DESIGN AND FABRICATE

A GANTRY TYPE OF CO_2 LASER CUTTING MACHINE

MOHAMMAD RAFIQ BIN RADZUAN

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Name : MOHAMMAD RAFIQ BIN RADZUAN

ID Number : MB 10040

Date : December 2012

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ABSTRACT

Now days, a flexible machining and precise positioning operation is typically refers to a gantry system that generate the idea to create a very own gantry type CO_2 laser cutting machine. To design and fabricate this gantry machine, some fundamental studies had been carried out in terms of its suitability, versatility, ergonomically and economical with provided budget. Comparison between other designs is needed to make sure it fulfils all the criteria. This project involves the process of designing the gantry machine considering to economic and ergonomic factor for people to use. After all the process, the machine had been successfully developed within light budget of RM 10,000 and successfully tested to prove its operation.

ABSTRAK

Pada masa kini, pemesinan fleksibel dan operasi kedudukan tepat biasanya merujuk kepada sistem gantri yang telah menjana idea untuk mewujudkan mesin gantry sendiri jenis laser pemotong CO_2. Untuk merekabentuk dan menghasilkan mesin gantri ini, beberapa kajian asas telah dijalankan dari segi kesesuaian, fleksibiliti, ergonomik dan ekonomi berdasarkan bajet yang disediakan. Perbandingan antara reka bentuk lain amat diperlukan untuk memastikan ia memenuhi semua kriteria. Projek ini melibatkan proses merekabentuk mesin gantri berdasarkan faktor ekonomi dan ergonomik untuk kegunaan orang ramai untuk. Selepas semua proses, mesin ini telah berjaya disiapkan dalam bajet RM 10,000 dan berjaya diuji untuk boleh beroperasi.

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LIST OF ABBREVIATIONS

UMP	Universiti Malaysia Pahang
FKM	Fakulti Kejuruteraan Mekanikal
CNC	Computer Numerical Control
CAM	Computer Aided Manufacturing
CAD	Computer Aided Drawing
PC	Personal Computer
Mach Mill 5	Machine Milling 5 Programs
CO_2`	Carbon Dioxide
RAM	Random Access Memory

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The purpose of this chapter is to explain about the project background, objectives of the projects, project scopes, project schedule and flow chart during this project. This chapter also give some overview about the title given and the overall procedure and how time is being distributed for this project.

1.2 PROJECT BACKGROUND

Now days, laser cutting is one of the most important cutting process manufacturing industry because it flexibility to cut many various material such as sheet metal, plastics, woods, plywood and many more. The quality of laser cutting cannot be predicted. Laser cutting quality is better than any conventional cutting process because of their high accuracy and repeatability. This can be achieved due to the process itself is non-contact process. Besides, it very fast process and favored by many industries worldwide.Our faculty are very interested with this laser cutting machine and try to develop our own laser cutting machine

1.3 PROBLEM STATEMENT

The flexibility of a machine relies on their machine structure itself. Gantry type machine is chosen because it provides large working space. Actually a prototype of laser machine was design before, figure 1.3.2, but without success. There have some weakness is found such as less rigid, wobbly and smaller working space. Besides, the past structure of the machine still cannot support the size of CO2 laser. The CO_2 laser is too heavy and wide for the structure to endure it, figure 1.3.1. These refer to my problem statement which are can be solved by proposed a new concept of gantry type laser cutting machine

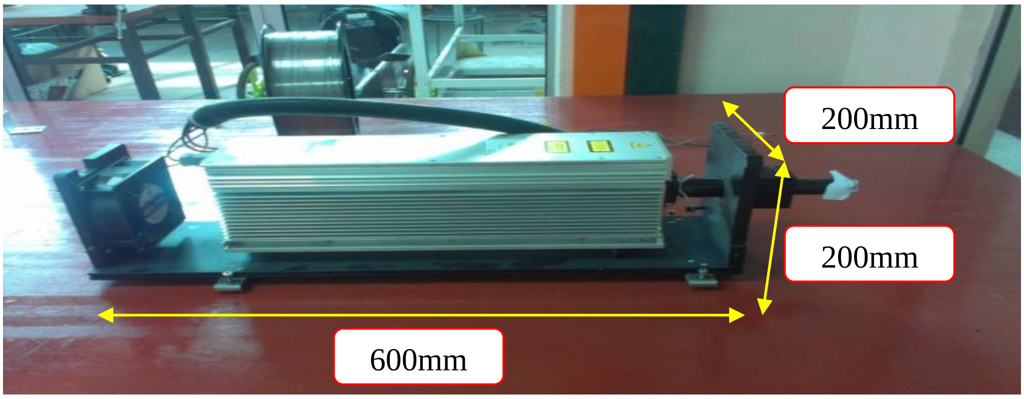

Figure 1.3.1: Laser cutter

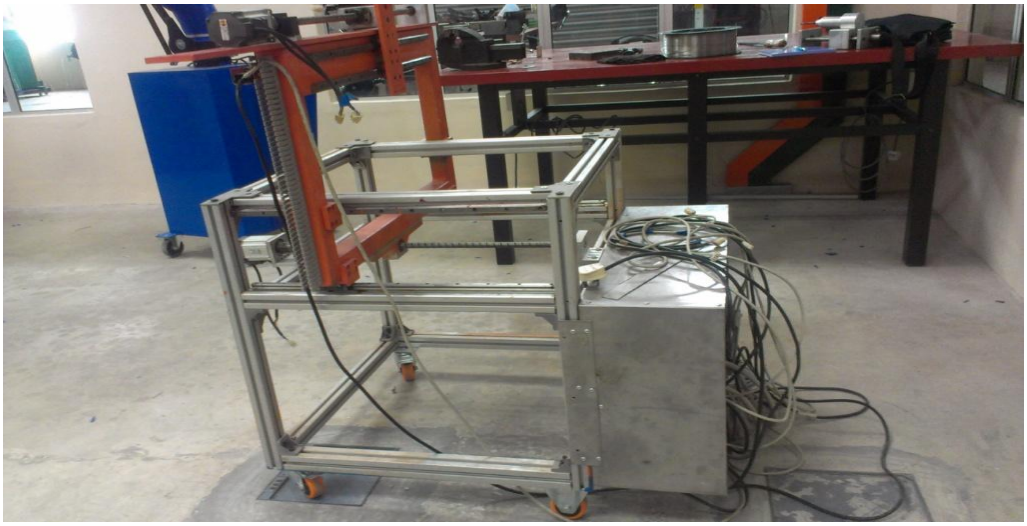

Figure 1.3.2: Older laser machine

1.4 OBJECTIVES OF THE PROJECT

Objectives of this project are:

I. To design a low cost CO_2 laser cutting machine.
II. To fabricate a low cost gantry type CO_2 laser cutting machine.

1.5 PROJECT SCOPES

Project scopes for this project are:

I. This project focuses on the development of gantry type CO_2 laser cutting machine.
II. The scope of work mainly focused on machine structure or frame design rather than laser itself.

1.6 PROJECT SCHEDULE

Table 1.6: Gantt chart

WEEK / TASK		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Briefing about PTA	PLANNED														
	ACTUAL														
Introduction	PLANNED														
	ACTUAL														
Literature review	PLANNED														
	ACTUAL														
Concept generation	PLANNED														
	ACTUAL														
Final concept	PLANNED														
	ACTUAL														
Material selection	PLANNED														
	ACTUAL														
Fabrication	PLANNED														
	ACTUAL														
Analysis and testing	PLANNED														
	ACTUAL														
Project report	PLANNED														
	ACTUAL														
Presentation report	PLANNED														
	ACTUAL														

Table 1.1 shows the Gantt chart for the final year project. It shows the planning and the actual progress of the project. There shows the difference between the planning of the project and the actual progress of it thus allowing a comparison to be made between two.

As shown in the Gantt chart, the time used for concept generation takes longer time than expected. The design satisfied from economical and ergonomically criteria. Furthermore, solid works software also gives some trouble for me designing the concept due to lack of RAM and incompatibility of the laptop used.

Time spending on the literature review is shorter because of the knowledge and research of this task has been done early. Ideas from both supervisors also helped to done this task shortly. Besides, more time is spending on concept generation and fabrication process.

The fabrication takes a lot of time than expected because of the project mostly uses the computer numerical control (CNC). The time takes for a one part to finish about 1 until 2 hours approximately. This machine takes some times for power up, vice setting, zero set, tool offset measurement, convert solid works drawing into Computer Aided Manufacturing (CAM) program and process selection before machining.

Other than that, the preparation for final report also started late. It was due to uncertainties that are caused by the delay of the fabrication process. Most of the chapters for this final report had to base on the fabrication product.

1.7 PROJECT PLANNING

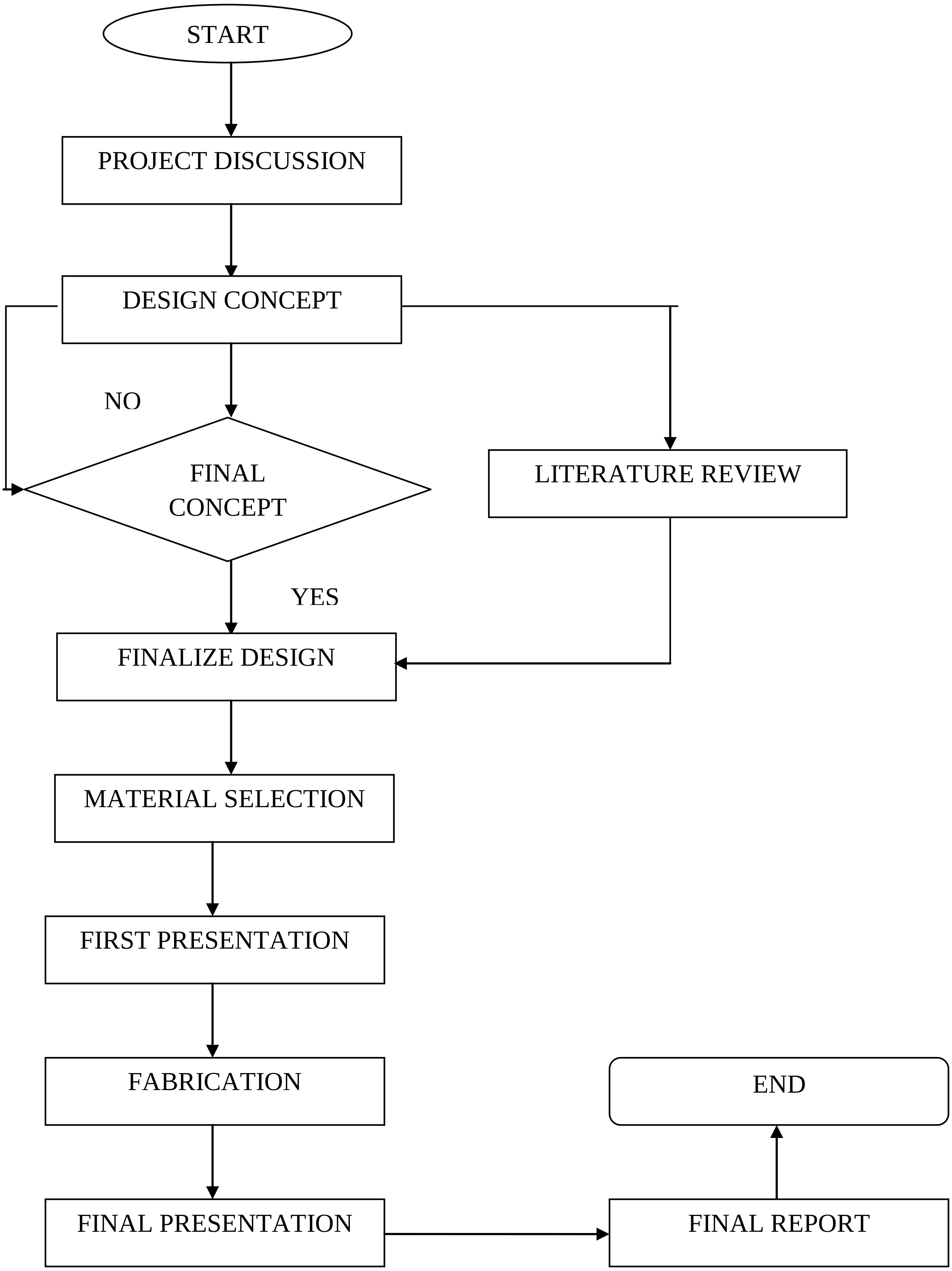

Figure 1.7: Flow chart

Figure 1.2 shows the flow chart for the final year project. For the starting of the project, a briefing from both supervisors is done to understand about the new project title given and manage the schedule of the weekly meeting. Problems are identified, objective comes out from the problem statement and project scopes were propose.

Designing phase started after all problem, objective and scope are clarified. A lot of sketches were purposed to both supervisor for their conformation and addition ideas to the sketching before the sketch was translate into the solid work for analysis.

When the concepts were verified, the final concepts have been proposed due to concept generation before. Final concept must have economical and ergonomic criteria before it going to fabricate. Analyses have been made to make sure no fracture will occur.

Material needs to fulfil all the criteria that have been proposed. Once received the materials, fabrication process is up. Fabrication process starts with measuring and cutting process. Then it's going to CNC labs for further process. Then follow up with assemble the work part.

After all the process done, the final report writing and presentation is being the last task to be accomplished during the week fourteen. The supervisors review the final presentation and revise the mistakes to be amended. The final presentation than again was presented to two panels. A draft report was then submitted to the supervisor for review. Corrections were done and the real final report is handed over as a completion of the final year project.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter introduces some literature review about the type of laser cutting in industry, comparison between two cutting process and a brief to laser cutting. According to the title, design and fabricate a gantry type CO_2 laser cutting machine requires an amount of excellent understanding on the knowledge of the machine structure. The information obtained is essentially valuable to assist in the fabrication process of this final year project.

2.2 INTRODUCTION TO CUTTING PROCESS

Cutting processes work by causing fracture of the material that is processed. Usually the portion that is fractured away in small sized pieces, called chips. Commonly cutting process includes sawing, drilling, laser, water jet, turning and milling. Although the actual machine, tools and processes for cutting look very different from each other.

2.3 COMPARISON BETWEEN TWO CUTTING PROCESSES

Table 2.2: Comparison between laser cutting and water jet

Laser cutting	Water jet cutting
Manufacturing include cutting, welding, heat and engraving.	More to the cutting process and structuring only.
Using gas laser as source of energy.	High pressure pump.
Cutting of flat sheet steel of medium thickness for sheet metal processing.	Cutting of stone, ceramics and metal of greater thickness.
Cut surface will show a striated structure.	The cut structure will appeal to have been sand-blasted, depending on the cutting speed.

2.4 LASER CUTTING

Laser cutting was one of the fastest growing processes in industrial manufacturing equipment. Laser cutting machines were being used by metal fabricators in place of older technology equipment like turret punches. Quality and speed were very high compared with other cutting technologies. Laser cutting machines offer significant advantages in productivity, precision, part quality, material utilization and flexibility. Laser Cutting was the solution to the manufacturing challenges of today and the future. The laser cutting system was a proven industrial machine tool that can operate day in and day out in an industrial fabricating shop. Laser cutting machines consist of several main components including resonator, beam delivery, machine frame, CNC or PC control, and drive system.

Laser cutting is a thermal process that can be applied to high quality precision cutting. The laser cutting process is similar to taking a magnifying glass outside on a clear day and focusing the sun's energy to burn paper or a leaf. Laser cutting energy from a resonator is focused on a material in order to melt burn or vaporize it. Some laser resonators produce a beam that can focus to a smaller hotter spot allowing faster, high quality laser cutting with lower operating costs. There have several types of laser cutting such as CO_2, Nd –YAG and fibre laser. Mostly CO_2 are usually used in industry because it cheaper than its kind.

2.5 MACHINE CHASSIS DESIGN

In recent years, the design of a high performance of a positioning system requires accurate knowledge of dynamic axis and the motion controllers need to be design to avoid contouring errors. Several types of design that usually used in industry, which were bed –type chassis, figure 2.5.1 and gantry type chassis design, figure 2.5.2. Bed –type were manufactured for high cutting speed work. It was very heavy so that make the machine were rigid and suitable for precise cutting process. This machine will provide more precise in cutting process because only the work piece was moving in mean while, the cutting tool stay steady.

While for the gantry type was a type of moving cutting tool machine or in detail was a framework of steel bars resting on side support to bridge that hold the cutting tool. For gantry type chassis the work piece was unmovable while cutting process was done by the moving cutting tool. The cutting tool was placed above the work piece. For the movement, a computer program that controls our gantry type machine. A gantry stage which was actuated by the motors with ball-screws was developed to achieve high performance positioning. The moving gantry stage was usually separated into two types, one was actuated by motor with ball-screw and the other was actuated by the permanent linear bearing. So, gantry chassis type is suitable for accurate cutting process.

Figure 2.5.1: Bed type machine

Figure 2.5.2: Gantry type machine

2.6 GANTRY TYPE LASER CUTTING MACHINE

Gantry type chassis design was choose because it can move to 3+ axes (X, Y, and Z). Each motion refers to linear motion in a single direction. Each of these motions were arranged to be perpendicular to each other and were typically labelled X, Y, and Z. X and Y were located in the horizontal plane and Z is vertical. So, the machine could move to any desirable position. Other than that, the manufacturing cost for gantry structure was inexpensive compared to G –type structure. The structure of G –type machine needs to use crane to accommodate their cutting tool compared to gantry type structure that only used aluminium plate for support the cutting tools. Besides, the maintenance cost and service for gantry type machine is more cheaper and easy because the motor is located outside compared to G –type machine which is located inside and some part have to be open first to service the motor of G –type machine. So, it reduces the time for maintenance service too. Gantry type machine structure is light but it is able to carry the heavy load (load of laser). These have to do with the nature of the gantry that can scalable for light to heavy.

But for gantry chassis design, their gantry stage cannot free standing. It needs a stand or other mounting to support the stage. This is one of weakness over gantry chassis design. Plus, gantry stage cannot reach outside from their working table. It can be only move according to their length of linear bearing or their structure design. So limit switch is needed to make sure that gantry stage move inside the table.

CHAPTER 3

PROJECT METHODOLOGY

3.1 INTRODUCTION

Chapter three would explain two drawing and design concept generated to do the gantry type of CO_2 laser cutting machine on the scope specified. The advantages and disadvantages of the design are also explained in order to select the best design concept to be fabricated. The designs are then compared using selection criteria that are considered to be importance in gantry type of CO_2 laser cutting machine.

3.2 DESIGN CONCEPT

The design of gantry machine must be compliance to several aspects. The aspect that must be considered in designing the machine is mechanical part of the machine, cost, material used, weight and versatility of the machine. Finally, the design that had been proposed should be compared and the suitable criteria were taken to generate the final concept.

3.2.1 Design Concept 1

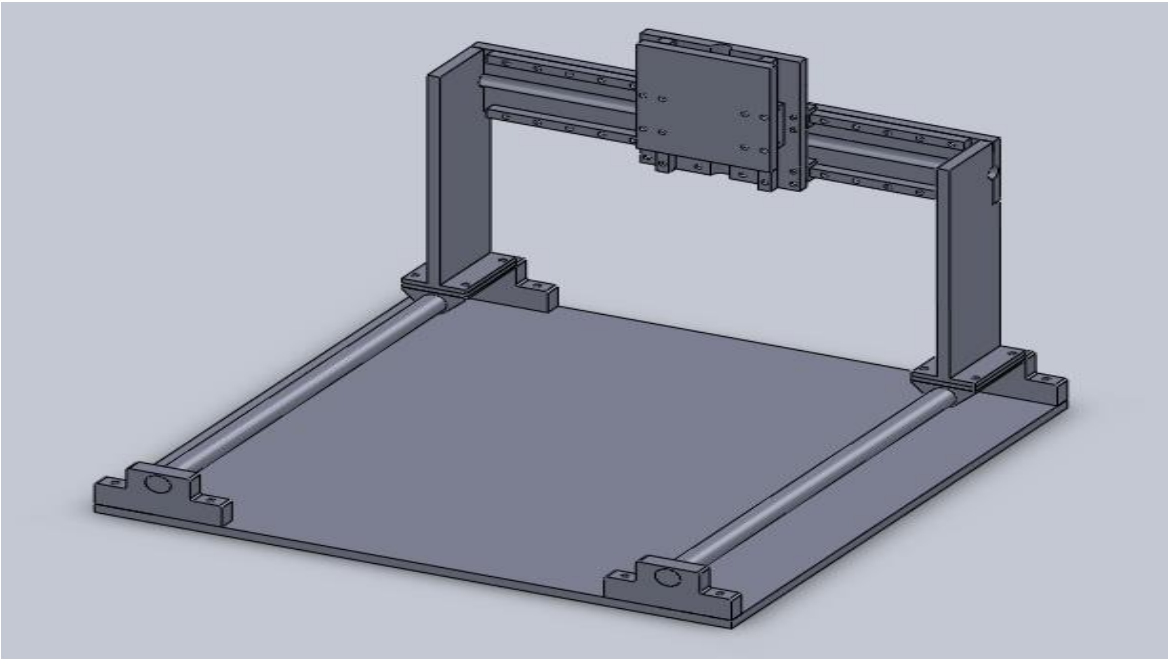

Figure 3.2.1: Design concept 1

2D drawing would be shown at appendix D1A

Figure 3.1 shows the isometric view of design 1. For this design, linear motion ball bearing was used which a very expensive compared to the other linear bearing. Other than that, weight of the laser was supported mostly to the rail. This can cause deflection occurs at the rail. this chassis also was less rigid due to their structure design. The advantage of this design was due to the fabrication process where less process was needed for built the structure.

3.2.2 Design Concept 2

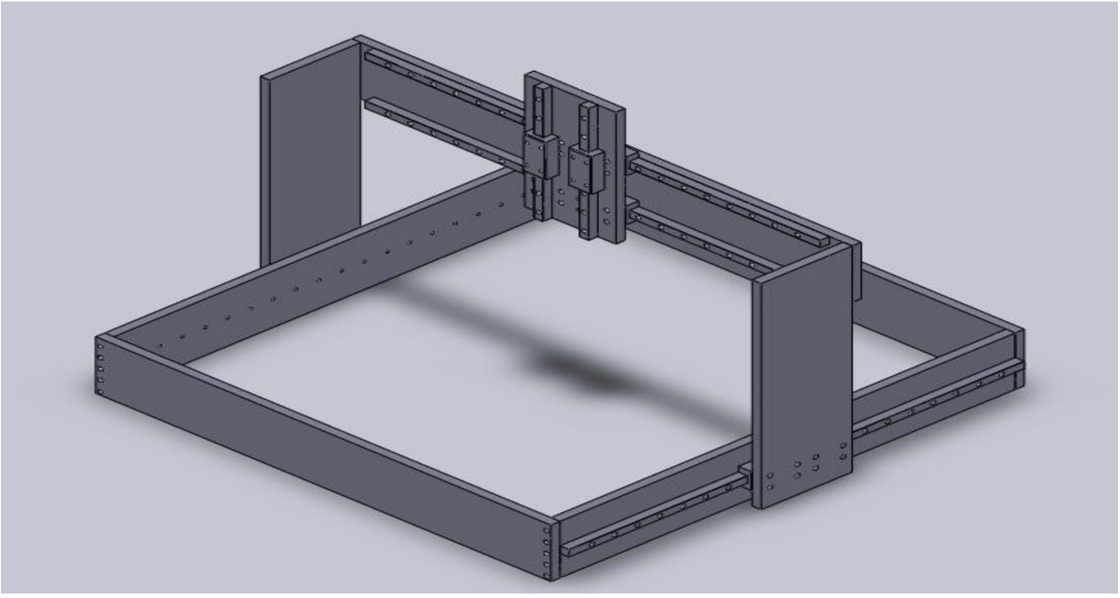

Figure 3.2.2: Design concept 2

2D drawing would be shown at appendix D2A

Figure 3.2 shows the isometric view of design 2. This design was quite complicated but rigid due to its machine structure. However, its takes time to fabricate because a lot of holes need to be drill. Other than that, this design also cannot hold the load from laser because the gantry stage just hanging without full support from the stand plate. Mostly, the load was supported by the screw. But the advantage of this design, it using the linear slide ball bearing which is quite affordable and low cost to manufacture.

3.3 FINAL CONCEPT

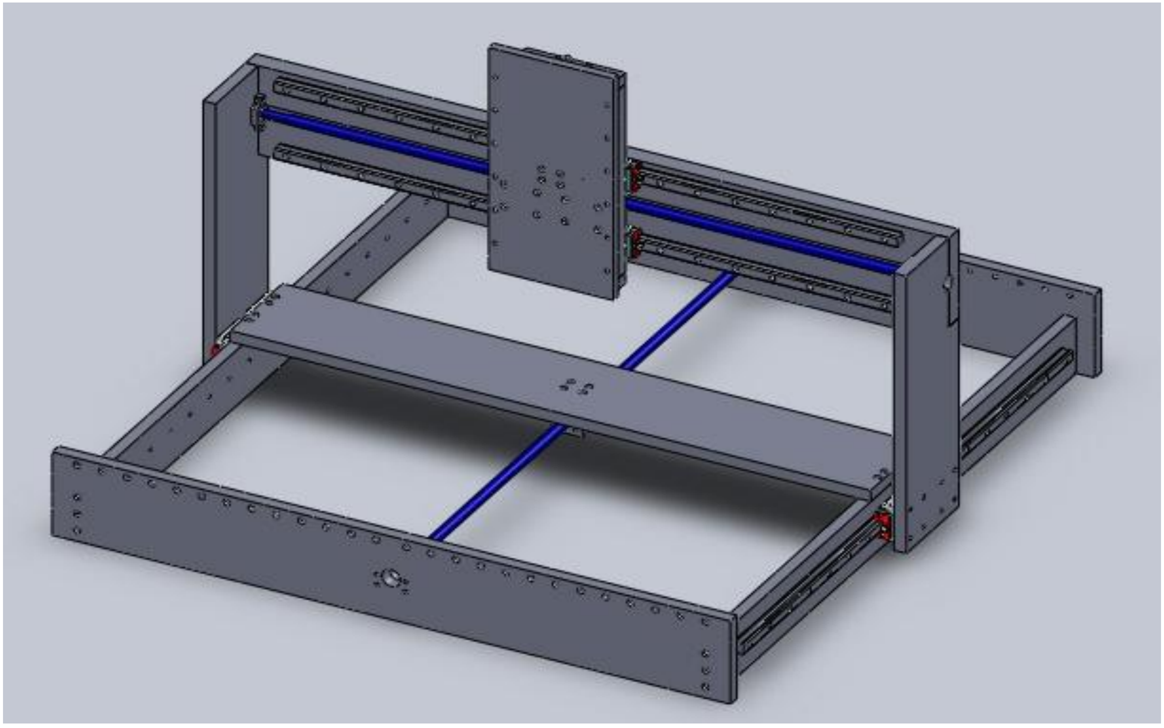

Figure 3.3: Final concept

2D drawing would be shown at appendix D3A

Figure 3.3 shows the isometric view of final concept. This concept was come out from referring the two design concept that has been proposed before. A very rigid gantry structure design was develop with refer to the concept generation before. The best criteria from the concept design were taken while the weakness has been improved. A low cost machine structure is design according to given budget. Besides, the structure of machine could support the load of laser because it stage was supported to the side plate. Even the fabrication process will take a lot of time, but it was the best deign and satisfied all the criteria for gantry type machine.

3.4 MATERIAL SELECTION

Aluminium Bar was used for this final year project. Aluminium was very suitable because of their property that was easy on metal working. Otherwise, aluminium also does not rust easily and had non-magnetic properties. Aluminium structure also lighter compared to other material. But there have some disadvantages using aluminium where it quite expensive. So, quantity of aluminium must been calculate before the material was taken. This to make sure that the material was not been wasted during the machining and follow the objectives that to fabricate a low cost machine. Aluminium also softer than other material and it easily found to fracture. Analysis of the structure must been made before material was choose. The length, width and height parameter must be analyzed to avoid fracture happened.

3.5 FABRICATION PROCESS

Fabrication process was the process to make or built the part or model of the project. This process needs to follow the exact dimension according to the drawing design. In making the design become a real product, several processes have been used to fabricate the mechanical part. Mostly of the part was used the CNC program because it deals with precision of the structure that will be produce.

3.5.1 Measuring and Marking Process

Figure 3.5.1 shows the measuring tape used to measure the material for the project. The fabrication process starts with measuring and marking the materials into dimension according to the drawing. Mostly all the measurement takes 0.2mm $\pm$ more for machining process

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Figure3.5.1: Measuring tape

3.5.2 Cutting Process

Figure 3.5.2 shows the bend saw used for cutting the material after the measuring and marking process has been done. Cutting process was done by referring the marking that been made before.

Figure3.5.2: Bend saw

3.5.3 Computer Numerical Control (CNC) Process

Figure 3.5.3.1 shows the computer numerical control (CNC) that mostly used for this project. The drawing of the part in final concept must be saved into .DWG format before it can use the Computer Aided Manufacturing (CAM), (figure 3.5.3.2). In the CAM program, slected process must been choosed properly before started the machining. Other wise, this program also could reviewed the working flow and process selected in 3D and 2D. So, any fault during machining can be detect. The suitable parameter also must according to the drawing and material used. This to avoid the tool break of crack during machinig. After all the steps, we could generate th G- codes and transfer directly into the machine operator. It will read the G-code and start the machining.

G-Codes would be shown at appendix B

Figure3.5.3.1: Computer numerical control machine

Figure3.5.3.2: Computer aided manufacturing program

3.5.4 Tapping Process

Tapping is used for make thread into a hole. Figure 3.5.4 shows hand tap that used in this project. The taps used were M6, M5and M4 tapper. CNC machine could not do the thread because it required very high skill and knowledge about machining.

Figure3.5.4: Hand tap

3.5.5 Drilling Process

Figure 3.5.4 shows hand drill used. Hand drill is used for assemble the part after the machining using screw.

Figure3.5.5: Hand drill

3.6 TOOLS AND EQUIPMENT

3.6.1 Centre Drill Bit

Figure 3.6.1 shows the centre drill that been used for marking the hole before drilling process. This tool was used during computer numerical program (CNC) process. Ø5 mm was used for this operation. Cutting speed for this operation was 1000 rpm and the feed rate was 100 mm/min.

Figure 3.6.1: Centre drill

3.6.2 Drill Bit

Figure 3.6.2 shows the drill bit that been used for drilling the hole. This tool also been used during CNC process. Drill bit that been used was Ø 3 mm, Ø 4.2 mm and Ø 6 mm. For drilling process, spindle speed used was 1200 rpm and for feed rate were 100- 80 mm/min. Peck drill is used during this operation for safety precaution during drilling process.

Figure 3.6.2: Drill bit

3.6.3 Edge Finder

Figure 3.6.3 shows the edge finder that been used for searching zero coordinate of work piece. For machining, zero part of the work piece was usually at the centre of the work piece. This according to the drawing that been draw in Master CAM program. Besides, to find the zero part in the middle was quite easy compared to zero part at the edge of the work piece. 200 rpm of spindle speed was used for this operation.

Figure 3.6.3: Edge finder

3.6.4 End Mill

Figure 3.6.4 shows the end mill that been used for drilling, pocketing, and countering. This tool also one of the processes in the CNC program. Ø 12 mm, Ø 16 mm and Ø 20 mm was been used during the process. There also have 2 type of end mill which is two flutes for drilling and pocketing and four flutes for contouring process. For end mill, 1200 rpm for spindle speed and 80-90 mm/min for feed rate.

Figure 3.6.4: End mill

3.6.5 Face Mill

Figure 3.6.5shows the face mill that been used for facing the surface of the work piece. This tool also one of the CNC process. Ø 100 mm face mill been used for this project. Usually, facing was needed when the work piece was come not in desired size. Spindle speed for this operation was 1200 rpm.

Figure 3.6.5: Face mill

3.6.6 Vernier Caliper

Figure 3.6.6 shows the Vernier caliper that been used for measuring internal and external length and depth. This tool was very important to make sure the precision of the work piece.

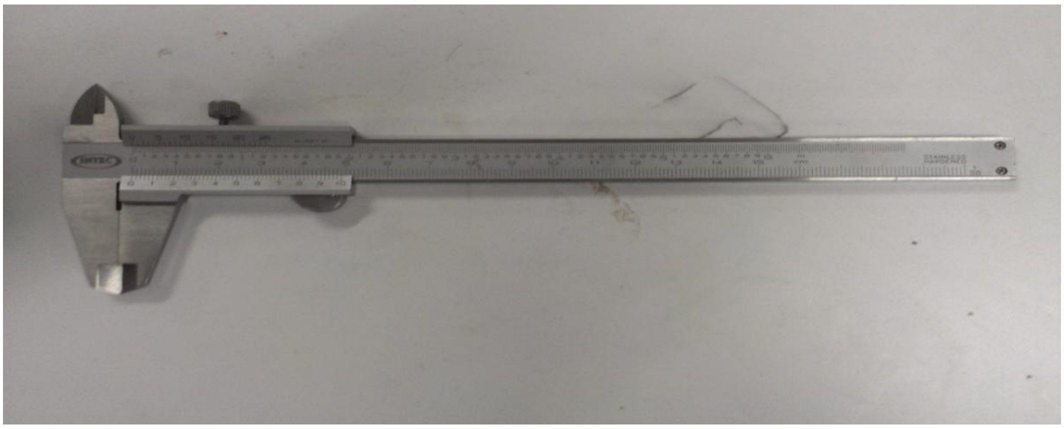

Figure 3.6.6: Vernier caliper

3.6.7 Tapper

Figure 3.6.7 shows the tapper that been used during fabrication process. This tapper must be combined with the hand tap before use. Tapper that been used during the operation was M4, M5 and M6 tap.

Figure 3.6.7: Tapper

3.7 ASSEMBLY GUIDELINE

3.7.1 Step Motors

After the completion of the machine structure, three step motor were installed (representing the X, Y and Z axis) and mounted on three ball screw on the machine as shown in figure 3.7.1. Step motors are used because to achieve precise positioning via digital control. The motor operates by accurately synchronizing with the pulse signal output from the controller to the driver. Step motor able to produce high torque at a low speed while minimizing vibration. It is ideal for applications requiring quick positioning over a short distance.

Stepping motors enable accurate positioning at ease. They are used in various types of equipment for accurate rotation angle and speed control using pulse signals. Step motors generate high torque within a compact body, and are ideal for quick acceleration and response. Step motors also able to hold their position accurately. Step motors system consist of drivers, shown at figure 3.7.2.2, which to takes pulse signal in and send them to the motor controllers.

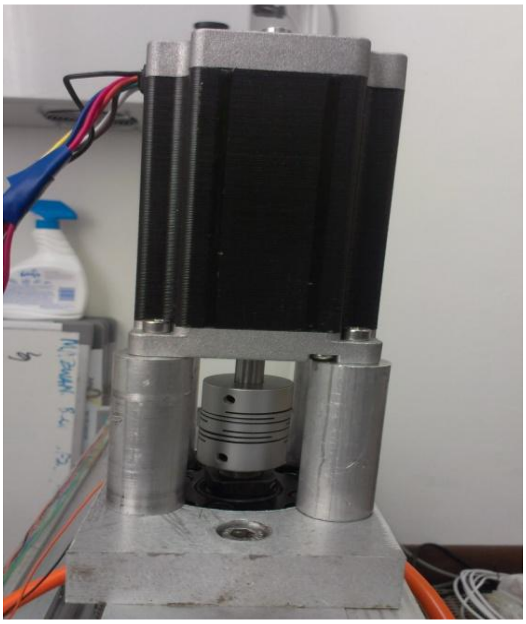

Figure 3.7.1: Servo motor

3.7.2 Step Motor Controller

The rotation angle and speed of the step motor can be controlled with precise accuracy by using pulse signal from the controller, as shown in figure 3.7.2.1. A pulse signal is an electric whose voltage level repeatedly between ON and OFF. Each ON and OFF cycle is counted as one pulse. A command with one pulse causes the motor output shaft to turn by one step. The signal levels corresponding to voltage ON and OFF conditions are referred to as High and Low respectively.

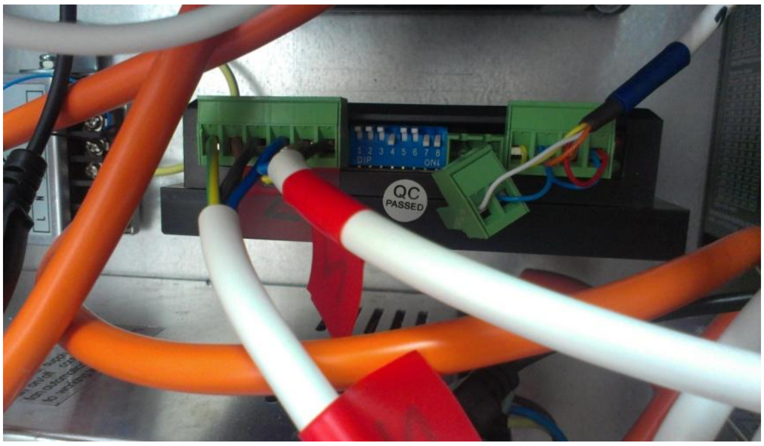

Figure 3.7.2.1: Step motor controller

Figure 3.7.2.2: Breakout board

3.7.3 Programmable Controller

To build- in pulse generation function allows the motor to be driven via a directly connected personal computer or programmable controller. Since no separate pulse generator required, drivers of the type save space and simplify wiring. Mach Mill 5 was used as the program to control the movement of the motor. This is the CNC software that can be used in the personal computer (PC), as shown in figure 4.2.3. To make sure that the driver acts to the correct movement, G-codes and M-codes was installed into this program. These codes were actually same like the CNC machine programming. These code converts the command given into the G-codes and send to the controller. After that, the controller receives the data and the motors moves according to the command given.

Figure 4.2.3: Mach Mill 5 interface

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 STRUCTURE ANALYSIS

Structure analysis is one of the important processes before to fabricate the machine. This analysis is to determine of the effects of loads on the physical structure and their component. Structure analysis is needed to compute a structure's deformation, internal forces, stresses, support reaction and stability of the machine. Gantry stage is the most important part in this design. Most of the load of laser is exert on this gantry stage. For the simulation, 500N load of laser was exerted on the gantry stage which is an aluminium plate 30mm wide, 160mm height and 1128mm long.

4.1.1 Von Mises Analysis

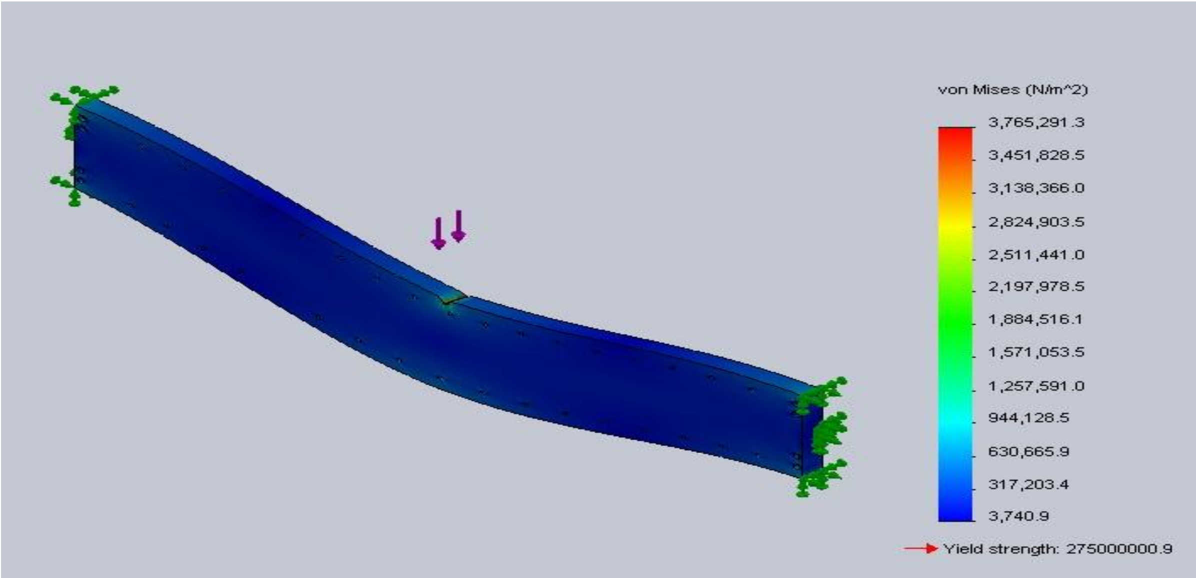

Figure 4.1.1: Von Mises analysis

Figure 4.1.1 shows the von mises analysis on the gantry stage of the structure. This analysis is to determine the strees exerted on the gantry stage if the load of laser is applied. The highest stress from the analysis is the red colour that show 3765291.3 N/m^2 but from the simulation the highest stress detected if the load of laser is applied just only the green colours which is only 2197978.5 N/m^2. This result also shows the stress are very far from the yield strength of aluminium which is 275000000.9 N/m^2. This means the gantry stage is structurally safe because the result is acceptable and it can support the load of laser without turn to plastic deformation.

4.1.2 Deformation Analysis

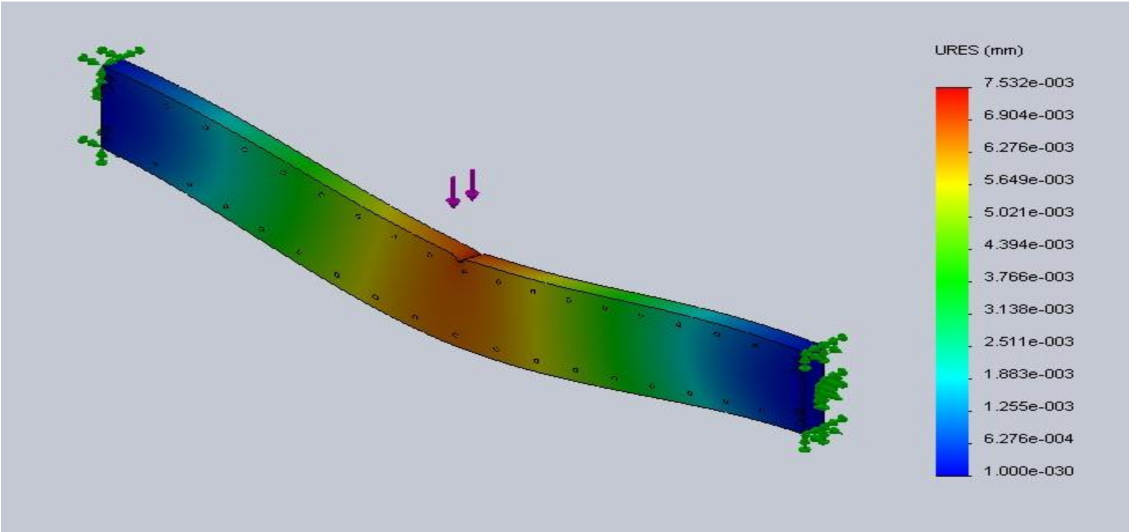

Figure 4.1.2: Deformation analysis

Figure 4.1.2 shows the deformation analysis on the gantry stage of the structure. This analysis is to determine the deflection of the aluminium plate if the load of laser was applied. From the result the highest deflection that could be occur is $7.532e^{-3}$ mm, but from the simulation it just $6.904e^{-3}$ mm detected. So, this means only small deflection occurs from the simulation. As the result, aluminium plate is very suitable to support the load of laser.

4.2 FINAL RESULT

After 14 weeks working for this final year project, a working gantry machine was successfully developed as shown in figure 4.2.1. Installation was not focused at the machine structure, it include the programming and wiring also. Three motor were mounted to this machine at the ball screw, shown at figure 4.2.4, for three movements which is X, Y and Z axis. These motor rotate and so does the ball screw to moved the gantry stage along at their linear bearing, shown at figure 4.2.3 All three motors which was step motor were linked to the operator box function as motor controller. This operator box, figure 4.2.2 will read the command given from Mach Mill 5, programming software to move the motors. All the command must refer to the G-code and M-code where been installed to this software. These codes allowed program to generate for the system using standard CAM/CAD. Initial test on the machine were promising. The gantry moved at a range without any problem being encountered.

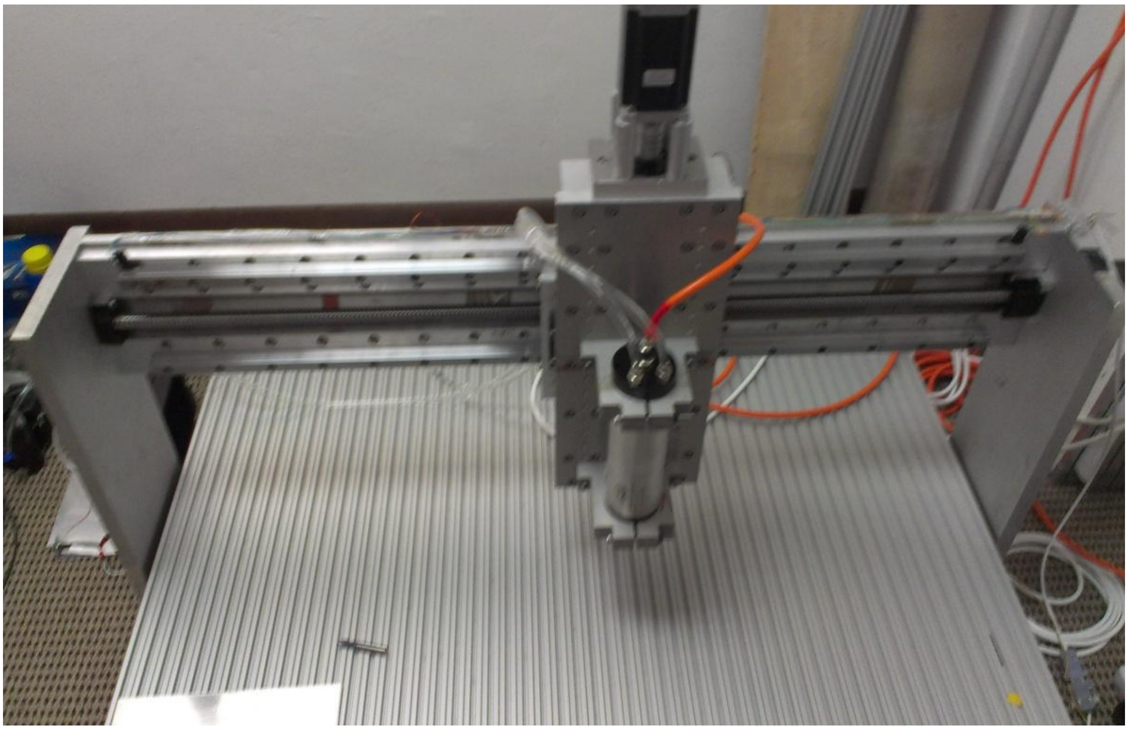

Figure 4.2.1: Final product

Figure 4.2.2: Operator box

Figure 4.2.3: Linear bearing guide

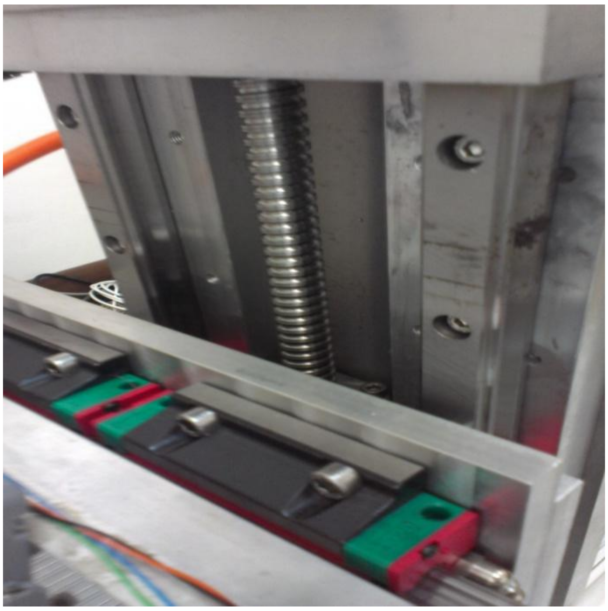

Figure 4.2.4: Ball screw

CHAPTER 5

CONCLUSIONS AND RECOMENDATIONS

5.1 INTRODUCTION

This chapter concludes the findings achieved in this project. Problem encountered during the course of this project also have been identify and some recommendation for future project of the same kind to improve it so that more knowledge understanding and enhanced application steps can be attained.

5.2 PROBLEM ENCOUNTERED

During the design and fabrication process of gantry type CO_2 laser cutting machine, many obstacles were faced. Firstly was the lack of knowledge in gantry chassis design. This lack exposure in the field caused a problem as the information of gantry chassis design was hard to attain either from the internet or any source.

Limited number of Computer Numerical Control (CNC) machine in mechanical CNC laboratory that causes delay during fabrication process. There only three machines that only provided from mechanical engineering faculty. So, there is competition in the use of the machine.

Thread of screw need to be done manually because to make thread using machine must have higher skill to make sure the tool is not fracture. This cause the problem during the fabrication process because a lot of hole need to make thread. This was one of the reasons of delay during fabrication.

5.3 CONCLUSIONS

As the conclusions, a low cost of gantry type CO_2 laser cutting machine has been successfully designed and a working laser machine also was successfully developed. A gantry type machine structure is seen as the most promising solution for this development work due to its advantages. The good machine design concept is important to ensure the machine is rigid so it can produce high repeatability and accuracy. The objective to design and fabricate a low cost gantry type of CO_2 laser cutting machine is achieved.

5.4 RECOMMENDATIONS

As for recommendation on the future, use of fibre laser is very promising compared to CO_2 laser cutter. These refer to its sizes where fibre laser is much smaller than CO2 laser. Other than that fibre laser also faster and provides more power that CO_2 laser. So, fibre laser is higher efficient compared to CO_2 laser cutter.

Next, fabricate the machine in larger space. A gantry machine is design to move freely along all the axes. So, more movement can be done in all axes and more work piece can be cut at the same time.

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http://www.orientalmotor.com/products/ac-dc-step-motors/ (online – 9 January 2013)

Matthew Grant, 2005, Quick start to drive a stepper motor, Microcontroller division

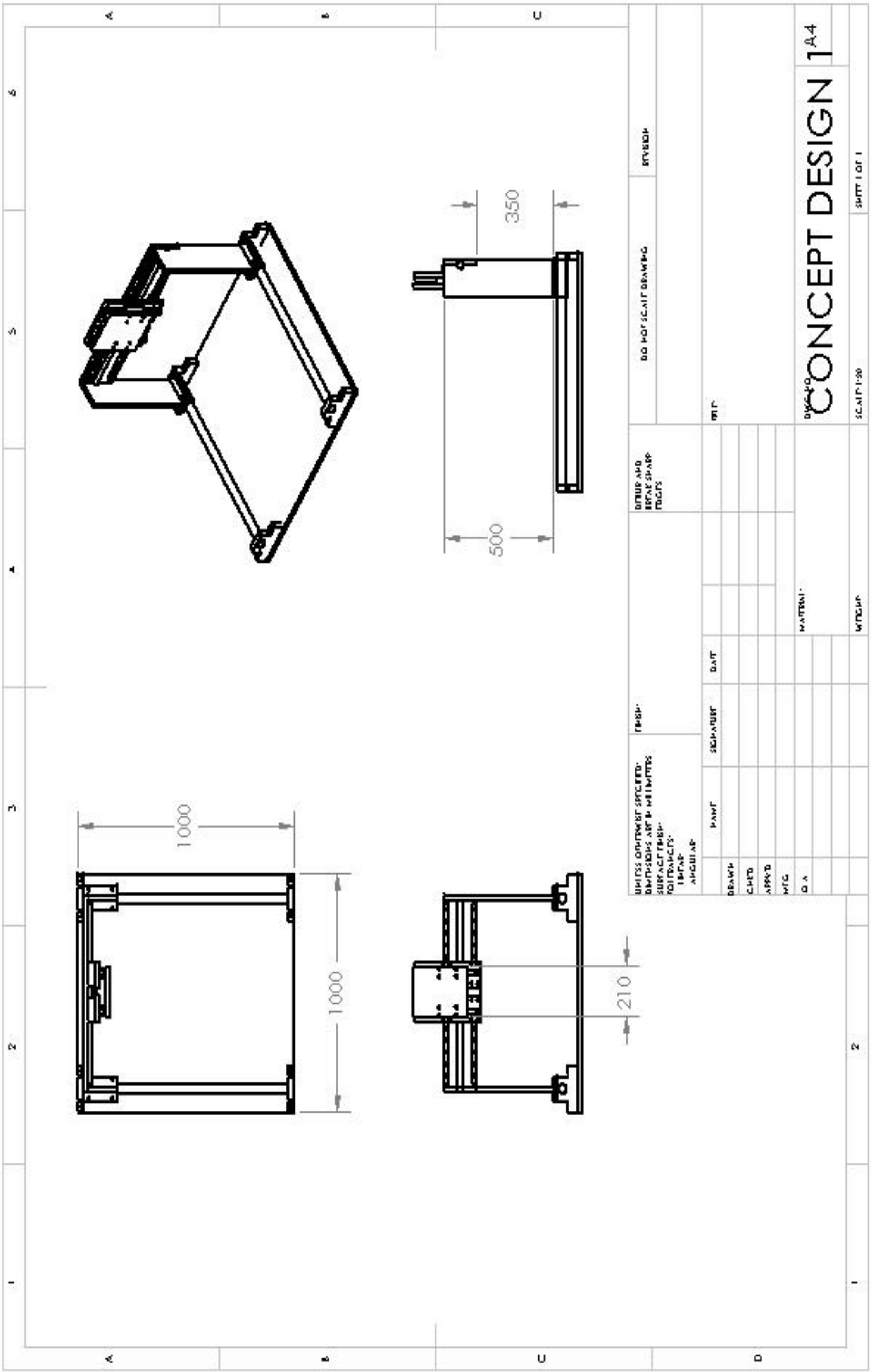
APPENDIX A

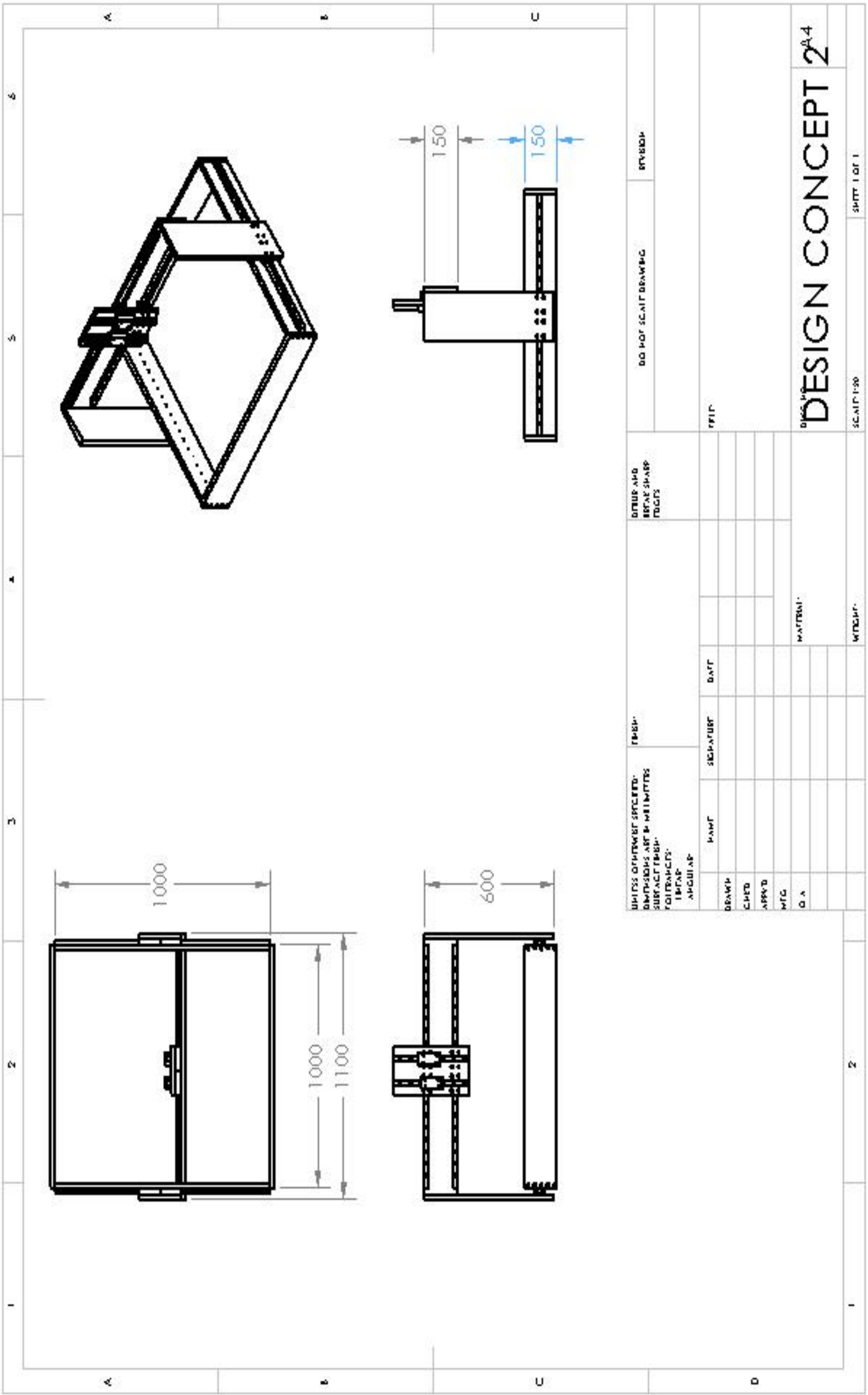
DRAWING

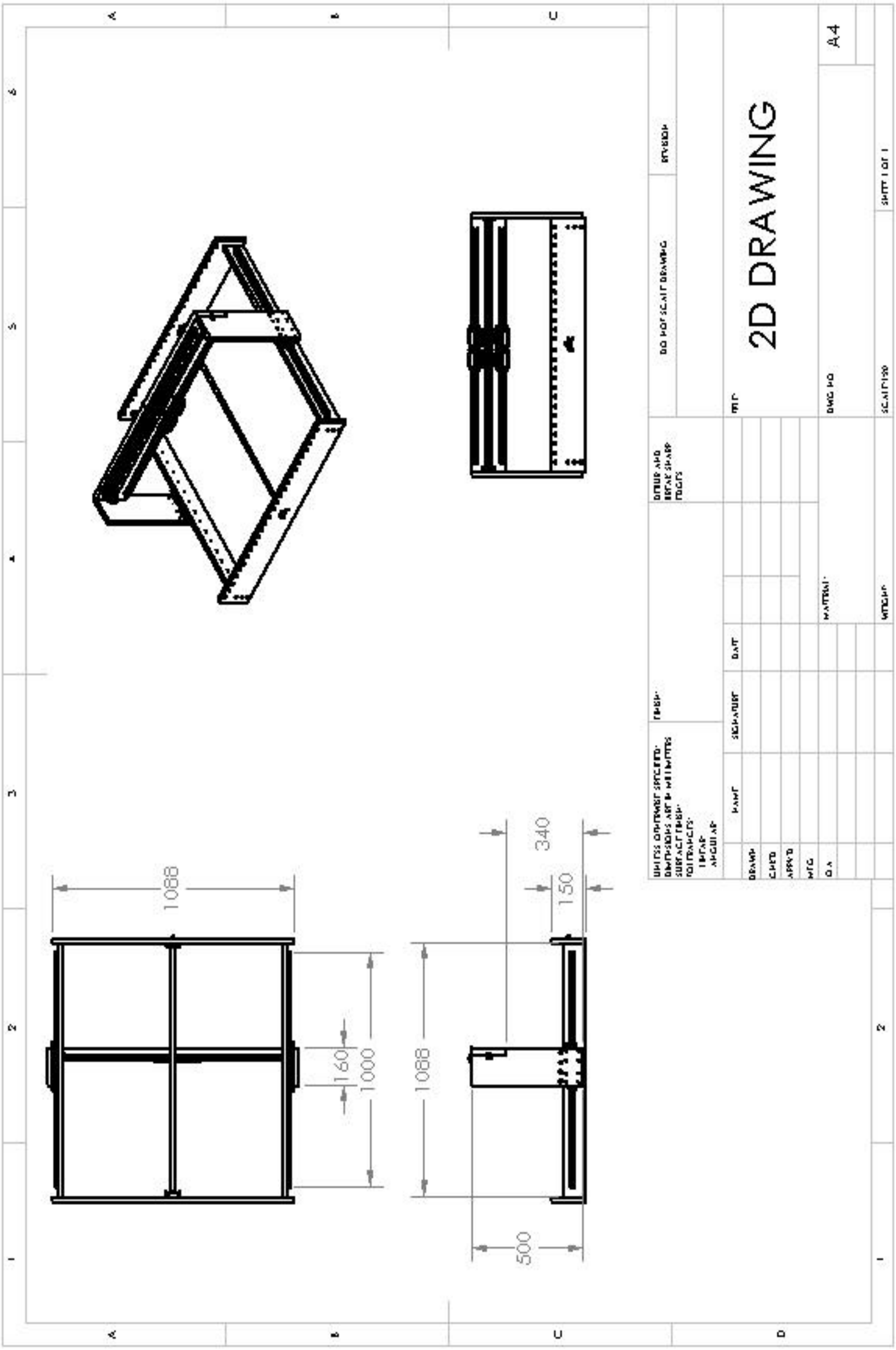
D1A shows 2D drawing for concept design 1

D2A shows 2D drawing for concept design 2

D3A shows 2D drawing for final concept


CONCEPT DESIGN 1
A4
1000
1000
500
350
210


DESIGN CONCEPT 2
A4
1000
1000
1100
600
150
150


2D DRAWING
A4
1088
1088
1000
160
340
150
500

APPENDIX B

G-CODES PROGRAMMING

1. G-Codes for Front Base Part Left and Right
2. G-Codes for Side Base Part Left and Right
3. G-Codes for Side Support Left and Right
4. G-Codes for Hanging Plates
5. G-Codes for Ball Screw Holder
6. G-Codes for Side Supporting Plate
7. G-Codes for Z- axis Bar
8. G-Codes for Z-axis Bracket

```
O0000(FRONT BASE)
 (MATERIAL - ALUMINUM MM - 2024)
( T1 |  5.0 CENTER DRILL | H1 )
( T2 |  3. DRILL | H2 )
N100 G21
N102 G0 G17 G40 G49 G80 G90
N104 T1 M6
N106 G0 G90 G54 X-300. Y10. A0. S1000 M3
N108 G43 H1 Z5.
N110 G99 G81 Z-8. R5. F100.
N112 X-240.
N114 X-180.
N116 X-120.
N118 X-60.
N120 X0.
N122 X60.
N124 X120.
N126 X180.
N128 X240.
N130 X300.
N132 G80
N134 M5
N136 G91 G28 Z0.
N138 A0.
N140 M01
N142 T2 M6
N144 G0 G90 G54 X-300. Y10. A0. S1000 M3
N146 G43 H2 Z5.
N148 G99 G83 Z-30. R5. Q1. F100.
N150 X-240.
N152 X-180.
N154 X-120.
N156 X-60.
N158 X0.
N160 X60.
N162 X120.
N164 X180.
N166 X240.
N168 X300.
N170 G80
N172 M5
N174 G91 G28 Z0.
N176 G28 X0. Y0. A0.
N178 M30
```

```
O0000(SIDE BASE)
(MATERIAL - ALUMINUM MM - 2024)
( T1 | 5.0 CENTER DRILL | H1 )
( T2 | 3. DRILL | H2 )
( T3 | 12. FLAT ENDMILL | H3 )
N100 G21
N102 G0 G17 G40 G49 G80 G90
N104 T1 M6
N106 G0 G90 G54 X-45.7 Y15.5 A0. S1000 M3
N108 G43 H1 Z5.
N110 G99 G81 Z-8. R5. F100.
N112 Y-22.5
N114 X-25.
N116 Y2.5
N118 Y27.5
N120 X-15.7 Y15.5
N122 Y-22.5
N124 X15.7
N126 Y15.5
N128 X25. Y27.5
N130 Y2.5
N132 Y-22.5
N134 X45.7
N136 Y15.5
N138 G80
N140 M5
N142 G91 G28 Z0.
N144 A0.
N146 M01
N148 T2 M6
N150 G0 G90 G54 X-45.7 Y15.5 A0. S1000 M3
N152 G43 H2 Z5.
N154 G99 G83 Z-12. R5. Q1. F100.
N156 Y-22.5
N164 X-15.7 Y15.5
N166 Y-22.5
N168 X15.7
N170 Y15.5
N172 X25. Y27.5
N174 Y2.5
N176 Y-22.5
N178 X45.7
N180 Y15.5
N182 G80
N184 M5
N186 G91 G28 Z0.
N188 A0.
N190 M01
N192 T3 M6
N194 G0 G90 G54 X-45.7 Y15.5 A0. S1200 M3
N196 G43 H3 Z5.
N198 G99 G83 Z-5. R5. Q1. F90.
N200 Y-22.5
N202 X-15.7
N204 Y15.5
N212 Y15.5
N214 G80
N216 M5
N218 G91 G28 Z0.
N220 G28 X0. Y0. A0.
N222 M30
```

O0000(SIDES SUPPORT)

(MATERIAL - ALUMINUM MM - 2024)

(T1 | 12. FLAT ENDMILL | H1)

N100 G21

N102 G0 G17 G40 G49 G80 G90

N104 T1 M6

N106 G0 G90 G54 X-235. Y0. A0. S1200 M3

N108 G43 H1 Z5.

N110 G99 G83 Z-15. R5. Q1. F90.

N112 X-210.

N114 X-185.

N116 X-170. Y2.5

N118 G80

N120 M5

N122 G91 G28 Z0.

N124 G28 X0. Y0. A0.

N126 M30

O0000(HANGING PLATES)

(MATERIAL - ALUMINUM MM - 2024)

(T1 | 5.0 CENTER DRILL | H1)

(T2 | 3. DRILL | H2)

N100 G21

N102 G0 G17 G40 G49 G80 G90

N104 T1 M6

N106 G0 G90 G54 X-268.6 Y10. A0. S1000 M3

N108 G43 H1 Z10.

N110 G99 G81 Z-5. R10. F100.

N112 X-208.6

N114 X-148.6

N116 X-88.6

N118 X-28.6

N120 X31.4

N122 X91.4

N124 X151.4

N126 X211.4

N128 X271.4

N130 G80

N132 M5

N134 G91 G28 Z0.

N136 A0.

N138 M01

N140 T2 M6

N142 G0 G90 G54 X-268.6 Y10. A0. S1000 M3

N144 G43 H2 Z10.

N146 G99 G83 Z-33. R10. Q1. F90.

N148 X-208.6

N150 X-148.6

N152 X-88.6

N158 X91.4

N160 X151.4

N162 X211.4

N164 X271.4

N166 G80

N168 M5

N170 G91 G28 Z0.

N172 G28 X0. Y0. A0.

N174 M30

```
O0000(BALL SCREW HOLDER)
 (MATERIAL - ALUMINUM MM - 2024)
( T1 |  5.0 CENTER DRILL | H1 )
( T2 |  4.2 DRILL | H2 )
( T3 |  12. FLAT ENDMILL | H3 )
N100 G21
N102 G0 G17 G40 G49 G80 G90
N104 T1 M6
N106 G0 G90 G54 X-150. Y0. A0. S1000 M3
N108 G43 H1 Z10.
N110 G99 G81 Z-8. R10. F100.
N112 X-100. Y-15.
N118 X-62. Y14.769
N120 X-62.001 Y-14.689
N122 X-30. Y0.
N124 X9.999 Y-15.
N126 X10. Y15.
N128 X30. Y0.
N130 X48. Y-15.
N132 Y15.
N134 X90. Y0.
N136 X150.
N138 G80
N140 M5
N142 G91 G28 Z0.
N144 A0.
N146 M01
N148 T2 M6
N150 G0 G90 G54 X-150. Y0. A0. S1000 M3
N152 G43 H2 Z5.
N154 G99 G83 Z-33. R5. Q1. F100.
N156 X-100. Y-15.
N158 X-90. Y0.
N160 X-100. Y15.
N162 X-62. Y14.769
N164 X-62.001 Y-14.689
N166 X-30. Y0.
N168 X9.999 Y-15.
N170 X10. Y15.
N172 X30. Y0.
N174 X48. Y-15.
N176 Y15.
N178 X90. Y0.
N180 X150.
N182 G80
N184 M5
N186 G91 G28 Z0.
N188 A0.
N190 M01
N192 T3 M6
N194 G0 G90 G54 X-100. Y15. A0. S1200 M3
N196 G43 H3 Z10.
N198 G99 G83 Z-15. R10. Q1. F90.
N200 Y-15.
N202 X-62.001 Y-14.689
N204 X-62. Y14.769
N206 X10. Y15.
N208 X9.999 Y-15.
N210 X48.
N212 Y15.
N214 G80
N216 M5
N218 G91 G28 Z0.
N220 G28 X0. Y0. A0.
N222 M30
```

```
O0000(SIDE SUPPORT PLATE)
(MATERIAL - ALUMINUM MM - 2024)
( T1 |  5.0 CENTER DRILL | H1 )
( T2 |  4.2 DRILL | H2 )
( T3 |  12. FLAT ENDMILL | H3 )
N100 G21
N102 G0 G17 G40 G49 G80 G90
N104 T1 M6
N106 G0 G90 G54 X-15. Y15. A0. S1000 M3
N108 G43 H1 Z5.
N110 G99 G81 Z-5. R5. F100.
N112 X15.
N114 Y-15.
N116 X-15.
N118 G80
N120 M5
N122 G91 G28 Z0.
N124 A0.
N126 M01
N128 T2 M6
N130 G0 G90 G54 X-15. Y15. A0. S1000 M3
N132 G43 H2 Z5.
N134 G99 G83 Z-13. R5. Q1. F100.
N136 X15.
N138 Y-15.
N140 X-15.
N142 G80
N144 M5
N146 G91 G28 Z0.
N148 A0.
N150 M01
N152 T3 M6
N154 G0 G90 G54 X-15. Y15. A0. S1200 M3
N156 G43 H3 Z5.
N158 G99 G83 Z-5. R5. Q1. F90.
N160 X15.
N162 Y-15.
N164 X-15.
N166 G80
N168 M5
N170 G91 G28 Z0.
N172 G28 X0. Y0. A0.
N174 M30
```

```
O0000(PART20)
(MATERIAL - ALUMINUM MM - 2024)
( T2 |  5. DRILL | H2 )
N100 G21
N102 G0 G17 G40 G49 G80 G90
N104 T2 M6
N106 G0 G90 G54 X-70. Y15. A0. S1200 M3
N108 G43 H2 Z10.
N110 G99 G83 Z-35. R10. Q1.5 F100.
N112 X-40.
N114 X-15.
N116 X15.
N118 X40.
N120 X70.
N122 Y-15.
N132 X-70.
N134 G80
N136 M5
N138 G91 G28 Z0.
N140 G28 X0. Y0. A0.
N142 M30
```

O0000(Z-AXIS BAR)

(MATERIAL - ALUMINUM MM - 2024)

(T1 | 5.0 CENTER DRILL | H1)

(T2 | 3. DRILL | H2)

N100 G21

N102 G0 G17 G40 G49 G80 G90

N104 T1 M6

N106 G0 G90 G54 X-268.6 Y10. A0. S1000 M3

N108 G43 H1 Z10.

N110 G99 G81 Z-5. R10. F100.

N112 X-208.6

N114 X-148.6

N116 X-88.6

N118 X-28.6

N120 X31.4

N122 X91.4

N124 X151.4

N126 X211.4

N128 X271.4

N130 G80

N132 M5

N134 G91 G28 Z0.

N136 A0.

N138 M01

N140 T2 M6

N142 G0 G90 G54 X-268.6 Y10. A0. S1000 M3

N144 G43 H2 Z10.

N146 G99 G83 Z-33. R10. Q1. F90.

N148 X-208.6

N150 X-148.6

N152 X-88.6

N154 X-28.6

N156 X31.4

N158 X91.4

N160 X151.4

N162 X211.4

N164 X271.4

N166 G80

N168 M5

N170 G91 G28 Z0.

N172 G28 X0. Y0. A0.

N174 M30

```
O0000(Z-AXIS BRACKET)
 (MATERIAL - ALUMINUM MM - 2024)
( T1 |  5.0 CENTER DRILL | H1 )
( T2 |  4.2 DRILL | H2 )
( T3 |    12. FLAT ENDMILL | H3 )
N100 G21
N102 G0 G17 G40 G49 G80 G90
N104 T1 M6
N106 G0 G90 G54 X-15. Y15. A0. S1000 M3
N108 G43 H1 Z5.
N110 G99 G81 Z-5. R5. F100.
N112 X15.
N114 Y-15.
N116 X-15.
N118 G80
N120 M5
N122 G91 G28 Z0.
N124 A0.
N126 M01
N128 T2 M6
N130 G0 G90 G54 X-15. Y15. A0. S1000 M3
N132 G43 H2 Z5.
N134 G99 G83 Z-13. R5. Q1. F100..
N140 X-15.
N142 G80
N144 M5
N146 G91 G28 Z0.
N148 A0.
N150 M01
N152 T3 M6
N154 G0 G90 G54 X-15. Y15. A0. S1200 M3
N156 G43 H3 Z5.
N158 G99 G83 Z-5. R5. Q1. F90.
N164 X-15.
N166 G80
N168 M5
N170 G91 G28 Z0.
N172 G28 X0. Y0. A0.
N174 M30
```