DESIGN AND FABRICATE OF PORTABLE CNC MILLING MACHINE

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Thesis submitted in fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
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25 JUNE 2013

EXAMINER'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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I declared that this dissertation entitled "Design and fabricate of portable CNC milling machine" 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 currently submitted in candidature of any other degree.

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Specially dedicated to
father, mother, family and someone special
who gave me encouragement and support toward this study

ACKNOWLEDGEMENT

First and foremost, I would especially like to devote a great appreciation to my supervisor, Mr. Fadhlur Rahman Bin Mohd Romlay for the ideas, guidance, suggestions and knowledge of Design and fabricate a Portable CNC milling machine and contributions in completion of this final year project. I also would like to take this opportunity to express my gratitude to my university, Universiti Malaysia Pahang (UMP) for giving me the opportunity in my studies. I would also like to thank my academic advisor and all lecturers in Faculty of Mechanical Engineering for the help, guidance and support. Not forgetting the lab technician for their help. A thousand thanks go to my family and friends for their endless prayers, encouragement, understanding and patience. To Syazwani, Liyana and Fariza, thank you for the support and opinions. Special thanks to my special friend Fairuz Bte Idris for the support, time and knowledge. Finally, thank you to everybody who helped me in completing the project and report writing, directly or indirectly, May Allah S.W.T blessed you all.

ABSTRACT

In manufacturing industry, portable CNC milling machine is important to produce a product. This project describes a design and fabrication of portable CNC milling machine. This project utilized operating principles of CNC milling machine where it can move in 3 axes specifically X, Y and Z. For this project Master CAM software was used to generate the G-code for milling cutting construction testing. The most important part is the holder of the spindle, without a strong spindle holder it because difficult to produce good quality products. This project develop a CNC machine in combination with a computer. Parallel port was utilized together with intermediate Mach3 software to move the machine during cutting process. The purpose of this project is to develop a low-cost project portable CNC milling machine. It can be transported using minimum manpower, easily handled and also suitable for small industry. AC power supply is used and sent to the noise filter to reduce signal interference before sent to the stepper motor to allow axes X, Y and Z move. CNC machine structure movement is controlled by the DC stepper motor. For example, when DC stepper motor gets signal, it was sent to the gear box and turn the ball screw that connect with each drivers X, Y and Z through the bearing. Then, the driver X, Y and Z moving to start cutting process according to the computer instruction until the cutting done.

ABSTRAK

Dalam industri pembuatan, CNC milling mesin adalah penting untuk menghasilkan produk. Projek ini menerangkan reka bentuk dan pembangunan CNC milling mesin. Projek ini menggunakan prinsip-prinsip operasi CNC milling mesin di mana ia boleh gerak secara 3 paksi iaitu X, Y dan Z. Untuk projek ini perisian Master CAM telah digunakan untuk menghasilkan G-code untuk pengujian pemotongan dilakukan. Bahagian yang paling penting adalah pemegang gelendong, tanpa pemegang gelendong yang kukuh, amat sukar untuk menghasilkan produk yang baik dan berkualiti. Projek ini adalah untuk membangunkan CNC mesin yang digabungkan bersama komputer. Port selari telah digunakan bersama-sama dengan perantaraan perisian Mach3 sebagai perantaraan mesin untuk menggerakkan mesin semasa pemotongan. Tujuan projek ini adalah untuk membangunkan satu projek kos rendah mereka bentuk mini CNC milling mesin. Ia boleh dialihkan dengan menggunakan tenaga manusia, juga senang dikendalikan dan sesuai untuk industri kecil. Bekalan kuasa AC digunakan dan dihantar ke penapis bunyi untuk mengurangkan gangguan sebelum isyarat dihantar ke motor untuk membolehkan paksi X, Y dan Z bergerak. Struktur CNC mesin pula pergerakan mesin dikawal oleh DC motor. Contohnya, DC motor mendapat isyarat, kemudian dihantar ke gear box dan memusingkan ball screw yang dicantum bersama setiap penggerak X, Y dan Z melalui bearing. Kemudian, penggerak X, Y dan Z bergerak untuk memulakan proses pemotongan mengikut arahan komputer sehingga pemotongan selesai dilakukan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

NC	Numerical control
CNC	Computer numerical control
DC	Direct control current
APC	Automatic pallet changer
IPM	Inches per minute
EDM	Electrical discharge machining
RPM	Revolution per minute
FPT	Feed per tooth
AC	Alternating current
CAM	Computer aided menufacturing

CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

This chapter describes the project overview, problem statement, project objectives, and project scope. Problem statement explains about engineering issues for this project. The project objective is the description of the expected result and goal of this project. Project scope explains about the limitations and boundaries on this project.

1.1 OVERVIEW OF THE PROJECT

This project is to develop a model of portable CNC Milling machine that can be moved with minimum handling.

1.2 PROBLEM STATEMENT

Since thousand years ago, human tried to find ways to make their work easier. Thus, variety of techniques and inventions are created to reduce the human work. Nowadays, CNC Machine is most popular in manufacturing sector. So as to reduce the burden on the people, portable CNC Milling machine this is the best option because it can be removed easily, saving time and reducing the use of space. CNC milling machine is a very important technology in the manufacturing industry nowadays. But there are some problems that arise among industrial developers, because the existing milling machine is compatible with a huge industry only. While for small developers, the problem is CNC milling machines available now have a large size, heavy and difficult to control. This problem is not suitable for small industry. The solution is to design and fabricate a model of portable milling machine. Operating Portable CNC milling machine with low cost and simply in design will be a good news for the developers of small-scale industries. Related to problem statement table 1.1 below show the existing milling machine on the market, the machine shows the weight of the machine specifications that cannot be lifted using human power and has huge size

Table 1.1 : CNC milling machine specification

No.	Model	Brand	Weight (kg)	Size (mm)
1	XK716	TOPSCNC	7800	3300 x 2500
2	XK7136C	RUIFENG	2500	2220 x 1850 x 2130
3	XK718	T	15000	3569 x 4100 x 3055
4	XK718D	FORTUNE	16000	4700 x 4310 x 3210
5	KD-1212	KD	750	1200 x 1800

Figure 1.1 and 1.2 below showed the example of CNC milling machine that already have in industry. The existing machine have dimension and weight is too big, heavy, cannot move anywhere with human energy and not suitable for small developers.

Figure 1.1 : XK718D

Figure 1.2 : XK 716

1.3 OBJECTIVE

The objective of this project is:

- To design and fabricate the machine component and assemble as a complete CNC milling machine.
- To design portable CNC Milling machine.
- To fabricate the portable CNC Milling machine.
- To assemble and testing the portable CNC Milling machine.

1.4 SCOPE OF PROJECT

The scope of this project includes:

- To produce a vertical portable CNC milling machine
- Should be operating as milling machine process.
- Should be used G-code to construction the milling cutting testing.
- Used Mach 3 software as machine interface.
- To produce a mini CNC milling machine that suitable for small industry.
- Machine testing material used wood and the tool bit from solid carbide.

Figure 1.3 below showed the flow chart scope of this project. This scope used to guide the implementation of the project.

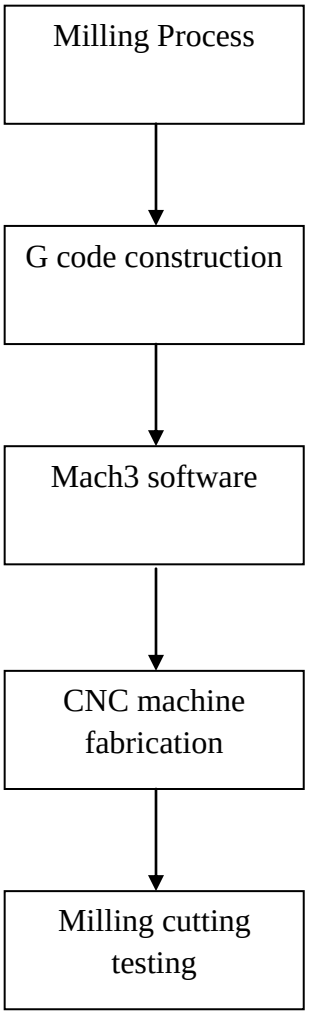

Figure 1.3 : Flow chart for scope of project

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

In this chapter, a review of previous research project that are related of this project will be discussed. This kind of surveys was held as one of the tools to have some ideas on how this project works. It is based on other achievement and also to formulate the advantages of proposed solution. This may help in problem solving skills and options required for design and develop of portable CNC Milling machine purposed.

2.1 INTRODUCTION OF CNC MACHINE

CNC stands for "Computer Numerical Control" and these machines have replaced many of the more traditional machines in the industry. Since CNC machine are already present in almost all manufacturing systems, the automatic programming of CNC machine become widespread in the last two decades (Vosniakos, 1988:Kovacic, 2002). The conventional machine that made improvement to CNC machine is lathe machine, milling

machine, drilling machine and etc. the solution differ in reliability efficiency, flexibility and universality.

Figure 2.1 below show about the basic element that have in all kinds of CNC machine. CAMS software commonly used to produce G code is Mastercam, CATIA, UG and another CAMS. While for the machine interface used Mach3, Fanux, Siemens, GSK, and another software to control the machine motion.

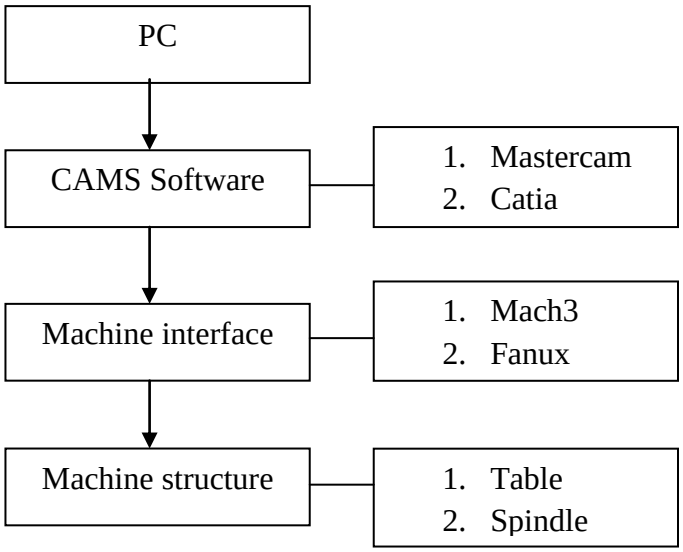

Figure 2.1 : Diagram of CNC component

2.1.1 General Operation of CNC machine

As stated, CNC has touched almost every facet of manufacturing. Many machining processes have been improved and enhanced through the use of CNC. Let's look at some of the specific fields and place the emphasis on the manufacturing processes enhanced by

CNC machine usage. Among the general operation of the CNC machine is face milling, contour milling, slot milling, etc. In similar fashion, all kinds of turning operations like facing, boring, turning, grooving, knurling, and threading are done on CNC turning centers (Mike Lynch, 2007). Another operation is reaming, tapping, countersinking, etc that can performed in a drilling machine.

2.1.2 Example of CNC machine

In today, there are many difference type of CNC machine used in the manufacturing industry of which is :

- Mills and machining centers
- Lathes and turning centers
- Drilling machines
- EDM Sinker and wire cut machine
- CNC grinders
- Water jet profilers
- Flame and laser cutting machine

2.2 HISTORY

2.2.1 CNC machine history

Before CNC machining was invented, all metalworking fabrication processes were completed with NC (Numerical Controlled) machines. The concept of was introduced in

1967 but the first CNC machines were introduced in 1976. Since then the popularity of CNC grew very significant and it was recognized as the industry standard in 1989. Today, almost all metalworking fabrication processes can be completed with CNC machines. Actually, there are many CNC variations for all metalworking equipment, such as grinders, turret punches, routers, milling machines, drills, lathes, EDMs, and high-powered cutting devices.

The main advantage is to improve safety, productivity, efficiency, and accuracy in metalworking fabrication. With CNC, operators do not have to interact directly in the metalworking processes and it significantly reduces risks at workplace. They can be operated continuously for 24 hours a day and 7 days a week. The machines only need to be turned off for regular maintenance. The reliability of these machines makes most companies to continue operating the machines during weekend, even without any human supervision. The machines are usually equipped with additional system that can contact off-site operator when an error occurs. When an error occurs, the process stops automatically (Natalie Eastaugh, 2011) .

2.2.2 CNC Milling machine history

Milling machines came originally from machine tools called rotary files. They were circular cutters that worked inside of a lathe. This machine was originally developed because hand filing materials was taking too long. The first of the milling machines was between the years 1814 and 1818. There were two armories that used the first milling machines, and they were called Springfield and Harpers Ferry. Soon after, various private factories began using these machine tools to quickly produce machined products at a rate much faster than what any number of workers using hand files could do on their own.

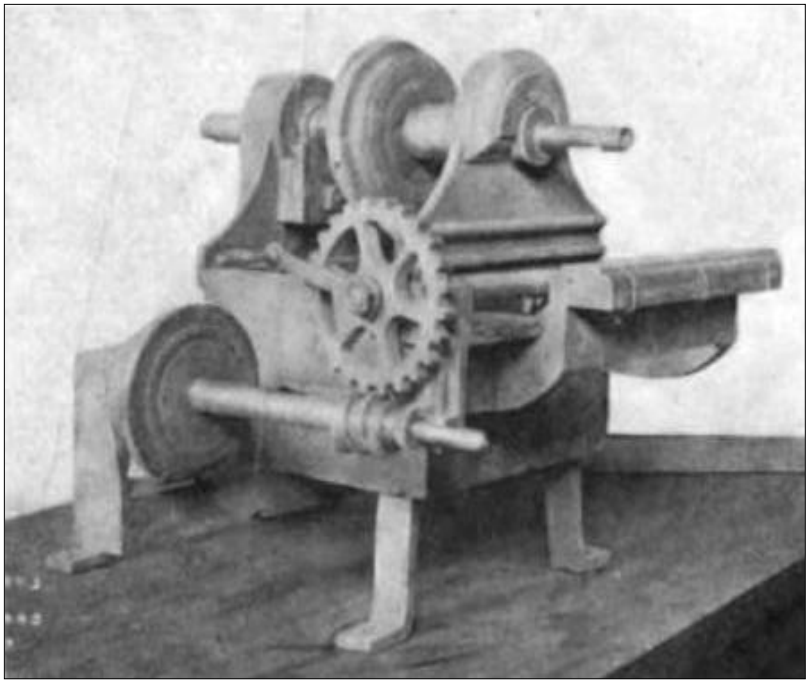

Figure 2.2 : Eli Whitney milling machine

Many private inventors began creating these machines at the same time. The most famous of these was Eli Whitney, who is generally given the honor of having created the first "true" milling machine. Other inventors have also been credited with contributing to the process, such as Robert Johnson, Captain John H. Hall, Simeon North, Roswell Lee, Thomas Blanchard, and others from Harpers Ferry, Springfield, and other locations running machine tools in the early 19th century. There is some controversy surrounding whether Eli Whitney actually created the first milling machine himself or not. Some scholars, such as Peter Banda, claim that the machine that was long credited to Whitney wasn't actually created until after his death.

The early part of the 19th century, such as the teens, were critical for the development of milling machines. For example, the inventor James Nasymyth made

milling machines that were quite advanced because they could mill a hex nut used in indexing fixtures, even though they had six sides. One problem that Eli Whitney's milling machines had classically, is that it had no room for the knee to move up and down during the milling process. Machine tools used by the Gay & Silver Corporation in the 1830s fixed this oversight, thus making it much more comfortable for people to use it, which increased productivity.

A reason for this oversight is likely because Whitney never envisioned just how far milling machines would be used. He thought that the machine tools would be used as a way to allow workers to not hand file everything. He likely envisioned a process where workers would use the machine for the rough parts of the project, and then finish up with hand files for the rest. The idea that hand filing would be eliminated altogether by the machines would've been a surprise. The Lincoln miller was a very influential machine from the 1840s. It was developed by George S. Lincoln & Company who made one for the Colt armory in 1855. This miller also had the problem of having no way to position it vertically. The development of machines that had better vertical positioning would not come until the problem was noticed later on (Dudley Meredith, 2011).

2.3 MILLING MACHINE

Milling machine can produce one or more machined surfaces accurately on work piece. Example of the process machining is flat, curved, or irregular surfaces by feeding the work piece against a rotating cutter containing a number of cutting edges. The milling machine consists basically of a motor driven spindle, which mounts and revolves the milling cutter, and a reciprocating adjustable worktable, which mounts and feeds the work piece. Milling machines are basically classified as vertical or horizontal. These machines

are also classified as knee-type, ram-type, manufacturing or bed type, and planer-type. Most milling machines have self-contained electric drive motors, coolant systems, variable spindle speeds, and power-operated table feeds.

Figure 2.3 below showed the principle of CNC Milling machine. CNC milling machine in two basic form, first vertical and second horizontal. Both type of position have the same direction of movement in which are two types of three-axis and five-axis.

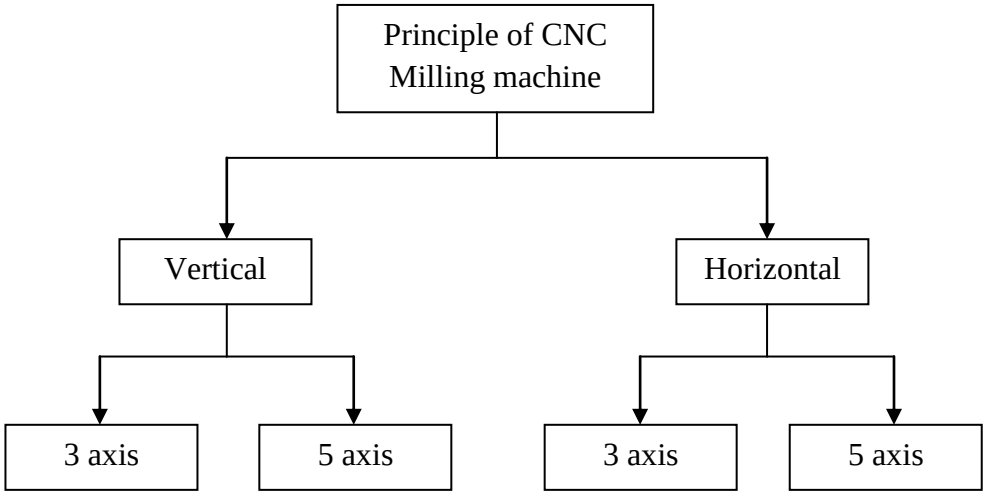

Figure 2.3 : Principle of CNC Milling machine

2.3.1 Principle of CNC milling machine

2.3.1.1 Vertical CNC milling machine

The machining stability of the vertical milling machine can be predicted based on the analytical model (Altintas, 1995:Budak, 1998) **.** In their approach, the time-varying force coefficient of the dynamic milling process model was approximated by Fourier-series components. Following this, the stability relationship between the chatter-free axial cutting depths (*Zmin*) and the spindle speed (*n*) in end-mill operation (Gagnol, 2007).

Figure 2.4 below shows the vertical spindle for CNC milling machine. This is the most popular machine for a job shop and mold maker. The advantages is trust of the cutting tool is directly absorbed into the machine table, ideal for large, flat plate work and single surface 3D contouring, heavy tools can be used without concern about deflection and less costly. This machine only have one of the disadvantages is the extensive chip buildup which obstructs the view and recuts chips.

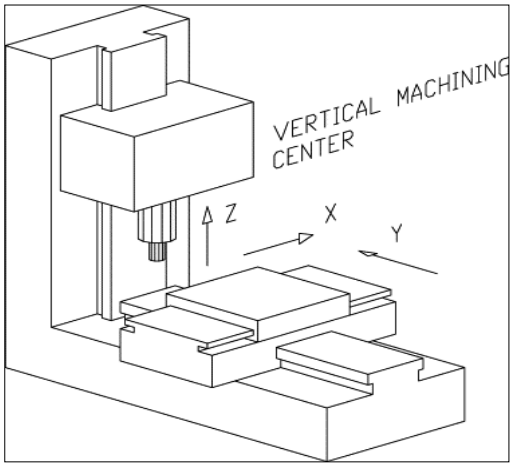

Figure 2.4 : Vertical CNC milling machine

Source : Bohez (2002)

2.3.1.2 Horizontal CNC milling machine

Operating the horizontal milling machine is not much different than operating the vertical milling machine until you begin using the over-arm supports and arbor driven cutters. When we use the horizontal milling machine in this way, a new set of operating principles need to be addressed. In the information that follows please pay close attention to the details. The information will help you not only make better parts and keep the machine running in proper order, but it may also keep you from getting seriously injured.

The Horizontal Milling Machine is a very robust and sturdy machine. A variety of cutters are available to removed/shape material that is normally held in a strong machine vice. This horizontal miller is used when a vertical miller is less suitable. For instance, if a lot of material has to be removed by the cutters or there is less of a need for accuracy - a horizontal milling machine is chosen.

Figure 2.5 below showed the horizontal spindle for CNC milling machine. Most popular for series production. The advantages to used this orientation is the table indexing capability enables multiple sides of a workpiece to be machined in one setup, chip drop out the way during machining, providing an uncluttered view of the cut and preventing recutting of chips and easy to provide APC. While the disadvantages is heavy tool deflect, trust of cutting tool must be absorbed by fixtures and more expensive than the vertical spindle machine (Luggen, 1991).

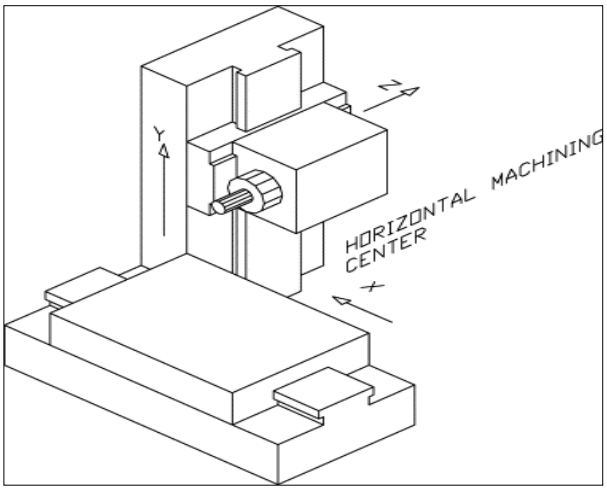

Figure 2.5 : Horizontal spindle machine

Source : Bohez (2002)

Three axis CNC machine

The number of axis of a machine tool normally refers to the number of degrees of freedom or the number of independent controllable motions on the machine slides. A three axis milling machine as three linear slides X,Y, and Z which can be positioned everywhere within the travel limit of each slides. The tool axis direction stays fixed during machining (Bohez, 2002). On 3 axis milling operations it is possible to identify three different cutting types, the type is downward cutting, the plane cutting and the upward cutting.

Figure 2.6 below shows that the cutting speed is not constant along the machining path. Figure 2.6 also shows that the cutting speed distribution in the tool edge is different for each one of the three cutting types.

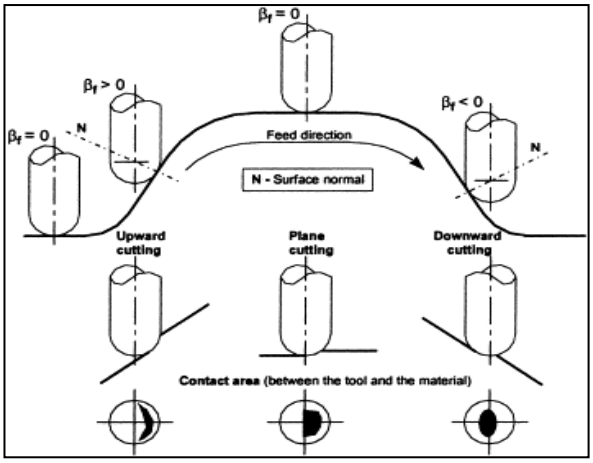

Figure 2.6 : Lead/lag angle

Source : Baptista (2000)

Figure 2.7 and 2.8 below show the general three axis machine tool for the vertical ang horizontal spindle.. the motion for both machine is same but the direction of spindle is difference.

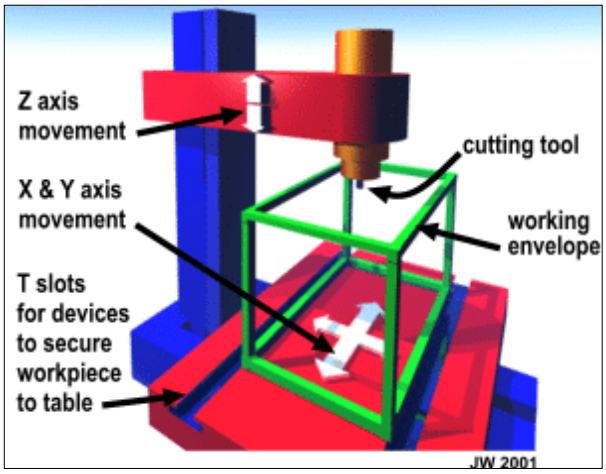

Figure 2.7 : Three axis machine tool (vertical)

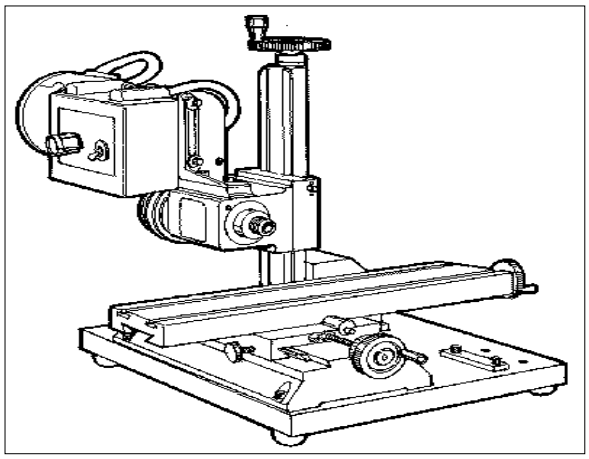

Figure 2.8 : Three axis machine tool (horizontal)

Five axis CNC machine

Five-axis CNC machining centers have become quite common today. The number of axes of a machine tool normally refers to the number of degrees of freedom or the number of independent controllable motions on the machine slides. One of the earliest (1970) and still very useful introductions to five-axis milling was given by Baughman (1970) clearly stating the applications. Many types and design concepts of machine tools which can be applied to five-axis machines are discussed but not specifically for the five-axis machine (Manfred, 1984).

Figure 2.9 b belo show the five axis milling operation. The five axis machine is similar two cooperating robots, one robot carrying the workpiece and one robot carrying the tool. Five degree of freedom are the minimum required to obtain maximum flexibility in tool workpiece orientation, this mean that the tool and workpiece can be oriented relative to each other under any angle.

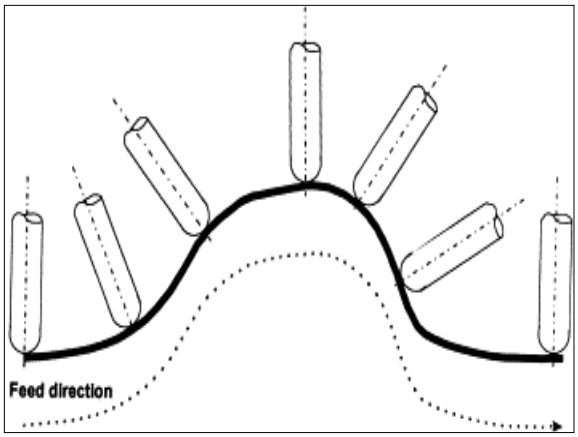

Figure 2.9 : 5 axis milling operation

Source : Baptista (2000)

Figure 2.10 and 2.11 below shows the five axis machine tool for the vertical and the horizontal direction of spindle.

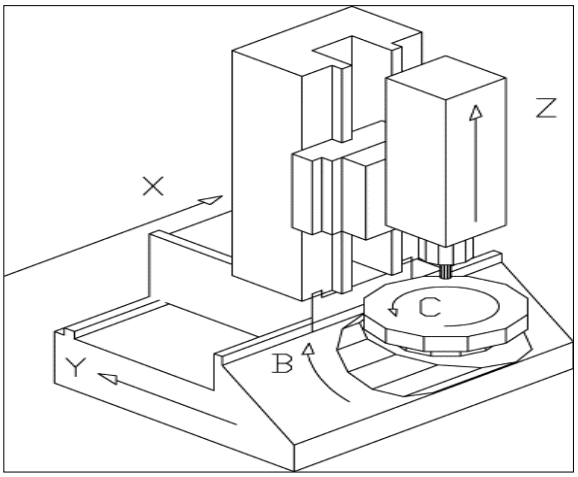

Figure 2.10 : Five axis machine tool (vertical)

Source : Bohez (2002)

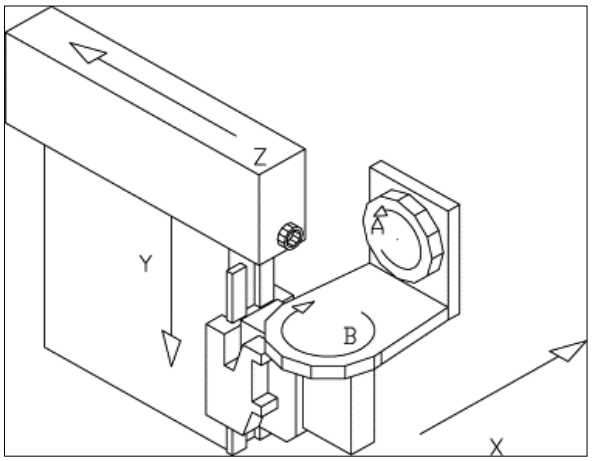

Figure 2.11 : Five axis machine tool (horizontal)

2.4 PERFORMANCE OF CNC MILLING MACHINE

There are three factors that make up the cutting conditions, cutting speed, depth of cut, and feed rate. In this information sheet we will concentrate on feed rate factors and calculations. The table feed rate on milling machines is given in terms of inches per minute (IPM). Inches per minute is the rate at which the tool will advance into the work. The feed rate, that can be used, is determined by the speed of the rotation of the cutter (RPM), the number of cutting teeth on the cutter, and by the size of the chip that the cutter can withstand. The chip size is called the feed rate in inches per tooth or chip load.

Figure 2.12 below shows the performance of CNC milling machine which includes input parameter and output parameter. In CNC machining parameters are usually selected prior to machining according to hand books. To assure high quality and productivity we need to optimize the machining parameters.

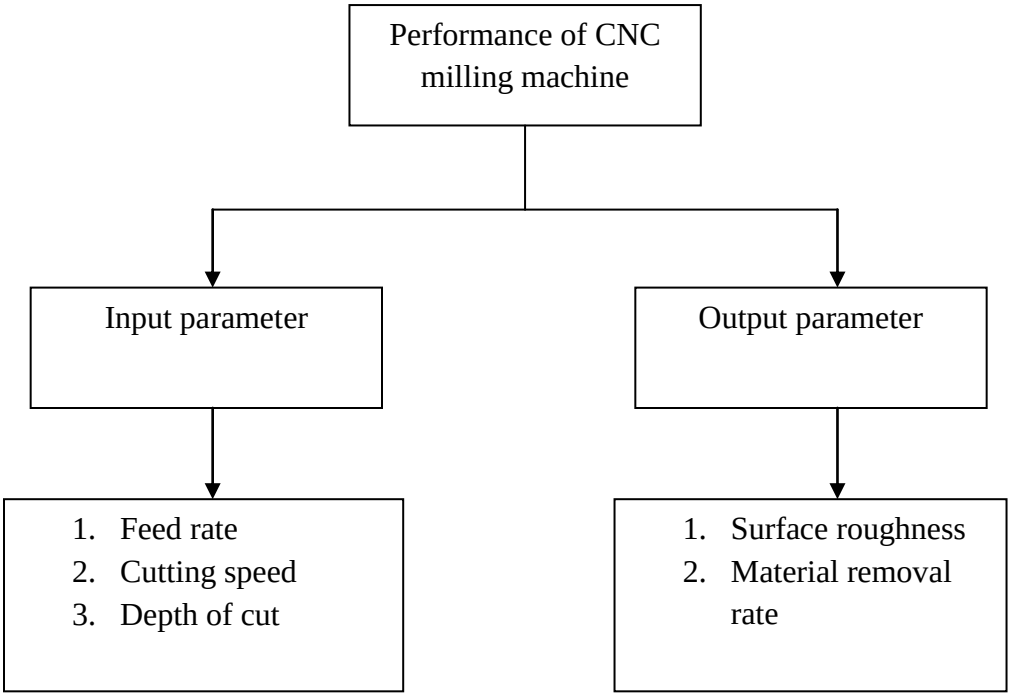

Figure 2.12 : Performance of CNC milling machine

2.4.1 Input parameter

Feed Rate(Milling Machine) refers to how fast a milling-tool moves through the material being cut. This is calculated using the Feed Per Tooth(FPT) to come up with the Inches Per Minute that a milling bit can move through a particular type of material. Thus, a Four-Flute End-Mill will cut through material at twice the speed of a Two-Flute End Mill. Feed Rates will decrease with dull tools, a lack of coolant, or deep cuts.

Cutting Speed(CS) of a material is the ideal number of Feet-per-Minute that the tool-bit should pass over the work-piece. This "Ideal" cutting speed assumes sharp tools and flood coolant. Adjustments need to be made for less than ideal cutting conditions. Different materials (High-Carbon/Low-Carbon Steels, Aluminums, Different kinds of Plastics) have different Cutting Speeds and can be worked/cut at different rates.

- Cutting Speeds

  $$r/min = \frac{CS \times 4}{D}$$

- Feed rate

  Feed Rate (in./min.) = N x c.p.t x r/min

  N = the number of teeth in the milling cutter.

  c.p.t = chip per tooth for particular cutter and metal as given in table.

  r/min = the number of revolution per minute of the milling cutter.

  RPM = (Cutting Speed x 4)/Diameter

Table 2.1 : Recommended cutting speed for milling in feet per minute (fpm)

Work Material	Hardness, Bhn	Cutting Speed, fpm	
		High-Speed Steel	Carbide
Plain Carbon Steel, AISI 1010 to AISI 1030	to 150	110 100 to 140	600 400 to 900
	150 to 200	100 80 to 120	450 300 to 700
AISI B1111, AISI B1112, AISI B1113, Steel	140 to 180	140 110 to 200	650 400 to 1200
Plain Carbon Steel, AISI 1040 to 1095	120 to 180	195 80 to 120	600 400 to 800
	180 to 220	85 70 to 110	350 300 to 500
	220 to 300	60 30 to 80	200 100 to 300
All Alloy Steels Having .3% or Less Carbon Content:	180 to 220	80 65 to 100	350 300 to 600
AISI 1320, AISI 3120, AISI 4130, AISI 4020, AISI 5020, AISI 4118, AISI 9310, etc.	220 to 300	60 30 to 80	300 200 to 350
	300 to 400	40 30 to 50	125 100 to 150
All Alloy Steels Having More Than .3% Carbon Content:	180 to 220	80 60 to 100	325 275 to 450
AISI 1340, AISI 2340, AISI 4140, AISI 4150, AISI 4340, AISI 5140, AISI 5150, AISI 52100, AISI 8660, AISI 9260, etc.	220 to 300	55 30 to 80	250 180 to 300
	300 to 400	30 20 to 50	100 80 to 130

Table 2.2 : Recommended feed per tooth for high speed steel cutter

Material	Side Mills		End Mills		Plain Helical Mills		Saws	
	Inch	mm	Inch	mm	Inch	mm	Inch	mm
Machine steel	0.007	0.18	0.006	0.15	0.010	0.25	0.002	0.05
Tool steel	0.005	0.13	0.004	0.1	0.007	0.18	0.002	0.05
Cat iron	0.007	0.18	0.007	0.18	0.010	0.18	0.002	0.05
Bronze	0.008	0.2	0.009	0.23	0.011	0.28	0.003	0.08
Aluminum	0.013	0.33	0.011	0.28	0.018	0.46	0.005	0.13

2.4.2 Output parameter

Surface roughness is not only a quality indicator but also the final stage in controlling the machining performance and the operation cost (Boothroyd, 1989:Dagnal, 1986). The most practical way of determining the surface roughness is to measure the surface roughness which is defined as the irregularities remained on the surface after machining process. The average roughness Ra is used in present study. Ra is measured using a surface roughness testing instrument which has a probe at one end. During measuring 3mm was set as the cut of length A method for the estimation of surface roughness ,starting from measured cutting forces in face milling. An in process surface roughness adaptive control system in end milling was developed employing a multiple regression model.

MRR is the measurement of productivity and Surface roughness is the measurement of Quality.MRR can be expressed as product of depth of cut(d) and feed(f) and width of the cutter(w). Surface roughness is measured during experimentation and is usually denoted as given below where x1,x2,x3 are empirical coefficients. Therefore, the address that the material removal rate (MRR) and the tool life are important control factors of

machining operation has been developed (Choudhury, 1999). As the MRR optimization under expected machining quantity for a single cutting tool is presented in the previous research (Lan and Yeh, 2003) the attention to analyses cutting force economically has become necessary to the field.

- Metal removal rate

  MRR = d x f x w

- Surface roughness

  $Ra = k V^{*1} f^{*2} d^{*3}$

CHAPTER 3

METHODOLOGY

3.0 INTRODUCTION

This chapter discussed about the design and development of portable milling machine. A proper planning is required to ensure this project is completed on time and the objectives are accomplished. Hence, this chapter discusses the methods and materials used in the design and fabrication of the project, as well as its manner of operation. It will show all the procedures and techniques for completing the project from the starting stage until it is completed.

3.1 FLOW CHART

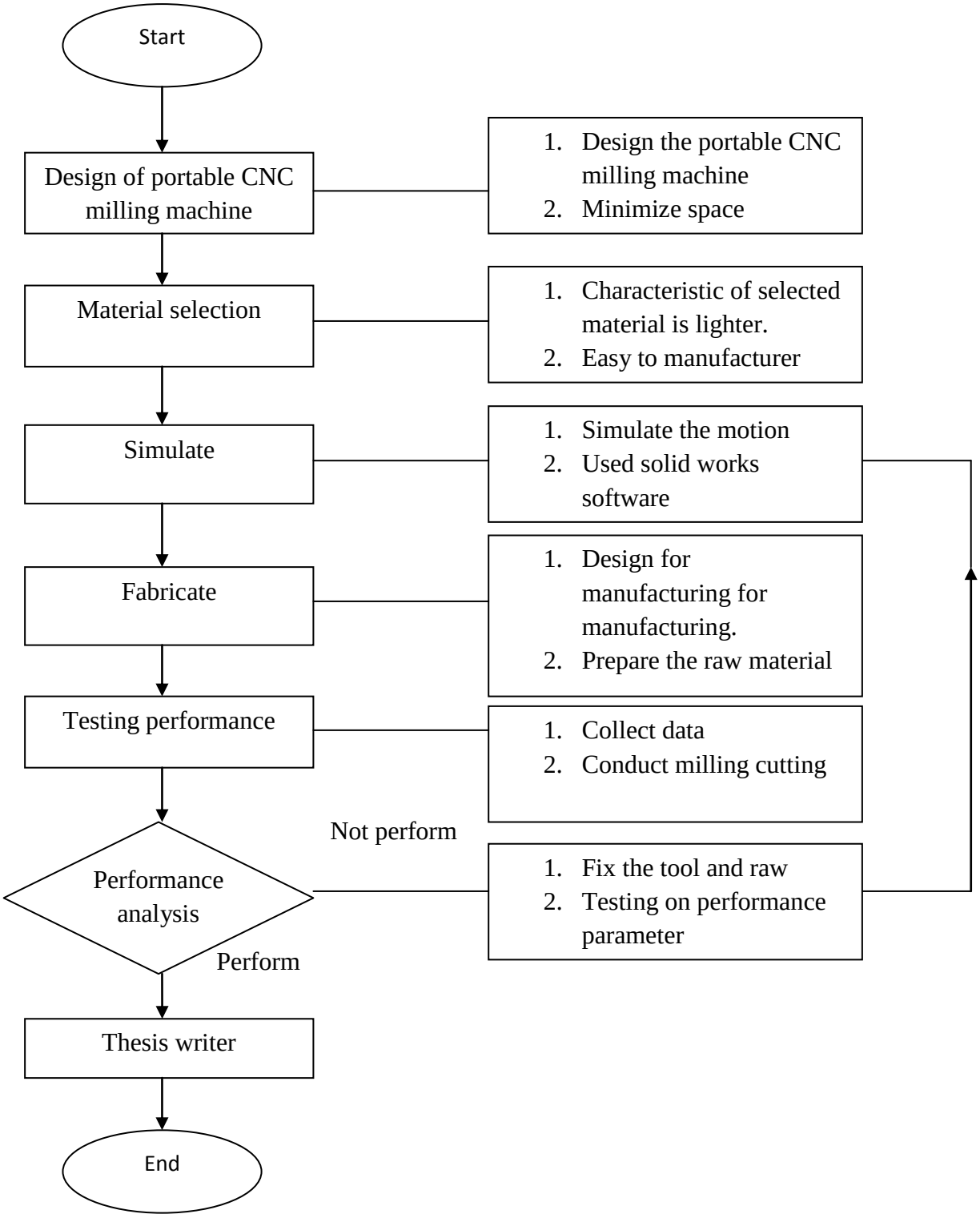

Figure 3,1 : Flow chart for methodology

Figure 3.1 above shows the process flow used as work carried out in this project. The first thing to do is to design a portable CNC machine milling to coincide with the scope set. Then the design has been made, finding the right material to machine parts. Then simulate the movement of the machine is done by using solid works. After that, build and develop the machine model. Then test the machine with a milling process to see the performance of the CNC milling machine and collect the data. Lastly, fix the tool and raw material that used and testing on performance parameter.

3.2 BLOCK DIAGRAM

3.2.1 Driver

Figure 3.2 below show the flow chart for driver give the direction to CNC milling machine for the motion. From the AC supply go to the noise filter for reduce the noise before sent to stepper driver to give direction to X,Y, and Z for the motion.

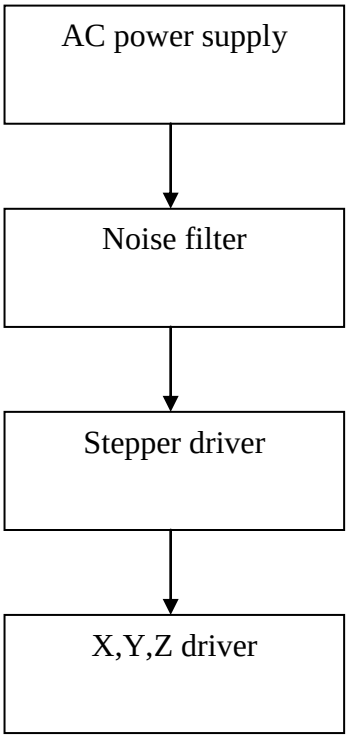

Figure 3.2 : Flow chart for driver CNC milling machine

3.2.2 CNC structure

Figure 3.3 below show the material that used to construct the motion of CNC milling machine in this project.. The DC stepper motor connect with their gearbox to rotate the bolt skru and the driver of CNC milling machine with bearing can move according to the instructions from mach 3 software.

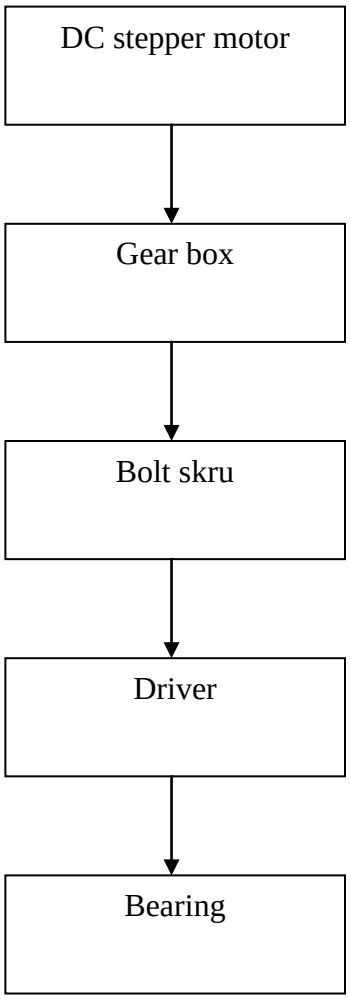

Figure 3.3 : Flow chart for CNC structure

3.3 DESIGN OF PORTABLE CNC MILLING MACHINE

After a long discussion with the supervisor, there are some material that had been decided to be use for the body structure and spindle. Identification and selection type of body and spindle to be used on the machine structure is important. It's to ensure suitability of body and spindle applied in this CNC machine model. The body structure and spindle

must be lighter, easy to manufacturer and cheaper. The body structure and spindle is the important part of this project. The idea of the project is by using aluminum as the main structure of body of machine. While the spindle using cast steel.

The design that this project is required to reduce the use of work space. This design characteristic also easy to construct. The most important for the design is suitable to used in cutting milling. For this project three designs in the designed to get the right design and quality with this project

Figure 3.4 below show the preliminary design of CNC milling machine. The design was made by SolidWorks software.

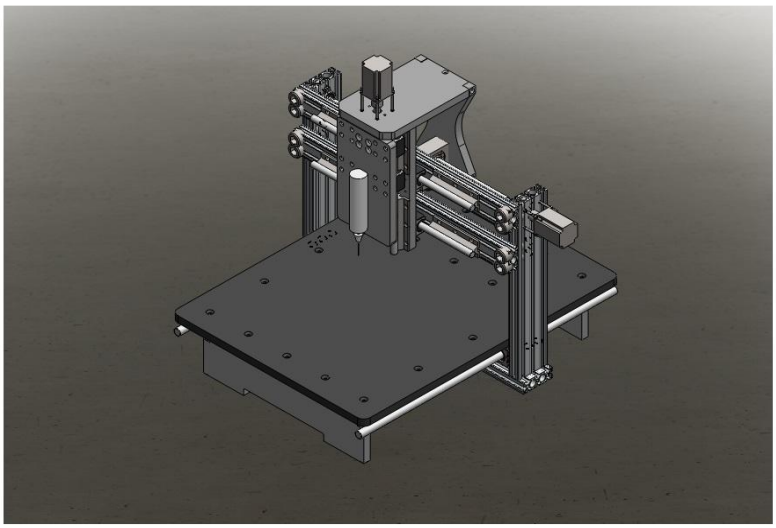

Figure 3.4 : First design

In this design the rail for the driver at above the work table as show in Figure 3.5. This is second design for this project.

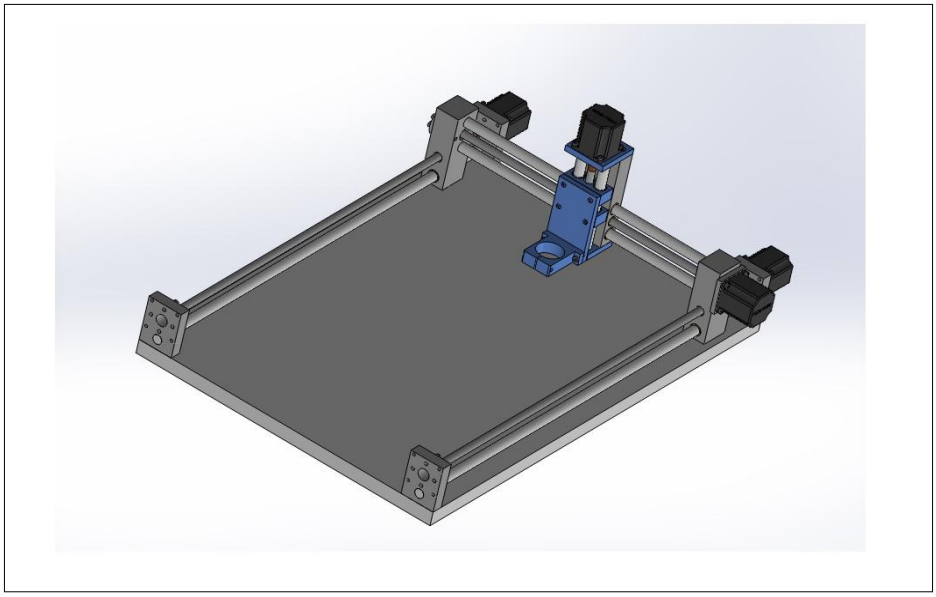

Figure 3.5 : Second design

Final design is important because this design is used in this project. For the last design build important thing is easy to build, the neatness and more safety. Figure 3.6 show the final design that used to develop of portable CNC milling machine in this project.

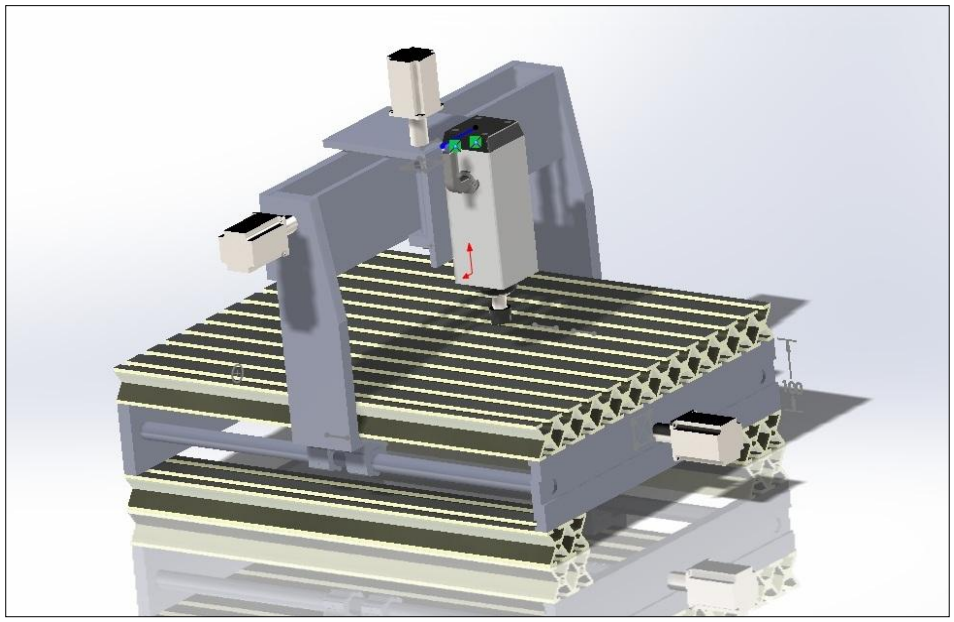

Figure 3.6 : Third design

3.4 MATERIAL SELECTION

Material selection is important to achieve the scope of project. In this project the main material selection for the frame of CNC milling machine is aluminum. While for the spindle is very important to select the right material because spindle part require high durability, the material that this project use also can reduce vibration and heat treatment. So the material that suitable for the spindle is stainless steel.

Aluminum is a light-weight metal with a bright silvery luster. Small amounts of other metals are added to aluminum to make harder alloys for most uses. Its affinity for oxygen makes it resistant to corrosion and attack by most chemicals. Most aluminum used in visible parts of appliances is lacquered or otherwise coated, anodized or painted.

Aluminum reacts with air to grow its own thin oxide coating very fast. This hard, dark gray coating protects the metal. It's found on all bare aluminum surfaces, including utensils which, if rubbed on a counter or range top, or other material, makes a dark gray mark. If washed off the outside of the pan, it quickly forms again. A commercial process, called "anodizing", thickens this coat and often colors it. Anodizing does not rub off. A special anodizing process produces a very hard, dark gray finish on professional type cookware.

3.4.1 Table

Figure 3.7 below show the material that used as table of CNC milling machine in this project . This material characteristic satisfy with the design for this project.

Figure 3.7 : T slot aluminum extrusion

3.4.2 Driver frame

Figure 3.8 below shows the aluminum sheet that this project used for the spindle driver in CNC milling machine structure.

Figure 3.8 : Aluminum sheet

3.4.3 Table frame

Figure 3.9 above shows the aluminum flat as the table frame in this project.

Figure 3.9 : Aluminum flat

3.4.4 Motor spindle

Figure 3. 10 above shows the motor spindle as the mill tools holder. The material of motor spindle is stainless steel.

Figure 3.10 : Motor spindle

3.4.5 DC stepper motor with gearbox

Figure 3.11 above shows the DC stepper connect with gearbox to drive the motion X,Y and Z. Three set of DC stepper motor and gearbox used in this project for the motion.

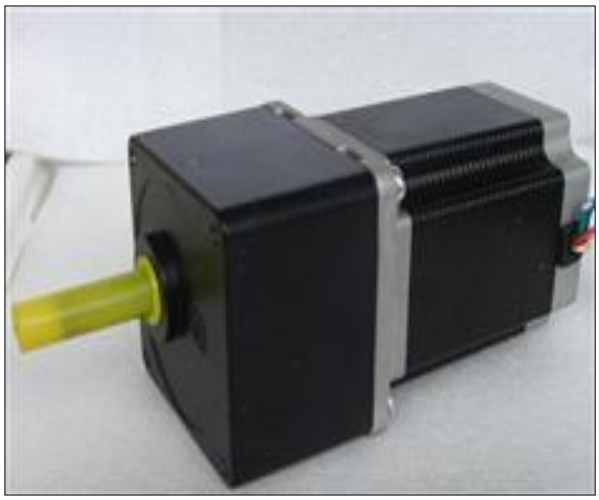

Figure 3.11 : Stepper motor with gearbox

3.4.6 Cable carries

Figure 3.12 showed the cable carries that this project used for cable and tubes for water coolant management. Cable carriers (also called cable chains) have arrived and are ready to ship. Cable carriers are used for cable management, but can be used for hoses, tubes, conduit, etc. as well. These are typically used on CNC machines, or machines that have moving axes, but can be used on other machinery, or factory motion system.

Figure 3.12 : Cable carries

3.4.7 Bearing

Figure 3.13 above show the bearing used in this project as the support of driver to move X and Y axis.

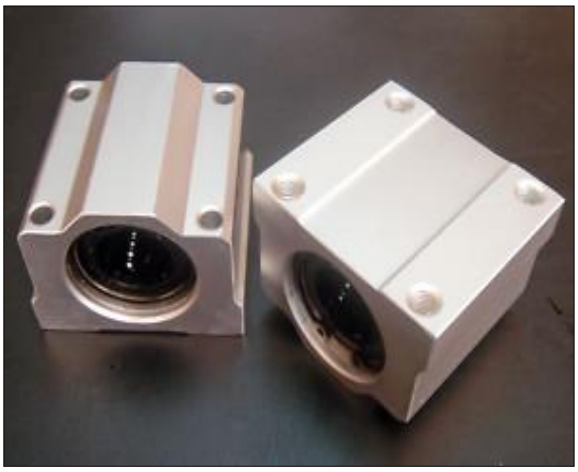

Figure 3.13 : Bearing

3.4.8 Limit switch

Figure 3.14 above show the limit switch that used for safety.

Figure 3.14 : Limit switch

3.4.9 Ball screw

A ball screw is a mechanical linear actuator that translates rotational motion to linear motion with little friction. A threaded shaft provides a helical raceway for ball bearings which act as a precision screw. As well as being able to apply or withstand high thrust loads, they can do so with minimum internal friction. They are made to close tolerances and are therefore suitable for use in situations in which high precision is necessary. Figure 3.15 showed the ball screw that used in this project.

Figure 3.15 : Ball screw

3.4.10 Allen key screw

Figure 3.16 show the joint used for assemble all part in this project

Figure 3.16 : Allen key screw

3.5 FABRICATION

Fabrication is one of the most important processes in development of portable CNC milling machine. The fabrication will include full assemble between the machine frame, X, Y and Z driver, and the small part.

3.5.1 Frame fabrication

The critical process in the development of this CNC milling machine is frame fabrication. Basically the frame has three function that very significant. Those are as a frame structure during X, Y and Z axis movement. Framework is an important part in developing this project. Strong framework is required to obtain high accuracy during milling cutting is done.

Basically the fabrication process of the portable CNC milling machine is start with selecting the best material with full dimension to make the machine. The material must be significant which is can stand during the cutting work. Here, the material that will use is the aluminum sheet with 20mm thickness.

After decide and choose the best material to make the machine frame, the process is carry on with marking process base on dimension of the frame in the drawing. Then the cutting process will do.

After done cutting all part of frame continue with process to assemble all the part. Before assemble the part, need to drill hole based on dimension to make the joining. Figure 3.17 below show the machine frame that done to assemble used the Allen key joint.

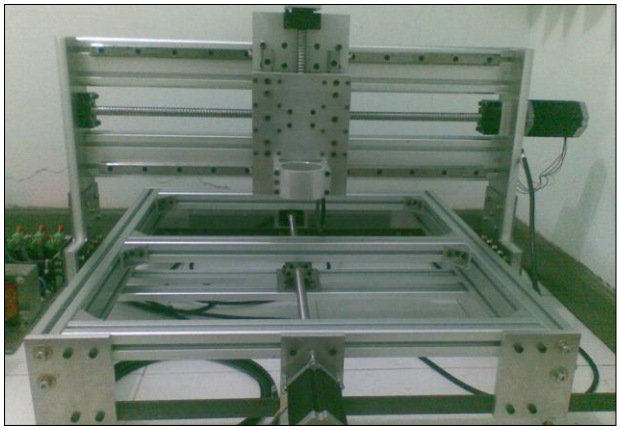

Figure 3.17 : Machine frame

3.5.2 Assemble X, Y and Z rail

After the frame assemble done. Second stage is to assemble the rail X first. Two bearing rail 600mm is use assemble fix to the frame and one ball screw 650mm is used and assemble to gear box. Then need to assemble rail for Y movement, used two bearing rail 700mm assemble fix to the frame and one ball screw 750mm also connected to gear box. Last to assemble the Z rail also used two bearing rail 200mm and one ball screw 250mm connected to gear box. Figure 3.18 show the bearing rail that used for this machine and figure 3.19, 3.20 and 3.21 is show the

Figure 3.18 : Bearing rail

Figure 3.19 : X axis rail

Figure 3.20 : Y axis rail

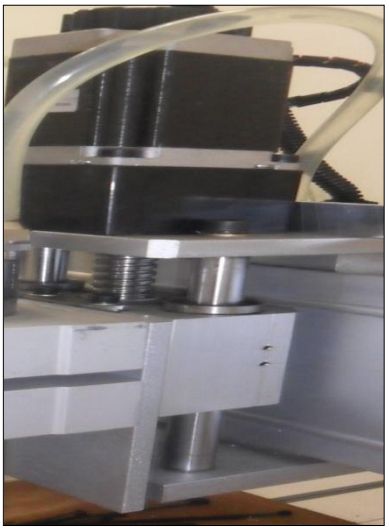

Figure 3.21 : Z axis rail

3.5.3 Assemble spindle

The process is carry on with assemble the spindle to the spindle holder

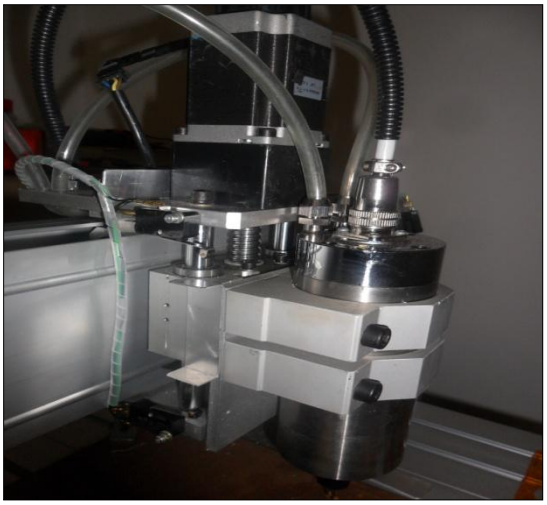

Figure 3.22 : Spindle

3.6 EQUIPMENT

Tools are the most important items that need to used in this project to success the fabrication.

3.6.1 Disk cutter machine

Figure 3.23 below show the disk cutter used for cut the material base on the dimension needs.

Figure 3.23 : Disk cutter

3.6.2 Drilling machine

Figure 3.24 show the drilling machine used in this project to make hole for the assemble process.

Figure 3.24 : Drilling machine

3.6.3 Grinding machine

Figure 3.25 below show the grinding machine used for the finishing the all part.

Figure 3.25 : Grinding machine

3.7 TESTING SET UP

Testing set up is process of set up all the related tools and milling machine itself to make milling cutting to produce the product. Figure 3.26 below show the desired shape for the milling cutting testing. This shape draw used the solid works.

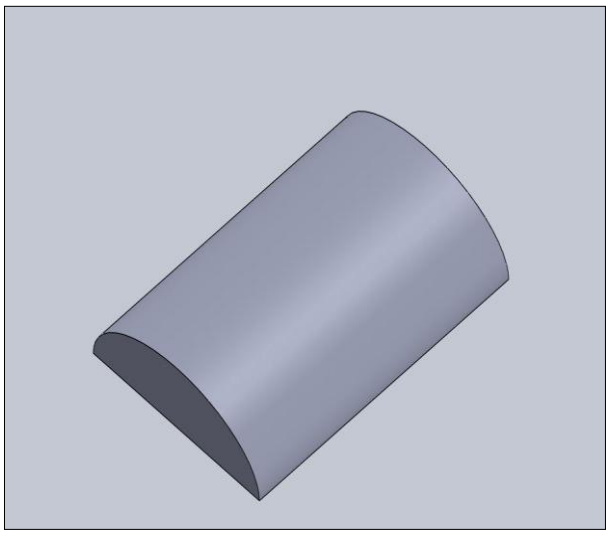

Figure 3.26 : Desired shape

The list of the tools or equipment needed in this testing are listed such as below ;

- Portable CNC milling machine.
- Master CAM software
- Mach 3 software
- Wood
- Tool bit
- Measuring tape

After done draw used solid works must draw at Master CAM software to develop G-code to transfer at Mach 3 software to run the testing. Figure 3.27 show the Master Cam drawing done for construct G-code.

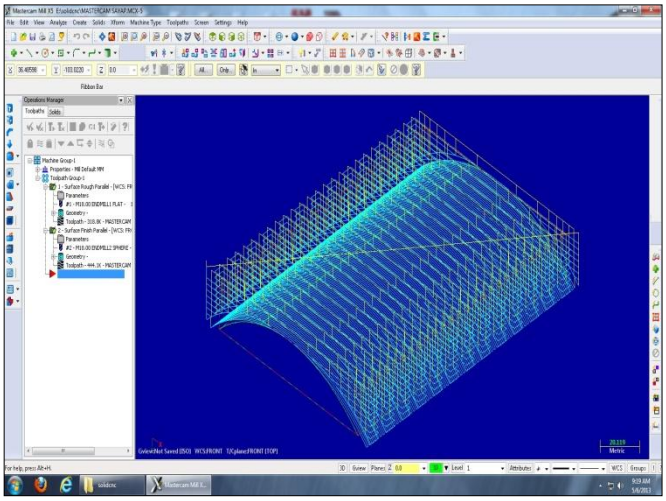

Figure 3.27 : Master CAM drawing

Figure 3.28 below show the simulation for the Master CAM. After the simulation done and don't have a error the G-code can develop now.

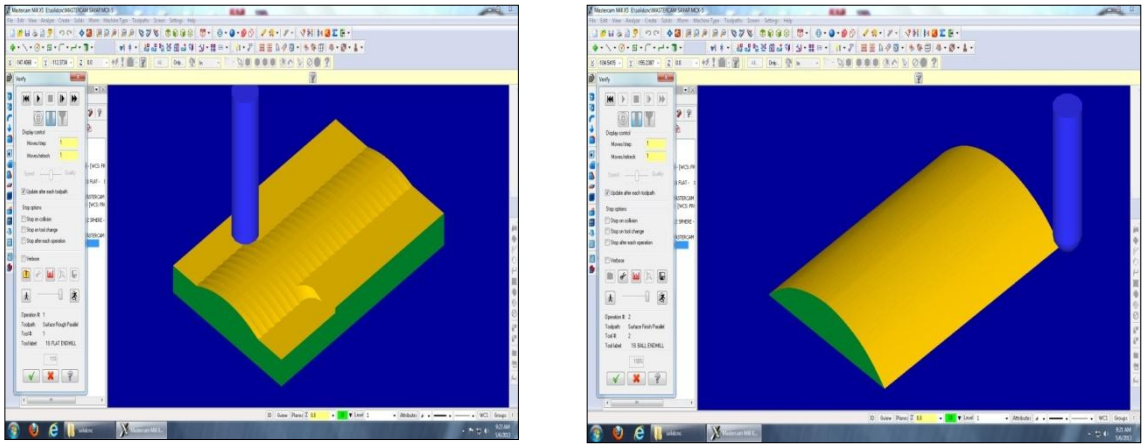

Figure 3.28 : Master CAM simulation

Figure 3.29 show the G-code construct from the Master CAM software. After editing this G-code now can transfer to the Mach 3 software for the testing.

```
%
T0 M6
G0 G90 G54 X52.069 Y-150. A0. S2000 M3
G43 H0 Z50.
Z5.8
G1 Z-.2 F100.
X5.199 F300.
X3.586 Z-.086
X3.516 Z-.083
X.035 Z-.001
X-.035
X-3.516 Z-.083
X-3.586 Z-.086
X-5.199 Z-.2
X-52.069
Y-146.053
X-5.199
X-3.551 Z-.084
X0. Z0.
X3.551 Z-.084
X5.199 Z-.2
X52.069
Y-142.105
X5.199
X3.551 Z-.084
X0. Z0.
X-3.551 Z-.084
X-5.199 Z-.2
X-52.069
Y-138.158
X-5.199
X-3.551 Z-.084
X0. Z0.
X3.551 Z-.084
X5.199 Z-.2
```

Figure 3.29 : G-code

CHAPTER 4

RESULT AND DISCUSSION

4.0 INTRODUCTION

This chapter discussed the result throughout the completion of portable CNC milling machine project. The result is analyzed and the problem encountered is discussed. These results help to measure the effectiveness of CNC milling machine to ensure whether it had met the outlined objective successfully.

4.1 DESIGN RESULT

Before development of portable CNC milling machine get started, there are some others idea need to be done first as a first step of ideas development in design a concept. The idea adaptation that came from many adaptation can used such as for the structure table of machine. Here, the best idea structure of machine and the reason will show on the Pugh concept below.

4.1.1 Result of portable CNC milling machine design.

Table 4.1 shows the Pugh concept of the overall machine design comparison between 3 main design of machine. It is including first design, second design, and third design. From the criteria have shown below, first design build with quietly at disadvantage where it have a big space to use and more cost if compare with the other concept. It is also heavy due to the more material use. For the second design is quietly lightweight due to the small amount of the steel material used. It is also ease to manufacture compare with others design concept. This design concept are not suitable to used as the milling machine because of the location working area are not suitable.

Here, the strong candidate for the best stand design concept goes to the third design concept. It is completed with movement feature which is easy to manufacturer and easy of used. The third design also easy to set up. Even though the cost is quite high compare to the second design due to the amount of the material used, others feature make it as a best design to through the fabrication process.

Table 4.1: The comparison of machine design

SELECTION CRITERIA	OVERALL STAND DESIGN COMPARISON			
	DESIGN 1	DESIGN 2	REFFRENCE	DESIGN 3
EASE OF USE	+	0	0	+
WEIGHT	-	+	0	+
ADAPTABILITY	0	-	0	+
COST	-	+	0	+
STABILITY	+	+	0	+
EASE TO MANUFACTURE	-	-	0	+
EASE OF SETUP	+	-	0	+
MOBILITY	+	-	0	+
BEST SHAPE	+	-	0	0
SUM + 'S	5	3	0	8
SUM 0 'S	1	1	10	1
SUM – 'S	3	5	0	0
NET SCORE	2	-2	0	8
RANK	2	4	3	1

4.1.2 Final design

After make the analysis on the all ideas design concept including design ideas base on weight, easy to manufacture, ease of use and etc, the best ranking part of design will conclude or combine to make the portable CNC milling machine. Figure 4.1 shows the final design for the fabrication process.

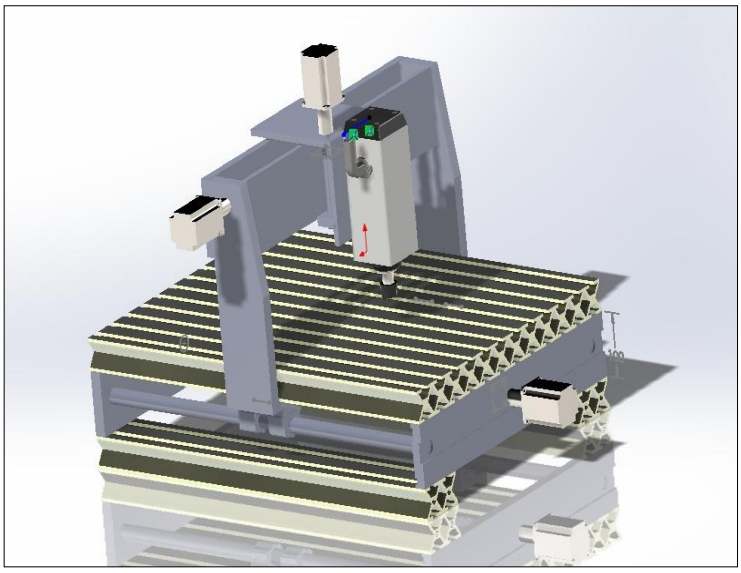

Figure 4.1 : Final design

4.2 PORTABLE CNC MILLING MACHINE RESULT

All the manufacturing process is done on the portable CNC milling machine fabrication and the result shows here. Base on the evaluation from the designing stage and the drawing, the fabrication of this machine started. Start from the designing stage, selecting the material, cutting, assemble all part and finishing process, it is all done to come out with the real portable CNC milling machine that can run the milling cutting and the objective are archived . The result fabrication of the portable CNC milling machine is shows in the Figure 4.2 and 4.3.

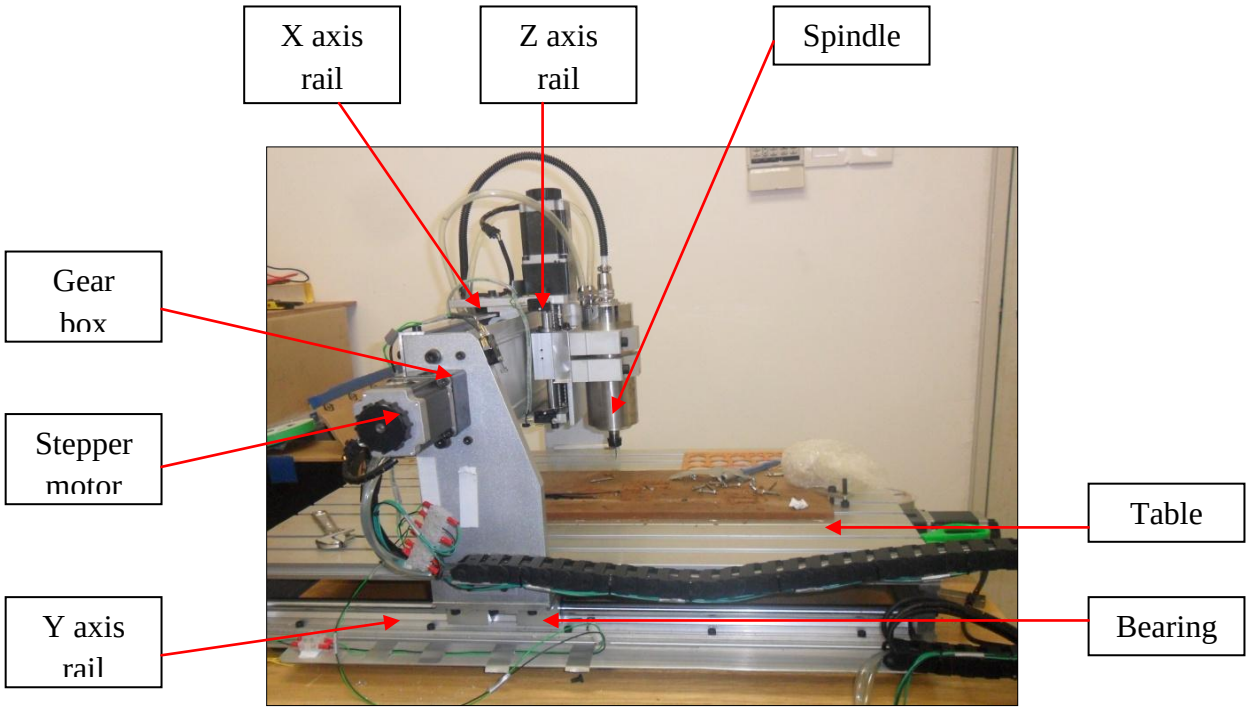

Figure 4.2 : Fabrication result of the portable CNC milling machine

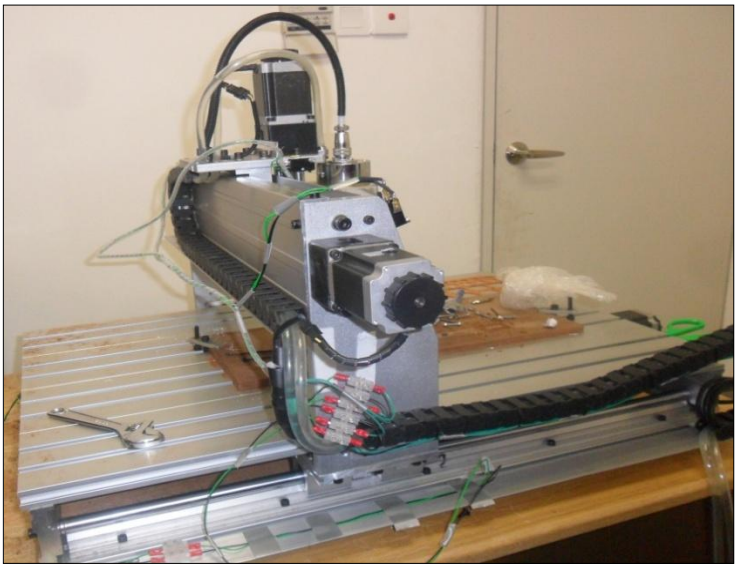

Figure 4.3 : Final product

4.2.1 Machine specification

Table 4.2 : Machine part parameter

Machine dimension	
Depth(Y) [mm]	700
Width(X)[mm]	540
Height(Z)[mm]	500
Max. working material dimension	
X[mm]	440
Y[mm]	500
Z[mm]	90
DC servo motor	
Consumption	200W
spindle speed	500-8000rpm/min
Cooling way	air-cooling
Driving unit	
X axis	1605 ball screw
Y axis	1605 ball screw
Z axis	1605 ball screw
Empty line speed	0-4000mm/min
Engraving accuracy	better than 0.05mm
Resetting accuracy	0.05mm
Carving speed	300-2500mm/min
Carving instructions	G code/nc file/NCC files
Communication interface	Parallel port with the computer
Machine weight (including controller box)	50KG

Table 4.3 : Controller box parameter

Operating Voltage	220V/110V adjustable
Drive unit	-3.5A TB6560 Drive board(with 2,4,6,8 Micro step). and spindle speed regulator
Switching power supply	24V, 10A 110/220 adjustable switching power supply
Computer connection	On parallel port
Tested software	Mach3
Command	G-code
Protection :	Emergency button and limit switch

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The knowledge and experience in the design and development of the portable CNC milling machine is a most valuable thing that are probably will not be forgotten. It is a good exercise to test the skills of a creative designer. In this project, teamwork work together to find the best design and method to develop the good design and development of portable CNC milling machine it. This project has helped in understanding and learns how to design a system that has input and output parameters are different. In the process of developing portable CNC milling machine requires knowledge and skills necessary mechanical and electrical engineering and applied. In producing this project, various problems have arisen. All these circumstances were faced and good solutions of each of problem were found.

In additional, this project developed the good system of portable CNC milling machine which is can did the basic operation of CNC milling machine which is run as milling cutting. The good designing of structure portable CNC milling machine should considering all the important aspects which are it material, sizes, shape, weight, safety, easy to manufacturer and easy to used. This entire requirement should be fulfilled to get the good system of portable CNC milling machine. Although this project seems simple in concept, but the implementation remains. It is difficult because this is a project of hardware design. The various risks facing them are damaged material. In conclusion, the project eventually produced a good operation of portable CNC milling machine. This project

achieved its objective to design and fabricate the machine component and assemble as a complete CNC milling machine.

CNC machine are machine tool that uses programs to automatically execute a series of machining operations. CNC machines offer increased productivity and flexibility. Nowadays, CNC Machine is most popular in manufacturing sector. So as to reduce the burden on the people, portable CNC Milling machine this is the best option because it can be removed easily, saving time and reducing the use of space. CNC milling machine is a very important technology in the manufacturing industry nowadays. But there are some problems that arise among industrial developers, because the existing milling machine is compatible with a huge industry only. While for small developers, the problem is CNC milling machines available now have a large size, heavy and difficult to control. This problem is not suitable for small industry. The Solution for this problem is to design and fabricate a model of portable milling machine.

Starting from the designing stage, selecting the material, cutting, assemble all part and finishing process, it is all done to come out with the real portable CNC milling machine that can run the milling cutting. From this project the size and weight of CNC milling machine is reduce. This machine also easy to used and suitable for light industry. As conclusion, the portable CNC milling is useful for small company in small industry of manufacturing. It also can used for engraving, advertising signs, PCB, nameplates, badges, seals, bronzing plate, aluminum alloy, acrylic plates, ABS resin double color plate, PVC foaming board, indentation plates, signs, construction models, instrument panels, wooden products, etc.

5.2 RECOMMENDATION

There is problem faced during development of this portable CNC milling machine. It need some modification for those who want to carry on with others experiment under this title. Firstly the selection of the material that used in portable CNC milling machine fabrication. The material that used is recommended to be more lighter and downsizing the specification of machine. Basically the raw material using in this project is aluminum, but many part to assemble, for the recommended to reduce the part of frame. This dimension of machine and the material used is not suitable for only one person to raise this machine.

Some others experiment also can be done on the investigate the performance of portable CNC milling machine with varying types of tools. Next experiment also can be carried out in various material.

REFERENCES

G. Vosniakos (1988). An intelligent software systems for automatic generation of NC program from wireframe models of 2-1/2D mechanical parts, Comput. Integr. Manufact. Syst. 11 (1/2) 53-65.

M. Kovacic, J. Balic (2002). Evolutionary programming of a CNC cutting machine, Int. J. Adv. Manufact. Technol. 22 (1/2) 118-124.

S. Chao-Ton, C. Mu Chen (1999). Computer-aided optimization of multi-pass turning operation for continuous forms on CNC lathes, IIE Trans. 31 (7) 583-596.

Y. Lin, An (1999). Adaptive tool path generation algorithm for precision surface machining, Comput. Aided Des. 31 (4) 237-247.

J.A. Baughman (1970). Multi-axis machining with APT, in: W.H.P. Leslie (Ed.), Numerical Control User's Handbook, McGraw-Hill, New York, pp. 271–298.

Manfred Weck (1984). Handbook of Machine Tools, vol. 1, Types of Machines, Forms of Construction and Applications, vol. 2, Construction and Mathematical Analysis, vol. 3, Automation and Controls, vol. 4 Metrological Analysis and Performance Tests, Wiley, Wiley Heyden Ltd

H.K Tonshoff, J Hernandez-Camacho (1989). Die manufacturing by 5 and 3 axes milling, J. Mech. Working Technol., 20, pp. 105–119

Mike Lynch (2007). CNC Concepts, Inc.

http://ezinearticles.com/?CNC-Machining-Centres&id=6197654

http://natalieeastaugh.articlealley.com/explaining-cnc-milling-cnc-turning-and-cnc-machining-2203023.html

Y. Altintas, E. Budak (1995). Analytical prediction of stability lobes in milling , Annals of the CIRP, 44, pp. 357–362

E. Budak, Y. Altintas (1998). Analytical prediction of chatter stability in milling—Part I: general formulation; Part II: application to common milling systems Transactions of the ASME, Journal of Dynamic Systems, Measurement, and Control, 120, pp. 22–36

V. Gagnol, B.C. Bouzgarrou, P. Ray, C. Barra (2007). Model-based chatter stability prediction for high-speed spindles International Journal of Machine Tools & Manufacture, 47 (7–8), pp. 1176–1186

W.W. Luggen (1991). Flexible Manufacturing Cells and SystemsPrentice-Hall, Englewood Cliffs, NJ

E.L.J. Bohez (2002). Five axis milling machine tool kinematic chain design and analysis International Journal of Machine Tools & Manufacturer 42 505-520

Boothroyd G ,Knight WA(1989). Fundamentals of machining and machine tools.Marcel Dekker Inc, New York

Dagnal H (1986). Exploring surface texture Rank Taylor Habson corp england

Rosales A Prediction of surface roughness by registering the cutting forces in face milling Eur Journal of Science and technology 41(2):228-237

Choudhury, S.K. and Appa Rao, I.V.K (1999). "Optimization of Cutting Parameters for Maximizing Tool Life," International Journal of Machine Tool & Manufacture, Vol.39, No. 2, pp. 343-353.

Lan, T.S. and Yeh, L.J (2003). "Dynamic Modeling and Approach of Optimum MRR and Tool Life Control," International Journal of Industrial Engineering-Theory, Applications, and Practice, Vol. 10, No. 4, pp. 628-635.

Yeh, L.J. and Lan, T.S (2002). "The Optimal Control of Material Removal Rate with Fixed Tool Life and Speed Limitation," Journal of Materials Processing Technology, Vol. 121, No. 2, pp. 238-242

Tian-Syung Lan (2007). Journal of Marine Science and Technology, Vol. 15, No. 3, pp. 201-209 Virtual CNC machining and implementation of optimum MRR with tool life control