figure 2.1. *Comparison of motors with different loads and power supplies.*