Design Innovation for Calligraphy Using Reverse Engineering and CNC Machining

By:

AHMAD AMIN AZMI BIN JALUDIN

(Matrix no.: 120782)

Supervisor:

Dr. Mohd Salman Bin Abu Mansor

June 2017

This dissertation is submitted to

Universiti Sains Malaysia

As partial fulfilment of the requirement to graduate with honours degrees in

BACHELOR OF ENGINEERING (MANUFACTURING WITH MANAGEMENT)

School of Mechanical Engineering

Engineering Campus

Universiti Sains Malaysia

DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree

Signed …… (AHMAD AMIN AZMI BIN JALUDIN)

Date ……....

STATEMENT 1

This thesis is the result of my own investigation, except where otherwise stated. Other sources are acknowledged by giving explicit references. Bibliography/references are appended.

Signed …… (AHMAD AMIN AZMI BIN JALUDIN)

Date ……

STATEMENT 2

I hereby give consent for my thesis, if accepted, to be available for photocopying and interlibrary loan, and for the title and summary to be made available to outside organization.

Signed …… (AHMAD AMIN AZMI BIN JALUDIN)

Date ……

ACKNOWLEDGEMENT

After going through all the countless effort, Alhamdulillah, praised to Allah S.W.T that always give me hopes and strength to complete my final year project and guide me to the right path. First and all, I would like to express my thank you to my final year project supervisor Dr Mohd Salman Abu Mansor who give me a lot of knowledge and guidance in completing my final year project. He give me a lot of encouragement and suggestion along this journey. This project would not be complete without the help of him.

Secondly, I would like to thanks to my school technician who are En. Mohd Zaimi Mat Isa which help me a lot in giving ideas about the project and suggestion about the project and helping in completing this project. Never forget En. Mohd Fariz, En. Norijas, En. Kamarul and En. Azrul who really helping me in designing and machining process until the project done very well.

Thirdly, thank you to my parents that never forget to encourage me in completing my project and thesis, my fellow friends that always give me motivation and always becomes my listeners when I had a hard time in this journey. Thank you so much guys for your motivation and time that you all spend for me.

Finally, special thanks to the authority of Universiti Sains Malaysia (USM) especially to School of Mechanical Engineering for providing me a good facilities needed to complete this project and thank you also to all people who involved directly or indirectly in helping me during this project.

Title of Thesis: Design Innovation for Calligraphy Using Reverse Engineering and CNC Machining

Date of Submission (Academic Year): 12th June 2017 (2016/2017)

Candidate (Matric No.): Ahmad Amin Azmi Bin Jaludin (120782)

Name of Supervisor: Dr Mohd Salman Abu Mansor

TABLE OF CONTENT

PAGE

DECLARATION ii

ACKNOWLEDGEMENT iii

TABLE OF CONTENT iv

LIST OF ABBREVIATIONS vi

LIST OF TABLES vii

LIST OF FIGURES viii

ABSTRAK x

ABSTRACT xi

CHAPTER 1 1

1.1 Background 1

1.2 Calligraphy Design Innovation 2

1.2.1 Calligraphy Design 2

1.2.2 Calligraphy Innovation 6

1.3 Definition of Calligraphy 7

1.4 History of Calligraphy 7

1.4.1 Islamic Calligraphy 7

1.4.2 Chinese Calligraphy 8

1.5 Problem Statement 10

1.6 Objectives 10

1.7 Scope of the Project 10

1.8 Outline of Thesis 11

CHAPTER 2 12

2.1 Overview 12

2.2 Calligraphy art 12

2.3 Reverse Engineering 15

2.4 CNC Machine 16
2.5 Industrial Clay 17
CHAPTER 3 19
3.1 Overview 19
3.2 Process Flow Chart 20
3.3 Design Innovation and Concept Selection Process 21
3.3.1 “BISMILLAH” Calligraphy 21
3.3.2 “REVERSE ENGINEERING LAB” Typography 24
3.4 Scanning and Editing Process 26
3.5 Material Selection 28
3.6 Machining Process 28
3.6.1 “BISMILLAH” Calligraphy 28
3.6.2 “REVERSE ENGINEERING LAB” Typography 30
CHAPTER 4 32
4.1 Overview. 32
4.2 Designing and Machining Result. 32
4.2.1 “BISMILLAH” Calligraphy 32
4.2.2 “REVERSE ENGINEERING LAB” 35
4.3 Comparing Time Taken 36
4.4 Comparing the Parameters 36
CHAPTER 5 38
5.1 Conclusion 38
5.2 Future Works 39
REFERENCES 40
APPENDICES 43

LIST OF ABBREVIATIONS

2D	- Two-dimension
3D	- Three-dimension
CDD	- Couple Coupled Device
CNC	- Computer Numerical Control
CAD	- Computer-aided Design
CAM	- Computer-aided Manufacturing
CMM	- Coordinate Measuring Machine
MRI	- Magnetic Resonance Imaging
ICT	- Information and Communication Technology
ID	- Identity
CATIA	- Computer Aided Three-Dimensional Interactive Application
EDM	- Electrical Discharge Machine
UAV	- Unmanned Aerial Vehicle
NC	- Numerical Control

LIST OF TABLES

Table 4.1 Comparison between Design Part and Machined Part.....34
Table 4.2 Comparison of REVERSE ENGINEERING LAB Typography.....35
Table 4.3 Comparison of distance between machined product and crafted clay.....37

LIST OF FIGURES

Figure 1.1 Traditional Ruling Pen. Already use in 1600s....2
Figure 1.2 Disassembled Grafos and Nibs of Different Width....3
Figure 1.3 Radiograph styli of different widths....3
Figure 1.4 Drawing board with T-square....4
Figure 1.5 Drafting Machine....4
Figure 1.6 Various Curves known as French Curves....5
Figure 1.7 SolidWorks Software....5
Figure 1.8 CATIA Software....6
Figure 1.9 AutoCAD Software....6
Figure 1.10 Hieroglyph....8
Figure 1.11 Hieratic....8
Figure 1.12 Character that wrote at low speed....9
Figure 1.13 Character that wrote at medium speed....9
Figure 1.14 Character that wrote at high speed....9
Figure 2.1 Classic Korean Calligraphy art....13
Figure 2.2 Modern Islamic Calligraphy (Khat)....13
Figure 2.3 Typography alphabet and Arabic Typography....13
Figure 2.4 UAV calligraphy performing on writing....14
Figure 2.5 Graphical interface for user handwriting input....14
Figure 2.6 The brush and holder of UAV calligraphy....14
Figure 2.7 Classification of Clay and their application....18
Figure 3.1 BISMILLAH Image....21
Figure 3.2 Creating profile to the imported image....21
Figure 3.3 Extruded BISMILLAH part....22
Figure 3.4 Rectangle profile drawn on new plane....22
Figure 3.5 Edited BISMILLAH....23
Figure 3.6 Creating the pen holder....24
Figure 3.7 Rendering part of BISMILLAH....24
Figure 3.9 Drawing of REVERSE ENGINEERING LAB....25
Figure 3.10 Crafting process....25
Figure 3.11 Crafted Clay....26
Figure 3.12 Scanned Clay....27
Figure 3.13 Left side (Editing Process) Right Side (Finished Product)....27

Figure 3.14 Milling Process 28
Figure 3.15 Cutting process 29
Figure 3.16 Machined product 29
Figure 3.17 CNC 5-axis milling machine DMU 40 Mono Block Deckel Maho 30
Figure 3.18 Machining process with applying the coolant to the material 31
Figure 3.19 Finished product 31
Figure 4.1 Combined plate 33
Figure 4.2 Aluminum rod that combined by using epoxy 33
Figure 4.3 Distance to measure 37

ABSTRAK

Kaligrafi adalah satu seni yang boleh diklasifikasikan sebagai satu seni mempunyai umur yang lebih lama. Ia bermula dari era dinasti di China. Sementara itu, kaligrafi Islam ditubuhkan pada 3200 sebelum Masihi di sungai Nil. Sekian lama, kaligrafi menjadi huruf yang berkomunikasi dengan rakyat dan juga menjadi seni. Dalam kaligrafi Islam, ia boleh dilihat kebanyakannya dalam masjid. Dengan cara tradisional, mereka mencipta seni ini dengan menggunakan tangan. Mereka mencipta kaligrafi di dinding dan juga kraf kaligrafi pada kayu sebagai hadiah. Mengukir kaligrafi dengan menggunakan tangan menyebabkan banyak masa yang diambil untuk menghasilkannya. Dengan teknologi yang ada di dunia ini, teknik kejuruteraan terbalik digunakan di mana ia dapat menghasilkan tanpa memerlukan ukuran atau pelan tindakan. Menghasilkan dengan menggunakan mesin CNC juga boleh menjadikan masa yang diambil dapat dikurangkan dan ia boleh menghasilkan permukaan yang lebih baik. Dalam projek ini, kaligrafi akan direka bentuk dan di inovasikan dengan menggunakan perisian reka bentuk yang boleh didapati seperti SolidWorks dan CATIA. Ia juga akan menjalani teknik kejuruteraan terbalik dan menghasilkan dengan menggunakan mesin CNC. Kemudian, parameter produk yang dihasilkan dengan menggunakan teknik kejuruteraan terbalik akan dibandingkan dengan produk yang sedia ada dan perbandingan masa akan diambil antara proses pemesinan dan proses ukiran tangan. Masa yang diambil bagi input pertama iaitu kaligrafi BISMILLAH mencatatkan 2 jam 35 minit dan 44 saat manakala untuk input kedua iaitu tipografi REVERSE ENGINEERING LAB mencatatkan 22 jam berdasarkan masa simulasi. Bagi hasil perbandingan parameter antara produk sedia ada dan produk yang dihasilkan, input kedua telah terlibat. Ia mempunyai 6 jarak yang telah di daftarkan untuk diukur. Peratusan perbandingan bagi Jarak 1, Jarak 2, Jarak 3, Jarak 4, Jarak 5 dan Jarak 6 masing-masing adalah 3.43%, 0.18%, 14.20%, 0.81%, 8.50% dan 25.21%.

ABSTRACT

Calligraphy is an art which is can be classified as one art that has the longer in age. It is started from era of dynasty in China. Meanwhile, Islamic calligraphy founded in 3200 B.C in nil's river. For so long, calligraphy becomes a letters that communicate with the people and even becomes an art. In Islamic calligraphy, it can be seen mostly in mosque. In traditional way, they create this art by using hand. They craft the calligraphy on the wall and even craft the calligraphy on the wood as a gift. Crafting calligraphy by using hand cause a lot of time taken to produce it. With the technology that available in this world, reverse engineering technique is applied where it is can be produce without needed any parameters or blueprint. Producing by using CNC machine can also become the time taken can be reduced and it can produced a better surface finish. In this project, the calligraphy will be designed and innovate by using the software design that is available which are SolidWorks and CATIA. It will also undergo with the technique of reverse engineering and producing by using CNC machine. Then, the parameters of the produced product by using reverse engineering technique will be compared with the existing product and compare the time taken between machining process and hand-crafting process. The time taken for first input which is BISMILLAH Calligraphy recorded 2 hours 35 minutes and 44 seconds while for the second input which is REVERSE ENGINEERING LAB Typography recorded 22 hours based on the simulation time. For the parameters comparison result between the existing and produced product, the second input was involved. It contains 6 distance that has been registered to be measure. The percentage different for Distance 1, Distance 2, Distance 3, Distance 4, Distance 5 and Distance 6 are 3.43%, 0.18%, 14.20%, 0.81%, 8.50% and 25.21% respectively.

CHAPTER 1

INTRODUCTION

1.1 Background

Calligraphy is an art that is related to the writing which is divided into two categories. Those are Classic Calligraphy and Modern Calligraphy. Classic calligraphy art commonly using a brush with a piece of paper and it will draw the letter of calligraphy on it. Mostly classic calligraphy can be readable. It is usually being used in the previous era such as Dynasty Era in China. Meanwhile, modern calligraphy design a very fine-art piece where the letters produce may or may not readable by people.

Nowadays, people start to evolve this art from draw into the letter to three-dimension which this techniques required a very skillful hand-work to craft. In Islamic Country like Malaysia, this art can be seen at the mosque where these art is usually will be created on the wall of the mosque as a decoration.

3D Calligraphy art like Islamic Calligraphy that commonly used as a wall decoration nowadays crafted from the material of wood or maybe it just write the letter and put it into the frame. In this project as the designing and innovation of the calligraphy, a new techniques is used which is to produce a 3D Calligraphy art by using the method of reverse engineering and producing it with the CNC Machine.

This techniques that is proposed basically as a new method to produce the 3D calligraphy art that will lead the shorter time taken to produce it. In fact, the time taken to produce the 3D calligraphy art is actually taking a longer time to craft by using hand. In the other hand, it might be a new 3D calligraphy that will be produce by using another material which is aluminum 6061 and produce by using CNC Machine.

This techniques also might be a solution to the workers that work to craft a 3D calligraphy art. One of the most accident that will cause during the crafting is making mistake to craft the calligraphy letter on woods. In conclusion, this project will replace

the previous technique which is handcrafting to produce a 3D calligraphy art into a new techniques which is using reverse engineering and also by CNC Machine.

1.2 Calligraphy Design Innovation

1.2.1 Calligraphy Design

Designing is practically being used by the designer to create an object, structure, and product with the help of the software or tools that available in this world. Basically, the traditional tools that being used before to draw such as pens, drafting board, T-square, drafting machine, French curves, rulers, compass, templates and perspective machines. Pens or mechanical pencil have their own types to use. Usually they have their own thickness lead which it produce a different contrast on the drawing. Commonly, line widths are 0.18 mm, 0.25 mm, 0.5 mm and 0.7 mm. Hardness varies usually from HB to 2H.

Figure 1.1 Traditional Ruling Pen. Already use in 1600s

Figure 1.2 Disassembled Grafos and Nibs of Different Width

Figure 1.3 Radiograph styli of different widths

Source: (Mills and Walter, 1986)

Drawing board or drafting board is a tool which commonly attach with the T-square. The paper will be attached and kept straight and still so that the drawing can be done accurate and nice without moving. It will use drawing pins or clamps to secure the paper from being move. Some board is magnetized and allow paper to be held by long steel strips. The T-square is created to be 90 degree angle. It use to draw a horizontal line to align other drawing instrument such Set Square which consist of 30 degree, 60 degree and two 45 degree angles. When comes the drafting machine, it replace the use of those set square. This device is mounted to the

drawing board. There are two main types of apparatus which are an arm-type parallelogram apparatus based on a hinged arm and a track-type apparatus which moves on a rail mounted to the top of the drawing board. Thus with this machine, it will allow the drawing of parallel lines becomes easy on the drawing paper.

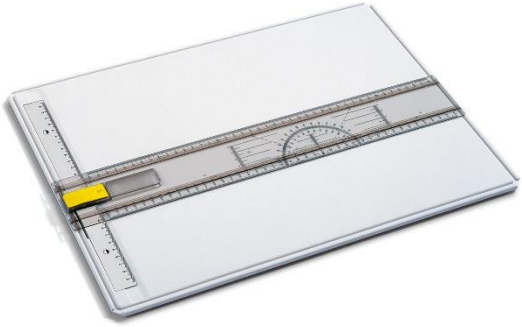


Figure 1.4 Drawing board with T-square

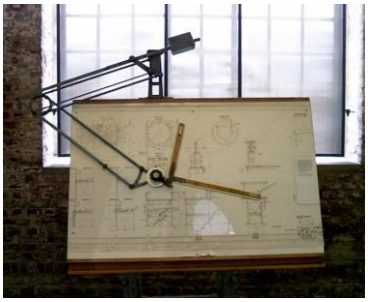


Figure 1.5 Drafting Machine

Source: (French, 1978)

French curves is a template that usually being made from wood, plastic or celluloid. With the French curves, the curves that the compass cannot drawn can be use this French curves to make it. Compasses are used for drawing circle or arc segments of circles. It physically has one leg that attach a sharp pivot point and the other attach with technical pen or pencil to create the drawing.

Figure 1.6 Various Curves known as French Curves

Nowadays, these tools to do drawing is rarely being used. It is because due to the time taken to draw by using those tools is longer and lead to longer period to finish one drawing. Other than that, it is requires a lot of skill to draw by using a traditional tools. For example to create an arc segments need a lot of lines and circle. Moreover, it will leave a lot of unnecessary reference lines and it will cause the drawing looks bad. Therefore, in this era of technology, some of the company such as Autodesk Inc. created a design software such as AUTOCAD, CADCAM and also the software that is available nowadays like Solid Works, CATIA and etc. that can help the designer producing a drawing without wasting their times. By this help of those software, the designer could also doing some simulation based on the product that they design. Moreover, this software design also does not required a lot of skill and even designer could learn through the tutorial that is provided by the software.

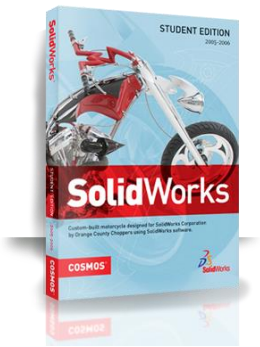


Figure 1.7 SolidWorks Software

Figure 1.8 CATIA Software

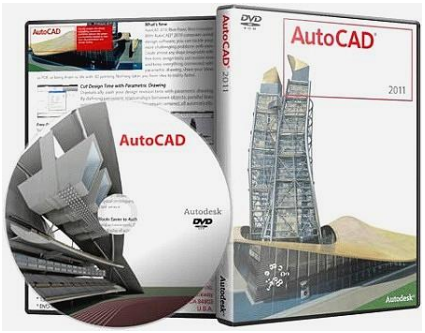


Figure 1.9 AutoCAD Software

1.2.2 Calligraphy Innovation

Innovation has become an important driving force for the economic growth in modern technology nowadays. It is one of the strategies which can increase the income for the country. Mostly Research and Development Department is always involved in this project of innovation (Brüggemann and Meub, 2017). Basically innovation is define as new idea or method. It is also can be defined as something that is original and more effective. Innovation also is something that doing an improvement of the existing product or else producing a new product that is not available in the market which can give benefits to the society.

Example of the innovation that the human being has made from the past year such as automobiles, mobile phones, and etc. Before mobile phones only created for the human to call and sending short messages and does not have any color on the screen. But now, as the era of technology, mobile phones comes out with various of type and brand such as Samsung, Apple, Alcatel, Vivo, Oppo and

etc. which provide a lot of application that could help people in finding information easily.

1.3 Definition of Calligraphy

Basically, calligraphy words came from Latin. In Latin “Kalios” is mean by beautiful and “graph’ is mean by letters. Meanwhile, in Arab Saudi the beautiful letters is mean by “Khath” and in English Language it is called as “Calligraphy”. On the other hand, Situmorang state that the true meaning of calligraphy or khath is actually a pattern or beautiful art that is form with full of interest in art from the deep of the creator heart

1.4 History of Calligraphy

1.4.1 Islamic Calligraphy

Originally, Islamic/Arabic calligraphy is founded in 3200 B.C at Nil’s river. It is from ancient Egypt called Hieroglyph and evolve to Hieratic. When both of this calligraphy founded, the illustration of picture cannot be clearly seen and the words created is difficult to read. In Arabic, their calligraphy art which is Khat is actually originally from hieroglyph and evolved to various type of khat such as Feniqi, Arami and Musnad. Al-Maqrizi which is historian in 4th century believe that the first Arabic Calligraphy start to evolve from Himyar community which this community use the Musnad khat. From old Musnad khat then it is transform into Kuffi Khat (Anshar, 2013)**.**

The importance of Islamic art in mosque interior not only about the ethnic, literary, religious, social and artistic features of traditional Islam, but it is also as a glue uniting the Muslims with the architectural and decoration of the ornamentations. Ornamentations could be different from one region to another for example Malaysian ways of ornamenting their mosque is different from the Arabs even both share the same religion (Othman and Zainal-Abidin, 2011)**.**

Figure 1.10 Hieroglyph

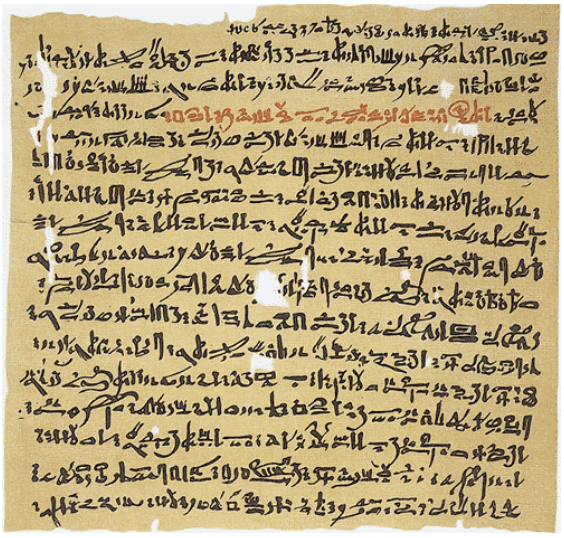


Figure 1.11 Hieratic

Source: (Anshar, 2013)

1.4.2 Chinese Calligraphy

In China, they are rarely considering calligraphy to be an art. They are not using the word of “Calligraphy” but describe as Chinese handwriting. Chinese believe that calligraphy can describe the personality of the maker or their behavior either bad or good from the art of their handwriting. The Chinese calligraphy consist of two element which is; form and spirit. Form commonly related to the size and shape and also the structure of a character that is produce. Where spirit is reflecting to the expression and personality of the writer on how the movement of

the brush in time and space including ink concentration or thickness. Thus, the perfect calligraphy is produce when the writer write the letter perfectly and nicely where if the writer wrote the letter in high speed it produce imperfect character (Xu *et al.*, 2016)**.**

Figure 1.12 Character that wrote at low speed

Figure 1.13 Character that wrote at medium speed

Figure 1.14 Character that wrote at high speed

Source: (Xu *et al.*, 2016)

1.5 Problem Statement

Existing Calligraphy art need to be improve in term of its design. One of the reason is because this art has becomes less popular nowadays. This art need to be sustained in order to ensure it will not be gone in the future. Common method to produce this art was crafting by using hand. Crafting by using hand can lead to a longer time taken to produce it and possibility to create a mistake when crafting is higher. Technology such as reverse engineering and CNC machine could be one of the method than can be applied in producing this art. Thus, with these technology it could be a new solution to the crafter to create this art at the easiest way.

1.6 Objectives

This project have objectives that need to achieve based on designing and also the fabrication. The objectives of this project are:

- To innovate a new design for calligraphy using method reverse engineering and CNC machining.
- To reduce the time taken to produce the calligraphy art and compare the time taken with the hand-crafting calligraphy.
- To compare the parameters of the scanned product with the existing product.

1.7 Scope of the Project

In this project, designing innovation of calligraphy is done by using the software that is provided which are SolidWorks and also CATIA V5. There are two project that need to be conducted. First project is producing a “BISMILLAH” khat and the second project is producing a typography “REVERSE ENGINEERING LAB”

Both project need to be fabricate by using the CNC machine that is available and the material that is being used to produce is using aluminum 6061. This project also need to take care for the time taken for the machine to fabricate the art because it need

to compare the time taken with the calligraphy that is being crafted by hand. For the second project, the parameters need to be tested with the existing product because it will give a different result based on the dimension and the size of the product.

3D scanner that is involved in this project was 3D Scanner Next Engine and also the CNC machine that is involved was CNC 5-axis milling machine DMU 40 Mono Block Deckel Maho and CNC EDM Wire Cut. Some discussion were made to clarify the different in result that is obtain from the process that is done and the technique that is being used in this project.

1.8 Outline of Thesis

This thesis consist of 5 chapter which are:

- **Chapter 1**

  Including project background, definition of design innovation for calligraphy by using reverse engineering and CNC machine, problem statement, project objectives, scope of project and thesis organization.

- **Chapter 2**

  This chapter include all the review of the other literatures that had done the research which is related with this project.

- **Chapter 3**

  This chapter will explain about the methodology of the project. The content include the flow chart of project, the scanning and editing process, material selection and machining process.

- **Chapter 4**

  This chapter will include the result and discussion of the project. The data that acquired from this project will be analyzed and will be compared.

- **Chapter 5**

  The last chapter is about the conclusion and also the future work will be included in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

Until recently, the researcher have shown their interest on producing the calligraphy art by using a robot. For example they build a robot arm which could generate the letter with the movement of the hand (Chao *et al.*, 2017). Other than that, nowadays also people start to produce the calligraphy by using CNC machine by using the method of tracing. In this chapter will explain about the calligraphy, reverse engineering, CNC machine and the Industrial Clay that involve in this project.

2.2 Calligraphy art

Many years we can see that the calligraphy art is being produce by the hand writing or maybe it could be the best term “art/design making by writing”. It is either classic calligraphy or modern calligraphy is using the same technique to produce it. Calligraphy education in the past have three categories which are first; self-purification, second; writing method of beautiful writing and third; calligraphy tools and how to prepare it (rasouli and Attaran, 2012). In modern, calligraphy becomes more typographic design. Typographic message is visual, auditory and oral. It could be watch, perceived visually, heard and interpreted audibly while they are being read and interpreted orally (Turgut, 2014). It also state that a good graphic design and typography could lead to communication between people with its understandability and creativity.

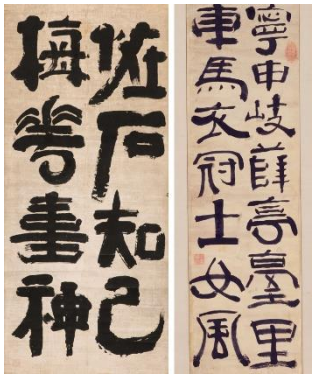


Figure 2.1 Classic Korean Calligraphy art

Figure 2.2 Modern Islamic Calligraphy (Khat)

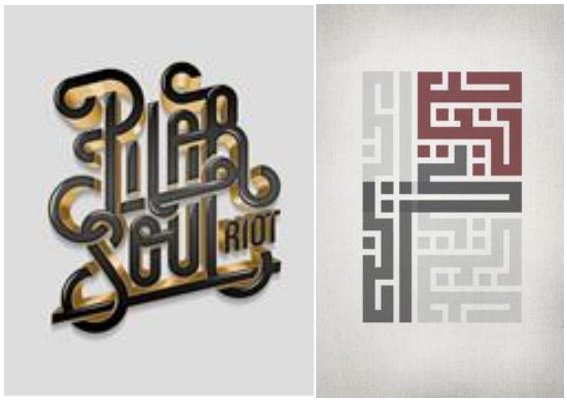


Figure 2.3 Typography alphabet and Arabic Typography

The development of UAV system for calligraphy shows that this art has become more advance in the process of producing it. Chinese calligraphy is one of the unique calligraphy art. The combination of this traditional calligraphy with the modern technology UAV have provide a UAV calligraphy. There are no researcher that has

successfully done the calligraphy writing by using the aircraft or by using the flying machine. Thus, this is one of the new ways to produce the calligraphy letter as before the latest one is only the researcher has only done the robotic arm that can create the calligraphy character (Phang *et al.*, 2015)**.**

Figure 2.4 UAV calligraphy performing on writing

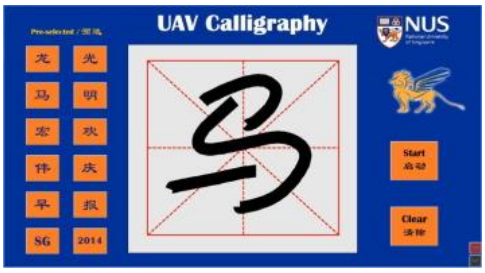


Figure 2.5 Graphical interface for user handwriting input

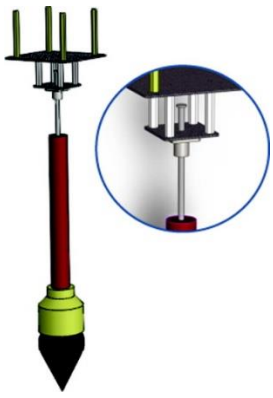


Figure 2.6 The brush and holder of UAV calligraphy

Source: (Phang *et al.*, 2015)

The font and size of Chinese character can be conclude into seven categories which is “Oracle”, “jin”, “seal”, “official script”, “Regular script”, “Semi-cursive script”, and

"Cursive script". Since the ancient time, to write these characters need a very good balancing and beautiful so that it can ensure the letter that is produce has become a nice art (Wang *et al.*, 2015)**.**

2.3 Reverse Engineering

Reverse engineering or also can be known as back engineering is a technique that produce the copy of original product or product without having any specific dimension (Várady, Martin and Cox, 1997). Commonly, reverse engineering related with the CAD software which they need to create a part design and making a modification. In the other hand, by using this techniques, it can reduce the cost of buying a new spare part and also could save time to buy a spare part (Motavalli, 1998). Besides, this technique of reverse engineering also has become a worldwide. In Korea, they use this reverse engineering techniques combined with the Rapid Prototyping machine to create a human souvenir. With the usage of reverse engineering techniques, it can scan a lot of object that available in this world and modified to another product to become a new product.

Reverse engineering (RE) method are representing important part in prototype creation (Dúbravčík and Kender, 2012). One of the option the used of reverse engineering method is servicing which is process of changing and repairing in the shortest time. In the other hand, part changing could taking a longer time when the spare part is not available. Thus, this is why the usage of reverse engineering is important since it can reduce the repair time to minimum.

The main techniques that used by the reverse engineering is digitizing where digitizing process is a process which transfer the scanned point into the CAD software. 3D Scanner is used as a machine that scanned the object and transfer the output object into the CAD/CAM software. There are several type of digitizing devices can used such as contact, laser, optical and destructive (Sokovic and Kopac, 2006). In traditional ways, the method of reverse engineering processes to acquire ID (point cloud data) or

2D (range image) are basically by using digitizing devices such as CMM, laser scanner and etc. or by using photography devices such as CDD camera, MRI and ICT (Miaoulis and Plemenos, 2008).

The process to produce a new model of the existing product can be reduce the time taken if compared with forward engineering which is conventional method. Moreover, it is cheaper rather than forward engineering (Anggoro, Bawono and Sujatmiko, 2015).

Process of reverse engineering also provide many alternative to produce a molds. Firstly, it can be produce by hand which it needs the prototype and second one is it can be produce by using 3D contact or non-contact CMM. After getting all the data that needed, there are two method which could be apply. The first one, the data that is get from the scanning process is transferred into the CAD software. Then, making up the curve and surface and edit it. Finally generate NC code to cut the part. The second one is cutting the part directly from the scanning data (Lin and Lin, 1999).

2.4 CNC Machine

Computer Numerical Control Machine or CNC Machine has a lot in this world. With this machine, people can fabricate a product at easiest way. This machine is fully automatic and has its own programmed. In modern, the CNC system is highly automated. The product that want to produce is defined by using computer-aided design (CAD) software and it then translated into manufacturing software which is computer-aided manufacturing.

CNC machine consist of three axes which are X-axis, Y-axis and Z-axis and even have 5-axes which add with A-axis and B-axis. Commonly the 5-axes could produce part that has a complex shape and angle with short period of time.

There are a lot of types of CNC machine that available in this world. For example router, plasma cutter, milling machine, lathe, CNC laser cutter and EDM Wire cut. The programmed or code that is used to generate a movement to the CNC is called as a G-code which this code provide a certain command to the CNC machine to do work.

Producing the calligraphy art by using CNC machine could be a new method replacing the traditional ways in producing 3D calligraphy art. Since producing calligraphy letters is quite difficult due to their parameters, it is suitable to use 5-axis CNC machine as this machine could cut a very complex shape, have a better control of tool positioning, efficient utilization of tools, reduction of machining time, and shorter process planning phase (Zębala and Plaza, 2014)**.** Some of the expert said that, smaller machine tools can be more effective to machine a small part. In late 19th century, it is been discovered that Japan has produce micro lathe machine which only 32mm in length by Okazaki and Kitahara. But this machine has their limitation on the accuracy and also the limited shape capability. It is then been develop a 200 mm in length of micro-lathe machine by Lu and Yoneyama which successfully turn a 300 micro meter brass wire down to 10 micro meter in diameter using diamond tools (Mao *et al.*, 2015)**.**

Error due to the machining dimension can cause the assembly of machine part and also the performance variability. The accuracy and repeatability of machine tools are important in order to achieve and maintaining a quality part. Some example of the error that can affect the quality of the part such as tool wear and deflection, the clamping error and work piece location and also work piece deflection (Gu, Agapiou and Kurgin, 2015)**.** Others error in CNC machine tools that can affect the accuracy and repeatability of part manufacturing including force and stress, geometrical deviations of machine tool structure, thermal variations, and cutting force induced errors (Soori, Arezoo and Habibi, 2013)**.**

2.5 Industrial Clay

Industrial clay is commonly related to the reverse engineering technique. An industrial clay does not have much expansion/shrinkage and remain hard at the room temperature which is at 25 degree Celsius. Because of this clay remain hard at the room temperature, a special oven is created to heat up the clay until the core of the clay becomes soft. The clay becomes soft at the temperature of 45 degree Celsius or 60 degree Celsius (depend on the type of industrial clay used). The clay minerals can be

classification both in term of their industrial applications and on the basis of mineralogical. Below is the table of a classification of the clay minerals in terms of their structures and compositions (Harvey, c. C. & murray, 1997).

Group name	Mineralogy	Major industrial applications
Kaolin	kaolinite	Industrial fillers, coatings and pigment in paper, paint, plastics, rubber and related industries. Modified to produce organo-clays for use in organic systems. Ceramic raw material. Calcined kaolins with improved light scattering properties for use in paper and paint systems.
	halloysite	Ceramics. Industrial filler. Cosmetics. Framework for catalysis.
Smectite	Na and Ca smectite (montmorillonite)	Oil drilling, pelletizing, foundry sand binder and filter aid. Containment barriers in landfills. Chemically modified for use in organic systems. Animal litter.
Hormites	palygorskite (attapulgite)	Oil drilling, bleaching oil, adsorbents, gellants, agricultural carrier.
	sepiolite	
Pyrophyllite	pyrophyllite	Refractories, ceramics, fiberglass.
Ball clay	kaolinite and minor mica/ illite, smectite, quartz, plus organics	Ceramics, pesticide carrier.

Figure 2.7 Classification of Clay and their application

For 80 years, the clay modelers using their own hand to create a two dimensional sketch of car design on the paper. Nowadays, clay modelers can now easily produce the design of the car with the full-size clay models. Clay is extremely malleable. It will allows the clay modelers to fair a line, to tuck a curve, until the body of the design car becomes prefect (auburn hills, 2015). In the other hand, with the using clay to produce a 3D models, it can shorten the design process and cut cost (Wilson, M., 2015).

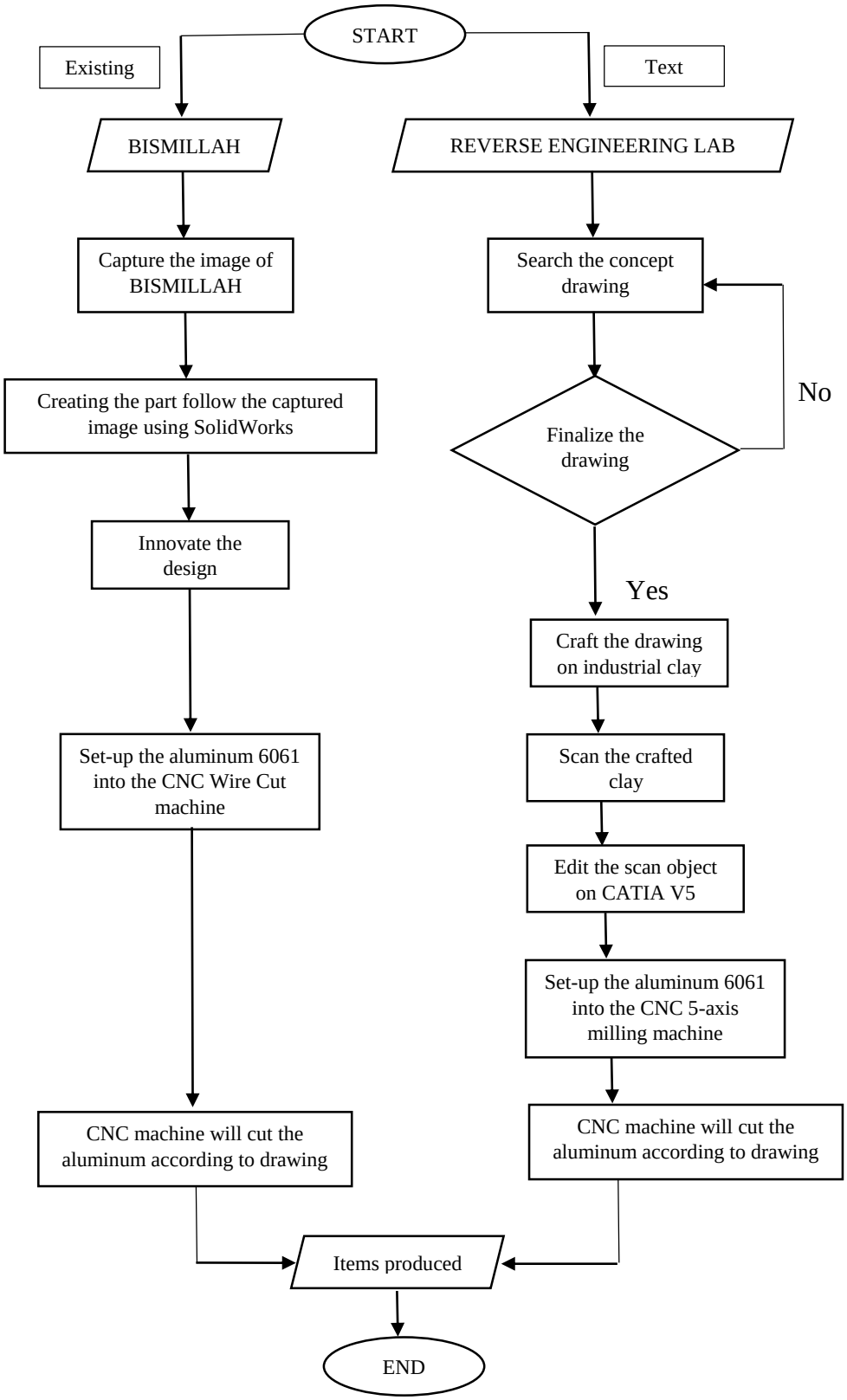
CHAPTER 3

METHODOLOGY

3.1 Overview

In this chapter, the process of producing the calligraphy is shown step-by-step until the prototypes is produce. This project consist of two product that need to be produce with the same method of process but different in output. The first input is about producing the innovation of “BISMILLAH” calligraphy and the second input is producing the typography of “REVERSE ENGINEERING LAB”. Both of these input will be producing by using the CNC machining and also by using technique of reverse engineering. In the second input, industrial clay is involved which the typography words needs to be crafted on the industrial clay by using the crafting tools.

3.2 Process Flow Chart



3.3 Design Innovation and Concept Selection Process

3.3.1 "BISMILLAH" Calligraphy

Image of BISMILLAH calligraphy was captured by using a camera. The image of BISMILLAH as shown below;

Figure 3.1 BISMILLAH Image

Then the image was imported into the SolidWorks software where this software was used to create the part based on the image that was been captured.

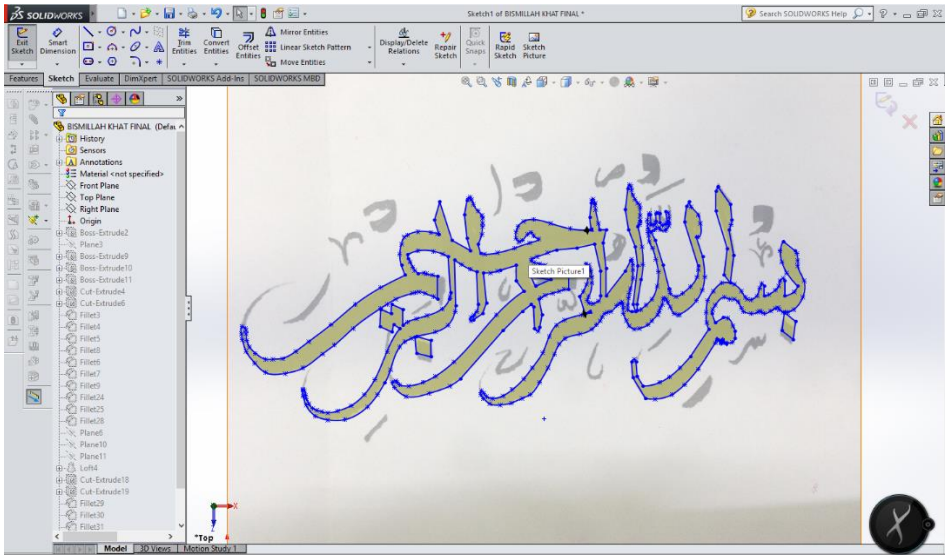


Figure 3.2 Creating profile to the imported image

Drawing tools that involved in this process are Line and also Spline. Both function was used to create the profile based on the Figure 3.2. The blue line in the picture above is the line that was created based on the imported BISMILLAH image. After finish creating the profile, it will be extruded with thickness of 5mm.

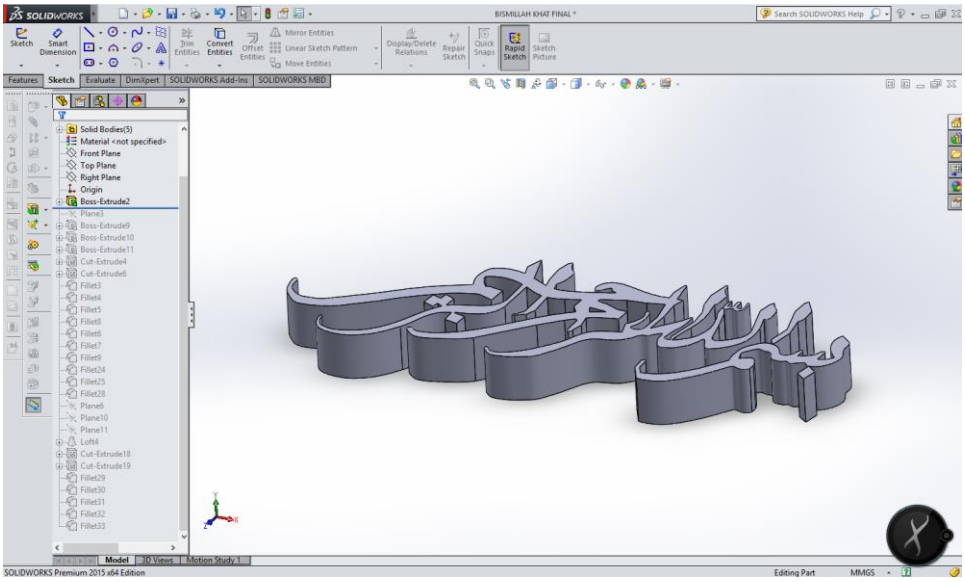


Figure 3.3 Extruded BISMILLAH part

The next step was to create the pen holder. Create another plane below the BISMILLAH part and draw a rectangle on the new plane created as shown in Figure 3.4 below.

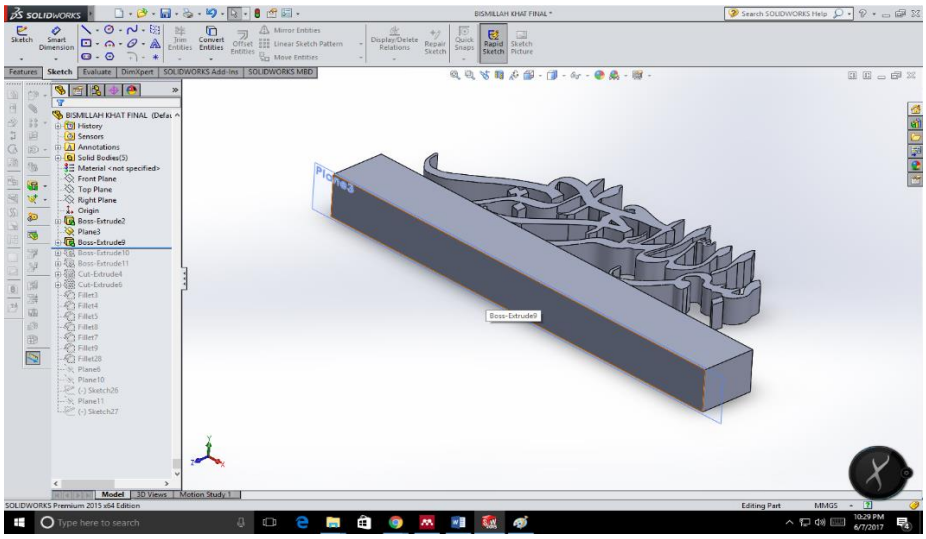


Figure 3.4 Rectangle profile drawn on new plane

After getting those part, the rectangle that was drawn will be edited to be attached with the BISMILLAH part and will be using extruded cut features to cut the edge, fillet features to create a fillet on the edge as shown in the Figure 3.5 below.

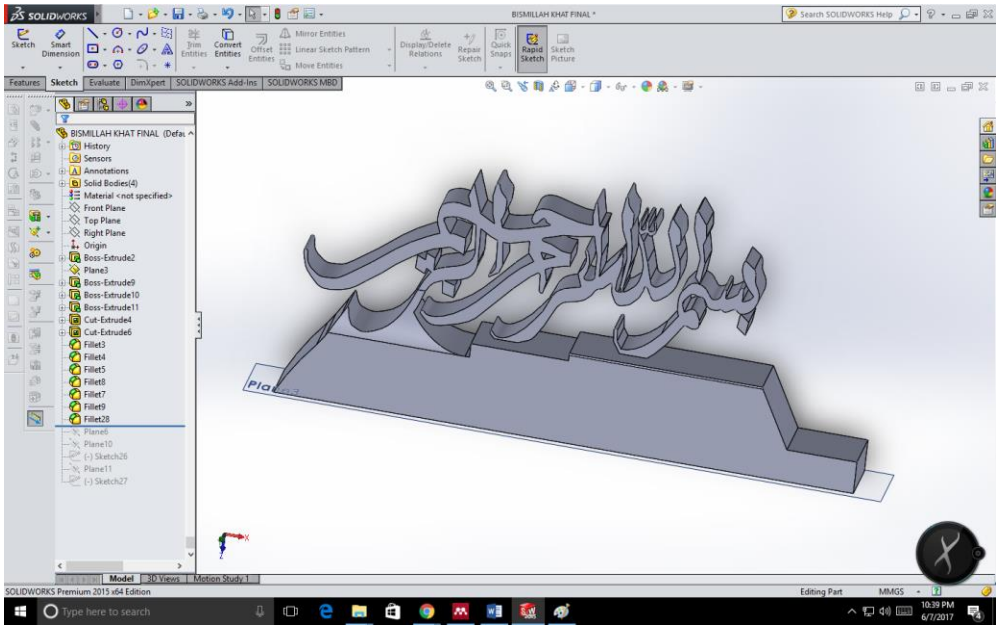


Figure 3.5 Edited BISMILLAH

The final process was producing the pen holder on the right side of the rectangle that is left based on the Figure 3.5. This process was same as the process to create the rectangle. But this process will need three plane to create the loft. After getting the loft, it will be extrude cut to get the hole and finally fillet the loft. Then, the part will be machine.

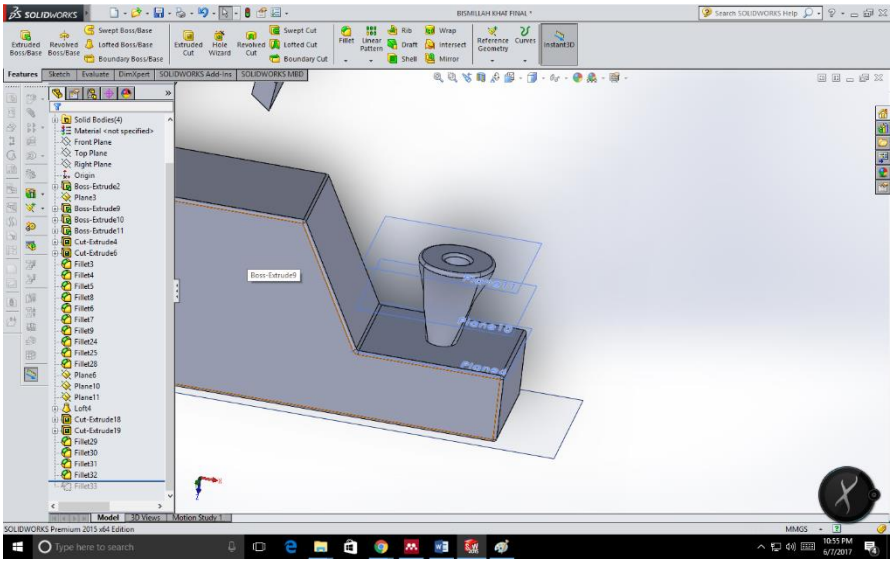


Figure 3.6 Creating the pen holder

Figure 3.7 Rendering part of BISMILLAH

3.3.2 “REVERSE ENGINEERING LAB” Typography

In this input, the concept of the drawing was taken from the concept of Boomerang. The reason behind this concept was selected because the characteristic of boomerang when it is being thrown correctly on the air, the boomerang will returns to its starting point. The characteristic of boomerang can be related with the process of reverse engineering which it is called also as back engineering.