



**UNIVERSITI TEKNOLOGI MARA
CAWANGAN TERENGGANU**

MEC299

**GENERATION OF G-CODE ON ALUMINUM BLOCKS
USING VERTICAL CNC MACHINE**

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SEM MARCH AUGUST 2022

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ABSTRACT

The Final Year (FYP) is called generation of G-Code on Aluminium Blocks using CNC Milling Machine. In computer-aided design and manufacturing (CAD/CAM), it is basically the language for computer numerical control (CNC). G-code is a metric-based numeric control system for CAM-controlled devices like CNC milling machines. Software such as SURFCAM can be used to generate the code. If using the conventional machining there will always be some differences and inconsistencies of the machined part. The aim of this study is to be able to generate G-Code of a design on aluminium blocks using vertical CNC milling machine and fabricate the machined part. After that, it will be precisely drawn in the software. When doing the machining process in the software, a warning is always displayed. It shows that if any imperfections occur, everything is solved perfectly in order to obtain good results. As a nutshell, after the machining process is complete, the software can generate the code automatically and it will come out beautifully. It provides the G-Code generation as well as an example of how it is used in actual programming code. To conclude this Final Year project (FYP), this project can surely help to master the generation of g-code using aluminium blocks using vertical CNC machine.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Eli Whitney invented milling machines in 1818 to mass-produce parts during the industrial revolution. They can be used for slotting, boring, circular milling, dividing, drilling, cutting keyways, racks, and gears [1]. CNC machines are machine tools that are run by a computer-controlled software using specialized numerical form with command data code numbers, letters, and symbols to produce the required product shape [2-3]. The product design is developed in CNC systems using computer-aided design (CAD) and computer-aided manufacturing (CAM) tools [4-6]. CNC milling machines produce unique precision components, prototyping, and complex parts [7-8]. End-to-end component design is highly automated in modern CNC systems using computer-aided design (CAD) and computer-aided manufacturing (CAM) tools. A control unit that can be saved, edited, and upgraded is used to control CNC machine tools. The CNC machine tool can be programmed directly using the keyboard and screen over a computer network, or it can be transferred using a USB storage device [7,9].

Today, the CNC is a soft-wired system that allows for a wide range of operations. All functions and programming are controlled by software, and the computer is in charge of translating a language like G code into the signals sent to the controller [10-13]. G-code is the most widely used computer numerical control (CNC) programming language in computer-aided design and production (CAD/CAM). G-code is a metric-based numeric control system for CAM-controlled devices like CNC milling machines. G-code and other CNC languages provide fine-grained control for additive and reduction-based fabrication with a variety of materials. G-code and other CNC code tells the computer that controls the manufacturing equipment's motors how far and at what speed to move. A spinning tip on a mill carves a metal block into an intricately machined item, for example. G-code can give computer-controlled equipment instructions to move the head through 3D movements at different speeds to make a camshaft, which for example might be used to manage valve timing in a gasoline-powered engine [14].

The spindle axis of a vertical mill is vertically orientated. The spindle holds milling cutters that rotate on its axis. The table can be lifted or lowered, or the spindle can be stretched,

to achieve the same effect, allowing plunge cuts and drilling [15]. The translational motion according to the X-Y of the table, as well as the translational and rotational motion of the cutting tool, are the two primary movements of a CNC milling machine. On a spindle axis, cylindrical cutters are oriented vertically on a vertical milling machine [17]. A set of motors was used to carry out these movements. Furthermore, control circuits and G-codes are included in the machine's complete control unit. As a result, the CNC vertical milling machine is made up of mechanical components (main shaft, ball bearing, bearing, tool table, tool drive, lead screw, and so on) as well as an electrical system (motor, control part, transmission parts, and so on [16]. Some vertical machining centres' tools can be operated on up to five axes using CNC technology to fabricate custom shapes, slots, holes, and features in three-dimensional items [17].

1.2 Problem Statement

- i. If using the conventional machining there will always be some differences and inconsistencies of the machined part.
- ii. In conventional machining, it requires manual labour, costs and skills to produce perfect product

1.3 Objectives

The main objective of this project is

- i. To conduct G-Code creating components using SURFCAM software
- ii. To fabricate machined part on aluminium blocks using CNC milling machine

1.4 Scope of Work

The scope of study for this project are simplified as follows:

1.4.1 Process

There are several processes that would be used in this project

- Designing

Designing is important as we need the desired shape and size of the product

- Coding

Coding is needed to make sure the CNC machine moves to produce the desired product

1.4.2 Material

The material that had been chosen or used in this project is:

- Aluminum

Aluminum is famous for its extremely versatile metal with a number of advantages, it is recognized for being both lightweight and flexible. It can be cast, melted, formed, machined and extruded meaning that it can be manufactured into a variety of shapes and then subsequently fabricated to suit a whole variety of uses.

1.4.3 Machine

- Vertical CNC milling machine

CNC milling processes that use vertical milling machines are referred to as vertical CNC milling. The machines have vertically oriented tooling, as the name suggests.

Because of this, they can be used in end milling processes that need tools with teeth on the perimeter and face.

1.4.4 Software

- SURFCAM v. 2020

SURFCAM is a CAM system that strikes the ideal combination of features and usability. SURFCAM is an excellent entry-level CAM platform that are full of capabilities.

1.5 Expected Result

```
G54 G90 G21 G40 G49 M5 M9
T1 M6 (Use an endmill, Ø18mm)
G43 H1 (Cutter length compensation by 50mm)
M8 S720 M3
G0 X91.90 Y-13.50 Z100.00
Z15.00
G1 Z0.00 F240.00
Y133.50
X74.80
Y-13.50
X57.70
```

Figure 1: Picture of expected result of Generation of G-Code [33].

CHAPTER 2

LITERATURE REVIEW

2.1 G-Codes

2.1.1 Introduction to G-Code

This study introduces G-codes in CNC vertical milling machine. It focuses on generating G-codes that provides metric-based number control of CAM-controlled equipment such as CNC milling machines. A machine controller which is industrial computer receives G-code instructions, that tell the motors where to move, how quickly to relocate, and what path to take. G-codes, also known as preparatory codes, are any words that begin with the letter G in a CNC programmed. In general, it's a code that tells the machine tool what type of action totake, such as a series of controlled feed motions that result in a hole being bored, a workpiece being cut to a certain dimension, or a profile shape being added to the edge of a workpiece andset of information about the tool, such as the offset. Additionally, actual prototypes will also be created in order to obtain information on the manufacturing process and assembly, which will be displayed in a picture gallery. Through this thesis, the reader will gain a better grasp ofG-codes as a way to speed up the manufacturing industries. At the conclusion, future trends and the potential scope of this study are discussed [32].

During the industrial revolution, cities attracted a large number of people. Because of the overcrowding in cities, the majority of people are forced to use public transportation as their primary mode of transportation for work in order to avoid being stuck in traffic jams, which can take hours, especially during peak hours. As the population grows rapidly and public transportation production is planned, this has resulted in congested public transportation. As a result, G-codes would be an effective and required technique of increasing production speed while ensuring the safety of public transportation.

The study of G-codes begins with their debut into people's lives and the efficient role they play in everything from the first piece of goods to today's outstanding composite product. Furthermore, this study aims to illustrate a wide range of design types that are compatible with G-codes, ranging from simple to complicated designs.

The ultimate goal of this thesis is to acknowledge the evolution of G-codes and the progression of utility in the production of G-codes that include mechanics, sustainability, and durability. Engineer drawing accomplishments enhance mechanical design by ensuring that

utility and beauty coexist. The purposes of the products commonly impact engineer drawings. Designers also benefit from some of the responsive engineer's rules.

2.1.2 Implementation of G-code

The majority of G code commands are in alphanumeric format and begin with the letter G, which stands for geometry. G-code programming, on the other hand, can be quite difficult for machinists due to the fact that different machines interpret G codes in different formats. The presence or lack of spaces between commands, as well as the number of zeros between the letter and number in the commands, are the main differences between most computers. A machine may, for example, utilize G3 while another uses G03. Machinists must always be aware of the machine they're working on. Otherwise, command errors can cause major problems with part production [31].

While G is the most commonly used letter in CNC programming, it is not the only one. Different commands are often represented by other letters. Some letters in the G code are as follows:

Table 2: Function of G-codes [27].

Variable	Description
A	It controls the tool's movement rotating the x-axis.
B	It controls the tool's movement rotating the y-axis.
C	It controls the tool's movement rotating the z-axis.
D	Cutter compensation diameter or radial offset. On lathes, D stands for depth of cut. It's used in photoplotters for angle selection and commands.
E	Precision feedrate for threading on lathes
F	Feedrate
G	Preparatory commands which tell the control what kind of motion is wanted
H	Tool length offset which corresponds to the z-axis
I	Arc center in x-axis for G02 or G03 arc commands. In some fixed cycles, it's also utilized as a parameter.
J	Arc center in y-axis for G02 or G03 arc commands. In some fixed cycles, it's also utilized as a parameter.
K	Arc center in z-axis for G02 or G03 arc commands. In some fixed cycles, it's also utilized as a parameter.
L	Fixed cycle loop counts which specification of what register to edit using G10
M	Miscellaneous function
N	Line or block number in program which the system parameters to change using G10
O	Program name
P	Serves as parameter address for various G and M codes

Q	Peck increment in canned cycles
R	Size of arc radius, or retract height in milling canned cycles
S	Speed, either spindle speed or surface speed depends on mode
T	Tool selection
U	Progressive axis relating to the x-axis (usually just lathe group A controls) also specifies dwell time (instead of "P" or "X").
V	Progressive axis relating to y-axis
W	Progressive axis relating to z-axis (usually just lathe group A)
X	Absolute or incremental position of x-axis. Also defines dwell time on some machines (instead of "P" or "U").
Y	Absolute or incremental position of y-axis
Z	Absolute or incremental position of z-axis

Lists of typical G-code commands and their interpretations for milling and turning operations.

2.2 M-Code

The M code likewise starts with the letter "M," just like the G code does. All of the machine's non-geometric activities are managed by the M code, a set of auxiliary commands. The code, which is used to stop programmes, flood the machine with coolant, and turn it off when the temperature falls, is referred to by machinists as miscellaneous codes. G and M codes should only have one command per block of information when building up a CNC letters programme. This is because they basically turn the machine on and off. Consequently, using them more than once in a single block may result in programming issues [31].

2.3 Aluminum as Material

In 2016, 58.8 million metric ton of aluminum were produced worldwide. Except for iron, it was the highest of any metal (1,231 million metric tons) [18]. Almost all aluminum is alloyed, which increases its mechanical qualities significantly, especially when tempered. For example, the common aluminum foils and beverage cans are alloys of 92% to 99% aluminum [19]. Aluminum combines the properties of both transition and non-transition metals. it has the characteristic physical properties of a post-transition metal, with longer-than-expected interatomic distances [20].

Aluminum is a chemical element with the atomic number 13 and the symbol Al. Aluminum has a lower density than most other common metals, about one-third that of steel. When exposed to air, it has a strong demand for oxygen and creates a protective coating of oxide on the surface. Aluminum has a color that is similar to silver and has a high ability to

reflect light. It is ductile, soft, and non-magnetic. Aluminum's strong affinity for oxygen results in its regular contact with oxygen in nature in the form of oxides [21].



Figure 2: Aluminum in Periodic Table [23].

Regardless of how common aluminum is, if it hadn't been for electricity, it might have remained concealed forever. When scientists discovered that they could use electricity to break down chemical compounds into their different atoms, they discovered aluminum. Christian Oersted, a Danish physicist, developed electrolysis to obtain aluminum in the 19th century. The process of electrolysis, also known as electrolytic reduction, is still used to make aluminum today [22]. In the late 20th century, the demand of aluminium changed because of advances in technology because most aluminium was consumed in transportation, engineering, construction, and packaging [23].



Figure 3: Aluminum block series Al1 7075 T7 [24].

2.4 CNC machine

2.4.1 Introduction to CNC Machine

CNC machining is a manufacturing method that can manufacture a wide range of items, including vehicle frames, surgical equipment, aeroplanes engines, gears, and hand and garden tools, and is suited for a wide range of industries, including automotive, aerospace, construction, and agriculture. Even though CNC machines make it simpler for less skilled operators to produce complicated, high-quality parts, they still need trained staff to set them up and make the appropriate

choices. For example, a worker needs to be able to recognise chattering and vibration because these can impact the machine's lifespan and the calibre of the finished product. During the programming phase, another potential problem can arise. A wide variety of mistakes could happen if the employee lacks programming competence.

These difficulties can be reduced with thorough employee training, which also ensures that the proper standards are being followed. The procedure includes a number of computer-controlled machining operations, such as mechanical, chemical, electrical, and thermal processes, that remove the required material from the workpiece in order to create a custom-designed part or product.

2.4.2 Types of CNC machines

a) CNC Drilling

Drilling machines with computer numerical control (CNC) play a significant role in today's production processes. The equipment can be used for drilling, spreading, weaning, and threading with a large number of accurate holes. The driving electronics and the PC-based CNC drilling machine were built in-house. For the drilling machine, they deployed a computer as a separate graphical interface. Since this manufacturing is now totally automated, CNC machines have advanced the hole drilling procedure. CNC Printed Circuit Board (PCB) drills, CNC vertical drills, CNC deep-hole drills, drilling centers, and other big CNC drilling machines are all examples of CNC drilling machines. This equipment is utilized for numerically controlled hole drilling and is widely employed in PCB hole processing technologies [25].



Figure 4: CNC Drilling Machine – Table type [27].

b) CNC Turning

Turning is a machining operation that removes material from a spinning workpiece using single-point cutting tools. To produce cylindrical parts with external and internal features such as slots, tapers, and threads, the equipment a CNC lathe machine, feeds the cutting tool in a linear motion along the surface of the rotating workpiece, removing material around the circumference until the desired diameter is achieved. Boring, facing, grooving, and thread cutting are all capabilities of the turning process. When deciding between a CNC mill and a lathe, milling, with its revolving cutting tools, is preferable for more complex items. Lathes, on the other hand, function best for creating circular parts since they have spinning workpieces and stationary cutting tool



Figure 5: CNC Turning and Multi-Spindle Machining [26].



Figure 6: CNC Turning Machine [28].

c) CNC Milling

Milling is a machining method that removes material from a workpiece by rotating multi-point cutting tools. The workpiece is normally fed to the cutting tool in the same direction as the cutting tool's rotation in CNC milling, whereas in manual milling, the workpiece is fed in the opposite direction of the cutting tool's revolution. Face milling, which involves cutting shallow, flat surfaces and flat-bottomed cavities into the workpiece, and peripheral milling, which involves cutting deep cavities, such as slots and threads, into the workpiece, are examples of milling capabilities [26].

2.4.3 Types of CNC Milling Machine

a) Horizontal CNC Milling Machine

CNC milling processes that use horizontal milling machines are referred to as horizontal CNC milling. The machines use horizontally oriented tooling, a rotating cylindrical cutter that may move along up to five axes to construct the shapes, slots, details, and holes of a three-dimensional part, as suggested by the name. End milling and plain milling are both possible with this design the former employs tools with teeth on the perimeter and face, while the latter uses tools with teeth just on the periphery [29].

Horizontal machining is particularly well suited to applications requiring slots, grooves, pocketing, or facing. A horizontal spindle orientation allows producers to operate quickly and efficiently, regardless of the machine's purpose, especially with projects that produce large numbers of chips. The horizontal layout allows chips to fall away or be easily removed, which is an unavoidable result of high-speed milling [29]. The cutters on horizontal mills are short and thick, allowing them to make deeper, heavier, and faster cuts [30].



Figure 7: Horizontal CNC Milling Machine Model HB110-B [34]

b) Vertical CNC Milling Machine

On a spindle axis, cylindrical cutters are oriented vertically on a CNC vertical mill machine. This is particularly useful for deep cuts and drilling, where these tools are considered to be the best for the forming cutting process. CNC milling processes that use vertical milling machines are referred to as vertical CNC milling. The machines have vertically oriented tooling, as the name suggests. Because of this, they can be used in end milling processes that need tools with teeth on the perimeter and face [17].

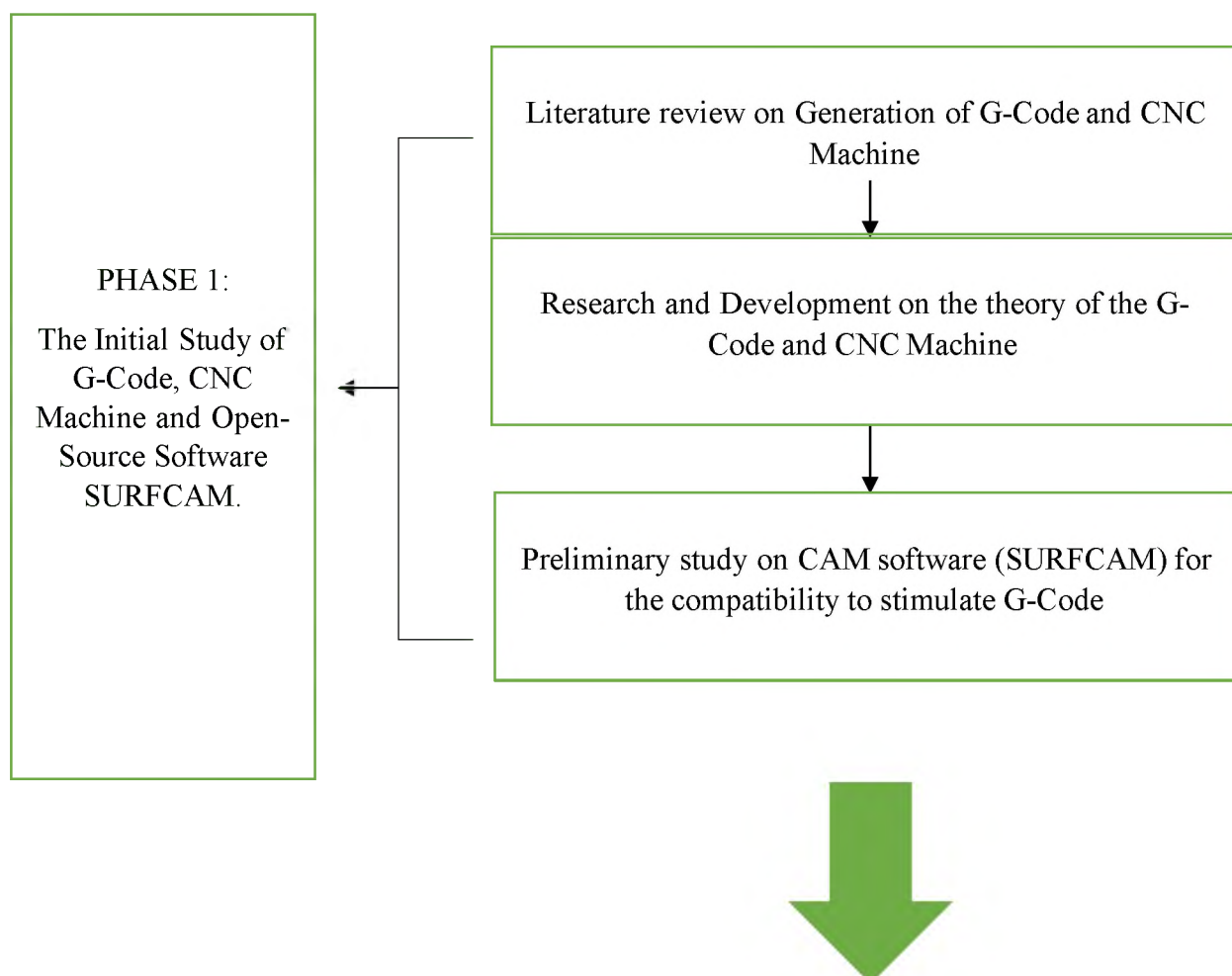
In a variety of industries, including aerospace, electronics, medical, automotive, and industrial projects, vertical milling can be utilized to make high-quality precision parts. CNC vertical machining is also a good alternative for prototype applications due to its flexibility of installation. Vertical milling machines are specialized in engine blocks, gearboxes, spindle boxes, irregular parts, such as brackets and bases [17].

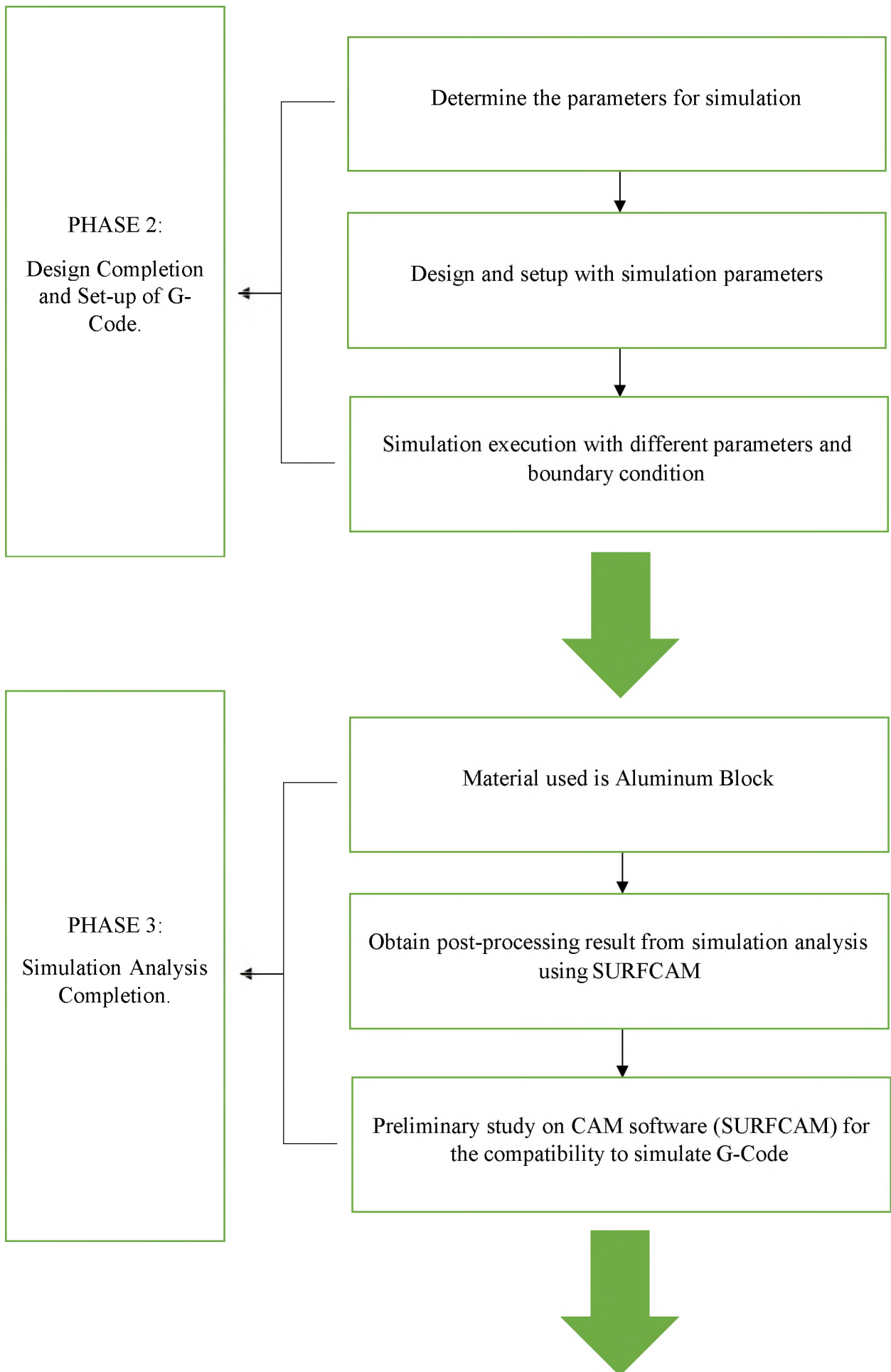
CHAPTER 3 METHODOLOGY

3.1 Introduction

The SURFCAM software will be used to design the desired designed. After that, the machining process will be done to the aluminum block using the machining simulation to get the required design. Because the simulation process may have failed, the design could not be implemented. To ensure that the design is manufactured precisely, the tool and method must be correct. When the perfect model and simulation are achieved, the G-code can be generated. This method can prevent failure because it will show up in the simulation if the procedure or tool utilized is incorrect.

3.2 Flowchart





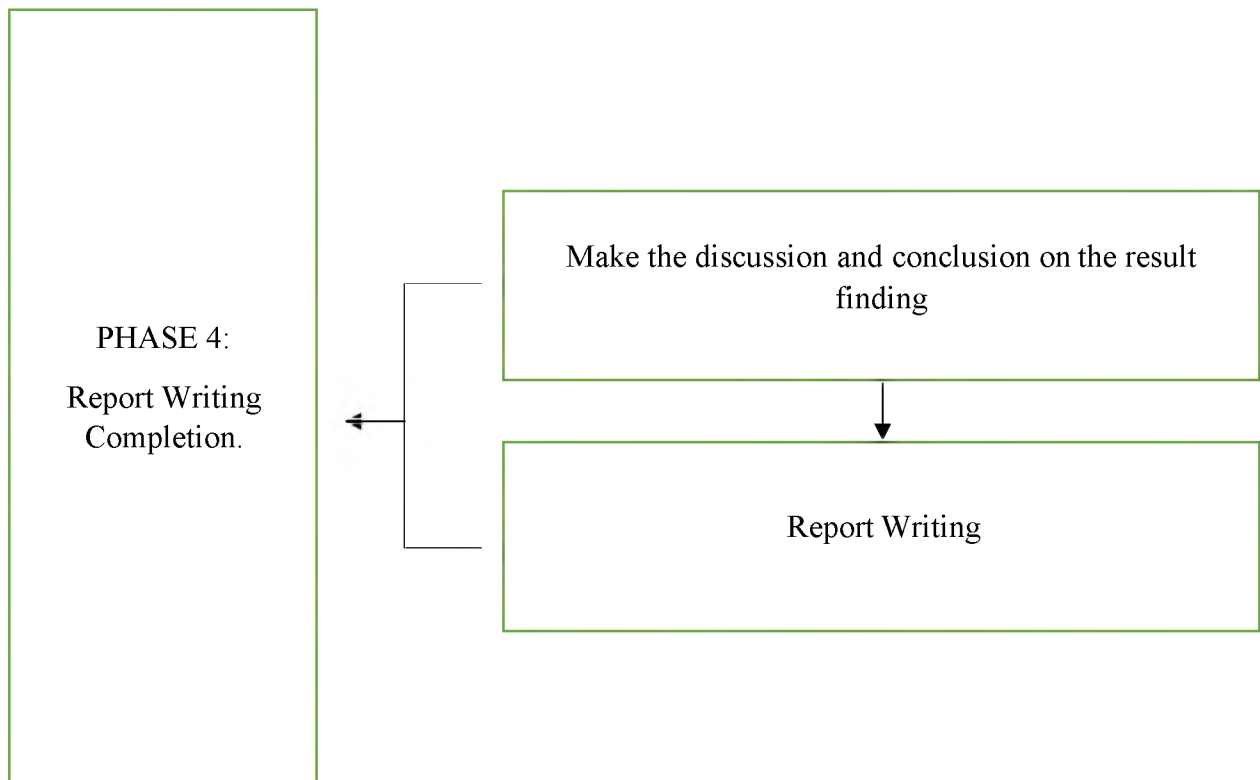


Figure 3 Flow chart of the project

The initial of the project, starting with finding some information about the generation of G-Code and CNC Machine in the internet. Read some articles to gather more information from the expert. In phase 1, there will be some literature review on generation of G-Code and CNC Machine. Next, I do Research and Development on the theory of the G-Code and CNC Machine. I start with Finding the different of the newest CNC Machine and the old CNC Machine in term of the technological upgrade. Then I do the Preliminary study on CAM software (SURFCAM) for the compatibility to stimulate G-Code. Making the sketch of the shape of aluminium block that will produce from the CNC Machine

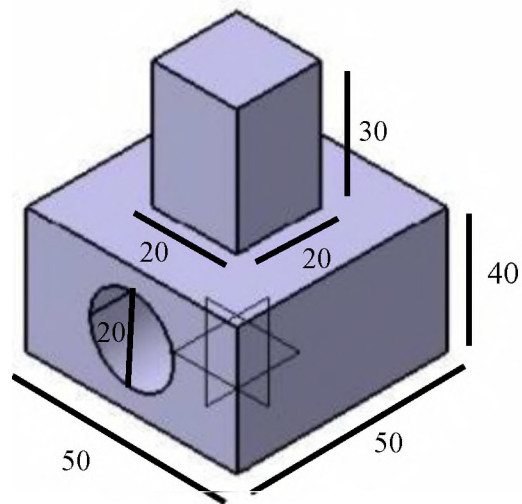
In the second phase, determining the parameters for simulation by sketching the aluminium block with the design that have chosen. Next is making a design and setup with simulation parameters using SURFCAM application in detail. Simulation execution with different parameters and boundary condition. I tried and error with few tools and tool's speed to avoid the block getting damage.

In phase three, determining the material to be use in this project. The Material used is Aluminum Block because it is the most suitable and affordable material to be use in this project. In this phase, obtain post-processing result from simulation analysis using SURFCAM. The final product simulation is obtained after finishing all the process using SURFCAM application. Then, making the preliminary study on CAM software (SURFCAM) for the compatibility to simulate G-Code by determining about

how this application will run the process in the CNC Machine without any problem and figuring the pros and cons of using this application for this project.

In the last phase, making discussion and conclusion on the result finding by looking back to all the work that have been done and discuss about all the aspect of this project. Lastly, the writing report using words application of this project so that it can be present clearly.

3.3 Preliminary Results



3.3.1 G-Code for Pocketing

%

O1000

N1 G49 G64 G17 G80 G0 G90 G40 G99

(PP WORD TABLE: IMS.PPTABLE)

N2 T0001 M6

N3 X-50.727 Y-52.5 S70 M3

N4 G43 Z80. H1

N5 G1 G94 Z-30. F300.

N6 X-52.5 Y-50.727 F1000.

N7 X-46.5 Y-52.5

N8 G2 X-52.5 Y-46.5 I8.833 J14.833

N9 G1 X-37.5 Y-52.5

N10 G2 X-52.5 Y-37.5 I0 J15.

N11 G1 Y-4.273

N12 X-50.727 Y-2.5

N13 X-52.5 Y-8.5
N14 G2 X-46.5 Y-2.5 I14.833 J-8.833
N15 G1 X-52.5 Y-17.5
N16 G2 X-37.5 Y-2.5 I15. J0
N17 G1 X-4.273
N18 X-2.5 Y-4.273
N19 X-8.5 Y-2.5
N20 G2 X-2.5 Y-8.5 I-8.833 J-14.833
N21 G1 X-17.5 Y-2.5
N22 G2 X-2.5 Y-17.5 I0 J-15.
N23 G1 Y-50.727
N24 X-4.273 Y-52.5
N25 X-2.5 Y-46.5
N26 G2 X-8.5 Y-52.5 I-14.833 J8.833
N27 G1 X-2.5 Y-37.5
N28 G2 X-17.5 Y-52.5 I-15. J0
N29 G1 Y-50.
N30 X-37.5
N31 G2 X-50. Y-37.5 I0 J12.5
N32 G1 Y-17.5
N33 G2 X-37.5 Y-5. I12.5 J0
N34 G1 X-17.5
N35 G2 X-5. Y-17.5 I0 J-12.5
N36 G1 Y-37.5

N37 G2 X-17.5 Y-50. I-12.5 J0

N38 G1 Y-47.5

N39 X-37.5

N40 G2 X-47.5 Y-37.5 I0 J10.

N41 G1 Y-17.5

N42 G2 X-37.5 Y-7.5 I10. J0

N43 G1 X-17.5

N44 G2 X-7.5 Y-17.5 I0 J-10.

N45 G1 Y-37.5

N46 G2 X-17.5 Y-47.5 I-10. J0

N47 G1 Y-45.

N48 X-37.5

N49 G2 X-45. Y-37.5 I0 J7.5

N50 G1 Y-17.5

N51 G2 X-37.5 Y-10. I7.5 J0

N52 G1 X-17.5

N53 G2 X-10. Y-17.5 I0 J-7.5

N54 G1 Y-37.5

N55 G2 X-17.5 Y-45. I-7.5 J0

N56 G1 Y-42.5

N57 X-37.5

N58 G2 X-42.5 Y-37.5 I0 J5.

N59 G1 Y-17.5

N60 G2 X-37.5 Y-12.5 I5. J0

N61 G1 X-17.5
N62 G2 X-12.5 Y-17.5 I0 J-5.
N63 G1 Y-37.5
N64 G2 X-17.5 Y-42.5 I-5. J0
N65 G1 Y-40.
N66 X-37.5
N67 G2 X-40. Y-37.5 I0 J2.5
N68 G1 Y-17.5
N69 G2 X-37.5 Y-15. I2.5 J0
N70 G1 X-17.5
N71 G2 X-15. Y-17.5 I0 J-2.5
N72 G1 Y-37.5
N73 G2 X-17.5 Y-40. I-2.5 J0
N74 G1 Z80. F1.
N75 M30
N76 M2
N77 M30
%

3.3.2 G-Code for Contouring

%
O2000
N1 G49 G64 G17 G80 G0 G90 G40 G99
(PP WORD TABLE: IMS.PPTABLE)
N2 T0001 M6

N3 X-52.5 S70 M3

N4 G43 Z80. H1

N5 G1 G94 Z-60. F300.

N6 X-2.5 F1000.

N7 G2 X0 Y-2.5 I0 J-2.5

N8 G1 Y-52.5

N9 G2 X-2.5 Y-55. I-2.5 J0

N10 G1 X-52.5

N11 G2 X-55. Y-52.5 I0 J2.5

N12 G1 Y-2.5

N13 Z80. F1.

N14 M30

N15 M2

N16 M30

%

3.3.3 G-Code for Holes

%

O1000

N1 G49 G64 G17 G80 G0 G90 G40 G99

(PP WORD TABLE: IMS.PPTABLE)

N2 T0004 M6

N3 X27.5 Y15. S70 M3

N4 G43 Z-1.5 H1

N5 G94 G81 X27.5 Y15. Z-52.5 R-1.5 F1000.

N6 G80

N7 M30



N8 M2

N9 M30

%

3.4 Gantt Chart

WEEK \ ACTIVITY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Title and Supervisor Selection	Planning	Actual														
2. Discussion with Supervisor		Planning	Actual	Actual												
3. Understand project and find relevant resources			Planning	Actual	Actual	Actual	Actual	Actual	Actual	Actual						
4. Introduction			Planning	Actual	Actual	Actual										
5. Literature Review							Planning	Actual	Actual	Actual						
6. Methodology								Planning	Actual	Actual						
7. Submission of Logbook and Proposal to Supervisor											Planning	Actual				
8. Preparation for Presentation											Planning	Actual	Actual	Actual		
9. Presenting to Panel													Planning	Actual		

 Planning
 Actual

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