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COLLEGE OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING
BSC AEROSPACE ENGINEERING

AUTOMATIC CONTROL (ME 363) PROJECT REPORT
GROUP 6

DESIGN AND SIMULATION OF AN AUTOMATED MACHINE FOR CUTTING PATTERNS OF IMPROVED COOK STOVE FOR FABRICATORS

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DECLARATION

We hereby declare that with the exception of the sources stipulated in the references, the contents of this report were based on our individual efforts through research.

ACKNOWLEDGEMENT

Our thanks to the Almighty God for seeing us through this project.

We would also like to appreciate our project advisor Dr. Eunice Adjei for her immense support and for presenting us with the opportunity to gain firsthand knowledge on the practical aspects of automatic control.

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ABSTRACT

Automatic control is a research area, theoretical based for mechanization, automation, employing knowledge from mathematics and engineering. Automatic control plays an essential role in a wide range of control systems from simple household washing machines to high performance fighter aircrafts. This deals with the arrangement of physical components connected in a manner to work as a unit with the aim of producing a desired output.

This thesis is centered on the design and simulation of an automated machine for cutting patterns of an improved cook stove for fabricators.

This report contains all the project tasks set for us from task 1 to task 6. It comprises a description of the automated cutting machine and the problem it seeks to remedy.

The laser cutting machine we decided on is made up of a motor, an Arduino board, a blade, and a belt. The machine also uses code which is programmed on the Arduino board which helps to set the length and shape of the cut.

A block diagram representation of the system is also included in this report.

This thesis appreciates how automatic control reduces human effort required to perform a desired operation both qualitatively and quantitatively and how it has reduced malfunctions caused by human error.

CHAPTER ONE

I. INTRODUCTION

1.1 Background to The Work

Over the years, there have been many attempts to reduce human effort in work and increase efficiency, speed and accuracy through automation.

Due to the increased need for energy conservation, there has been a spike in the demand for improved cook stoves. However, the manual and mechanical means in cutting the patterns of the cook stove slows down production thus the need for an automated cutting machine.

This project consists of 5 tasks:

Task 1. Identify Automatic Control components at the assigned application area.

Task 2. Identify the representative problems associated with the selected automatic control components at Task 1.

Task 3. Use block diagram to represent the system at Task 1 and Task 2; obtain the resulting transfer function to analyse the stability of the system and interpret the implication of stability on the physical system.

Task 4. Use mathematical model to represent the system at Task 1 and 2.

Task 5. Write computer program to solve the problem identified at Task 2.

1.2 Problem Statement

To design and simulate an automated machine for cutting patterns of improved cook stove for fabricators.

1.3 Objectives

To design a machine for cutting patterns of improved cook stove.

To characterize the system using block diagram system representation and calculate the transfer function.

To mathematically model the system.

To develop a computer program for cutting the patterns

To simulate the system

CHAPTER TWO

II. LITERATURE REVIEW

2.1 Theory

2.1.1 Cutting Machines, what are they?

Cutting machines are devices used for cutting out parts of materials.

2.1.2 Types of Cutting Machines

There are several types of cutting machines, but only a few would be looked at in this report

Die cutting machine

The cutting machine is named as Die cutting machine which involves in pressing a rigid blade through the lay of fabric. When using small motifs with particular pattern shape are need for cutting, then this machine is very helpful. The main advantage of this machine is to cut sharp and small parts of fabrics.

Drill cutting machine

The Drill cutting machine is used to mark on end of components fabrics especially for the pockets position. We can use this machine for marking on the middle of the different components of dresses. Permanent hole can be made with the help of this machine

Drill Cutters cut holes in fabric in given specific spots. These holes can later be used for rivets, attaching different fabrics to one another with anchor spots, or helping to build structure with darts or pleats. Normally power operated, drill cutters are compared by their punching power and like a drill press punch through the fabric or other medium's layers to create holes.

Laser Cutting Machines are capable of cutting intricate designs in many different mediums. A normal tool used in jewellery making, the laser cutting machine is great choice in stronger or tougher mediums including plastic, metal, and paper. With a most exact computer guiding it, very complicated designs can easily be done and due to the accuracy, you lose less of the product between cuts.

Water Jet Cutting Machines take cutting to the next level and increase your choices of medium greatly. With the water jet cooling down the friction created during the cutting process, there are many different options including specialty tile work, metal, wood, and glass. Like a normal saw, water is pumped onto the cutting wheel to reduce the heat that is created. This allows for the water jet cutting machine to work more efficiently and with less friction, there is less need for replacing the cutting blades.

Plasma Torch Cutting Machines

They are great solutions when cutting conductive materials like metal. These are expensive tools but create amazing punched out pieces easily and quickly. Like the laser cutter, there are many intricate designs that can be constructed and easily cut out with the plasma torch cutting machine's automated computer system.

2.1.3 **The Need to Automate Cutting Machines**

Advantages commonly attributed to automation include higher production rates and increased productivity, more efficient use of materials, better product quality, improved safety, shorter workweeks for labour, and reduced factory lead times. Higher output and increased productivity have been two of the biggest reasons in justifying the use of automation. Despite the claims of high quality from good workmanship by humans, automated systems typically perform the manufacturing process with less variability than human workers, resulting in greater control and consistency of product quality and a more efficient use of materials.

Worker safety is an important reason for automating an industrial operation. Automated systems often remove workers from the workplace, thus safeguarding them against the hazards of the factory environment. Another benefit of automation is the reduction in the number of hours worked on average per week by factory workers. In addition, the time required to process a typical production order through the factory is generally reduced with automation. Though there are disadvantages of automation of cutting machines such as worker displacement, the high capital required to invest in automation, the merits of automation of machines in general out numbers and outweighs the demerits

2.1.4 Why do we need cutting machines in this project?

A (pattern) cutting machine is needed for the cutting of the various parts or patterns of the improved cook stoves for the fabricators. This is to help reduce if notcompletely eliminate the human effort by these local fabricators in cutting the parts manually, and to make production process faster and more efficient

2.1.5 **Parts or Patterns of an Improved cook Stove**

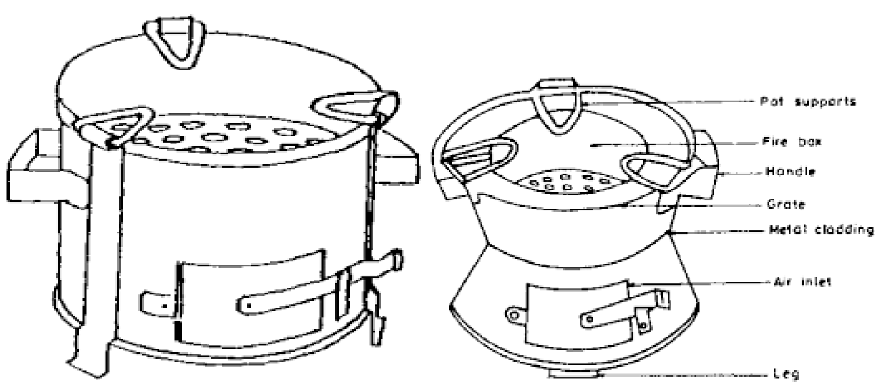

Figure 1

2.1.6 The Traditional Cook Stove verses the Improved Cook Stoves

Figure 2

Figure 3

CHAPTER THREE

III. SET UP / METHODOLOGY

3.1 Concepts

We came up with three different concepts or methods to chose from.

3.1.1 Concept one

HYDRAULIC SLAM PATTERN CUTTING MACHINE

The basic working principle of this machine was integrated from the bakery and pottery industry of old London.
Patterns would be designed and vertically projected into cutting edges. These edges would be shaped into the desired pattern to be cut out and mounted onto a flat surface.
Various configurations have been made to suit and satisfy the desired patterns required for work.
Depending on materials to be worked on, the cutting edges are machined from metals suitable to withstand the hardness of the workpiece.
The particular configuration presented here is specialized to cut out metal sheets and hard wood.
The cutting blades are made of stainless steel and hardened carbon-steel metals, this is to withstand
the hardness of the wide range of metal workpiece to be worked on.
The cutting blades are removable to accommodate for different cutting patterns.
This machine is suitable for cutting patterns out of aluminium, copper and hard wood.

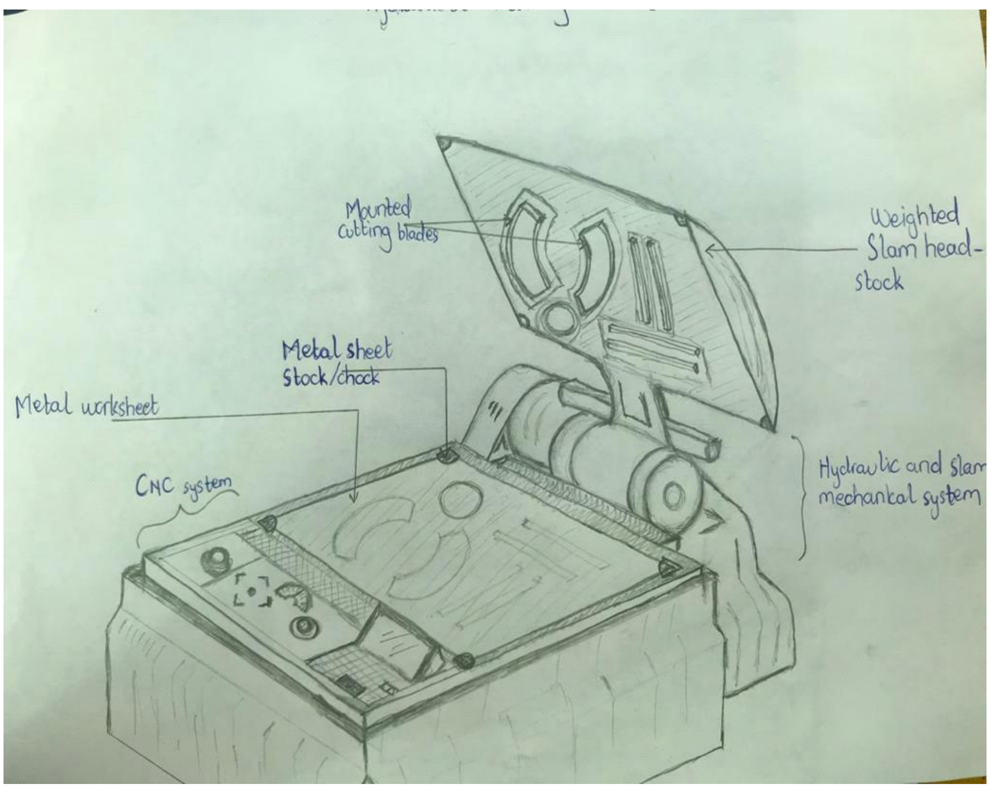

Figure 4

3.1.2 Concept two

PLASMA TORCH CUTTING MACHINE

Plasma Torch cutting is a process that cuts through electrically conductive materials by means of an accelerated jet of hot plasma. Typical materials cut with a plasma torch include steel, stainless steel, aluminum, brass and copper, although other conductive metals may be cut as well. Plasma cutting is often used in fabrication shops, automotive repair and restoration, industrial construction. Due to its high-speed precision cuts, plasma cutting is widely used especially for large-scale industrial CNC applications.

The basic plasma cutting process involves creating an electrical channel of superheated, electrically ionized gas i.e. plasma from the plasma cutter itself, through the work piece to be cut, thus forming a completed electric circuit back to the plasma cutter through a grounding clamp. This is accomplished by a compressed gas (oxygen, air, inert and others depending on material being cut) which is blown through a focused nozzle at high speed toward the work piece.
An electrical arc is then formed within the gas, between an electrode near or integrated into the gas nozzle and the work piece itself. The electrical arc ionizes some of the gas, thereby creating an electrically conductive channel of plasma. As electricity from the cutter torch travels down this plasma it delivers sufficient heat to melt through the work piece. At the same time, much of the high velocity plasma and compressed gas blow the hot molten metal away, thereby cutting through, the work piece.

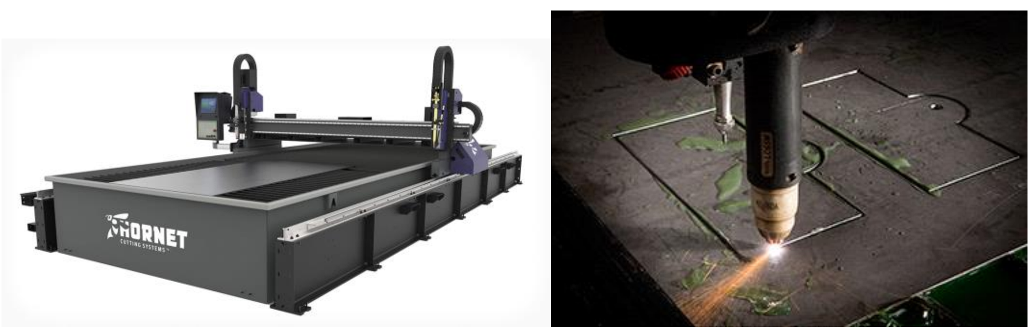

Figure 5

3.1.3 Concept Three

LASER CUTTING MACHINE

Laser cutting is a technology that uses a laser to cut through materials. While typically used for industrial manufacturing applications, it is gradually gaining grounds in usage by schools, small businesses, etc. Laser cutting works by directing the output of a high-power laser most commonly through optics. The laser optics and CNC (computer numerical control) are used to direct the material or the laser beam generated. A commercial laser for cutting materials uses a motion control system to follow a CNC or G-code of the pattern to be cut onto the material. The focused laser beam is directed at the material, which then either melts, burns, vaporizes away, or is blown away by a jet of gas, leaving an edge with a high-quality surface finish. Generation of the laser beam involves stimulating a lasing material by electrical discharges or lamps within a closed container. As the lasing material is stimulated, the beam is reflected internally by means of a partial mirror, until it achieves sufficient energy to escape as a stream of monochromatic coherent light. Mirrors or fiber optics are typically used to direct the coherent light to a lens, which focuses the light at the work zone. In order to be able to start cutting from somewhere other than the edge, a pierce is done before every cut which slowly makes a hole in the material.

Advantages of laser cutting over mechanical cutting include easier work-holding and reduced contamination of work-piece (since there is no cutting edge which can become contaminated by the material or contaminate the material). There is also a reduced chance of warping the material that is being cut, as laser systems have a small heat-affected zone.

Laser cutting for metals has the advantages over plasma cutting of being more precise[9] and using less energy when cutting sheet metal; however, most industrial lasers cannot cut through the greater metal thickness that plasma can. Newer laser machines however are approaching plasma machines in their ability to cut through thick materials.

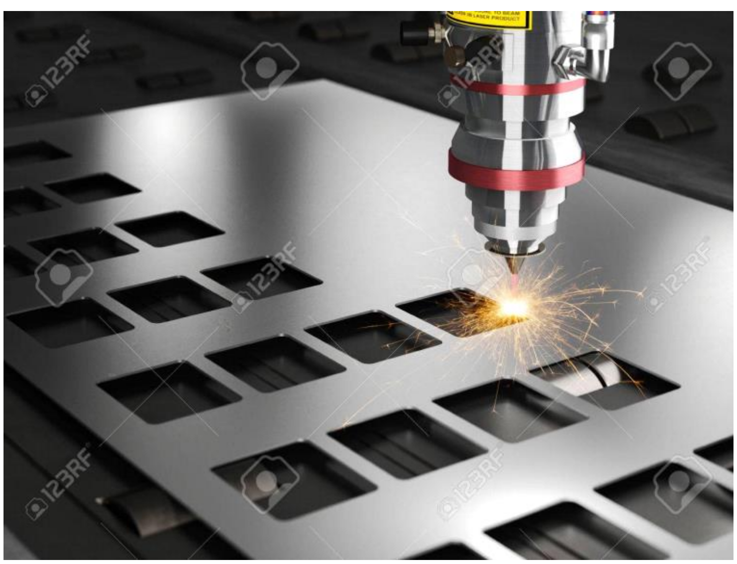

Figure 6

3.2 **CONCEPT EVALUATION MATRIX**

CRITERIA	WEIGHT (100%)	CONCEPT ONE		CONCEPT TWO		CONCEPT THREE	
		Rating	Rating X Weight	Rating	Rating X Weight	Rating	Rating X Weight
COST	20	1	20	3	60	2	40
MATERIALS	12	1	12	3	36	2	24
POWER CONSUMPTION	15	1	15	3	45	2	15
EASE OF MANU-FACTUREBILITY	14	2	28	3	42	1	14
MOBILITY	9	3	27	2	18	1	9
SAFETY	30	3	90	2	60	1	30
TOTAL			197		261		132

RANGE (FROM 1 – 3) **CHOSEN DESIGN: CONCEPT THREE (3)**

1 EXCELLENT

2 VERY GOOD

3 GOOD

3.4 LASER CUTTING MACHINES

3.4.1 What are Laser Cutting Machines?

Laser cutting is a technology that uses a laser to slice materials. Laser cutting is mainly a thermal process in which a focused laser beam is used to melt material in a localized area. Laser cutting machines are a tool used in a wide range of industries for precision cutting and designing projects.

The laser cutting machine emits a high-powered laser beam to either cleanly cut or etch a specific design on materials such as steel, plastic or wood. It is generally used more for industrial manufacturing applications and the beam will either burn, vaporize or melt away the excess product, leaving a superior finished design or edge.

3.4. 2 The Science or Working Principle of Laser Cutting Machines (How They Work)

There are three major varieties of laser cutting: fusion cutting, flame cutting and remote cutting. **In fusion cutting**, an inert gas (typically nitrogen) is used to expel molten material out of the kerf. Nitrogen gas does not exothermically react with the molten material and thus does not contribute to the energy input**. In flame cutting**, oxygen is used as the assist gas. In addition to exerting mechanical force on the molten material, this creates an exothermic reaction which increases the energy input to the process. **In remote cutting**, the material is partially evaporated (ablated) by a high-intensity laser beam, allowing thin sheets to be cut with no assist gas.

The laser cutting process lends itself to automation with offline CAD/CAM systems controlling either three-axis flatbed systems or six-axis robots for three-dimensional laser cutting. Generation of the laser beam involves stimulating a lasing material by electrical discharges or lamps within a closed container. As the lasing material is stimulated, the beam is reflected internally by means of a partial mirror, until it achieves sufficient energy to escape as a stream of monochromatic coherent light. Mirrors or fiber optics are typically used to direct the coherent light to a lens, which focuses the light at the work zone. The narrowest part of the focused beam is generally less than 0.0125 inches (0.32 mm) in diameter. Depending upon material thickness, kerf widths as small as 0.004 inches (0.10 mm) are possible in order to be able to start cutting from somewhere other than the edge, a pierce is done before every cut. Piercing usually involves a high-power pulsed laser beam which slowly makes a hole in the material, taking around 5–15 seconds for 0.5-inch-thick (13 mm) stainless steel, for example.

The parallel rays of coherent light from the laser source often fall in the range between 0.06–0.08 inches (1.5–2.0 mm) in diameter. This beam is normally focused and intensified by a lens or a mirror to a very small spot of about 0.001 inches (0.025 mm) to create a very intense laser beam. In order to achieve the smoothest possible finish during contour cutting, the direction of beam polarization must be rotated as it goes around the periphery of a contoured workpiece. For sheet metal cutting, the focal length is usually 1.5–3 inches (38–76 mm)

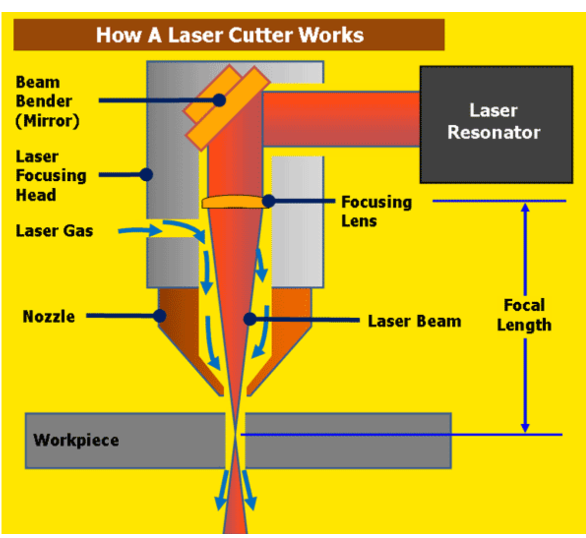

Figure 7

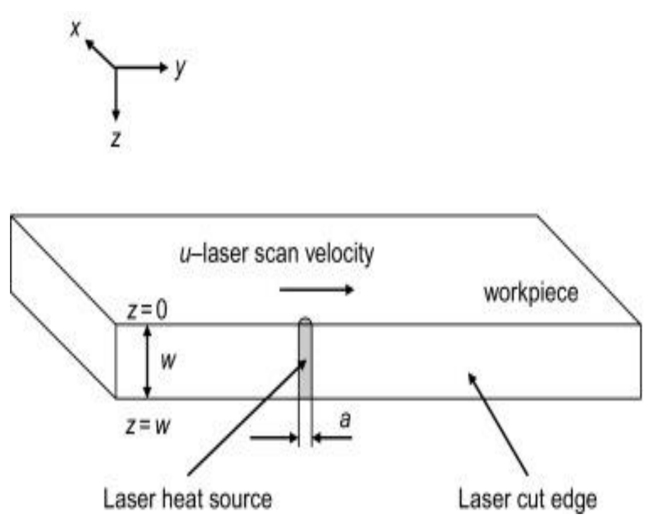

Figure 8

3.4.3 **Advantages of LASER Cutting over others**

Advantages of laser cutting over mechanical cutting include easier work holding and reduced contamination of workpiece (since there is no cutting edge which can become contaminated by the material or contaminate the material). Precision may be better, since the laser beam does not wear during the process. There is also a reduced chance of warping the material that is being cut, as laser systems have a small heat-affected zone. Some materials are also very difficult or impossible to cut by more traditional means.

Laser cutting for metals has the advantages over plasma cutting of being more precise and using less energy when cutting sheet metal; however, most industrial lasers cannot cut through the greater metal thickness that plasma can. Newer laser machines operating at higher power (6000 watts, as contrasted with early laser cutting machines' 1500-watt ratings) are approaching plasma machines in their ability to cut through thick materials, but the capital cost of such machines is much higher than that of plasma cutting machines capable of cutting thick materials like steel plate. The advantages of laser cutting are flexibility, precision, repeatability, speed, cost-effectiveness, great quality, contactless cutting, versatility and automation possibilities.

3.5 Components Of A Laser Cutting Machine

3.5.1 The Working Nozzle

The cutting head is the laser output device of the fiber laser cutting machine, which consists of a nozzle, a focus lens and a focus tracking system. The cutting head of the laser cutting machine will travel according to the set cutting track, but the height of the laser cutting head needs to be adjusted and controlled under different materials, different thicknesses, and different cutting methods.

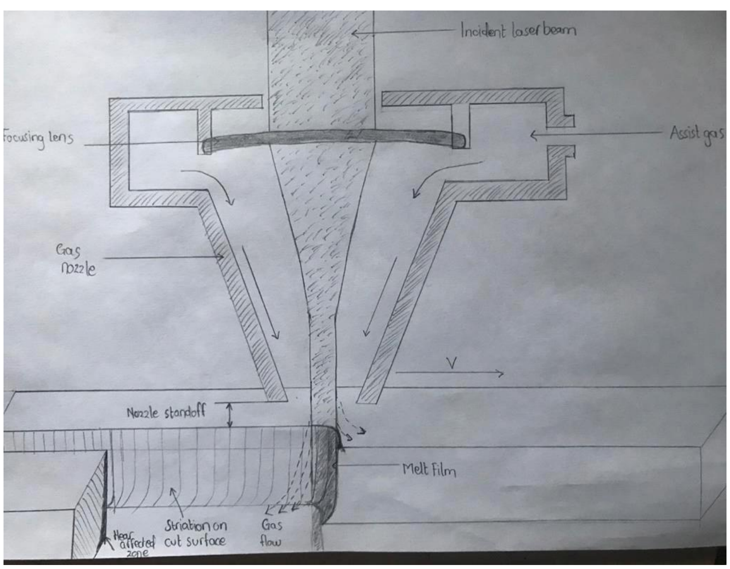

Figure 9

3.5.3 The Nozzle

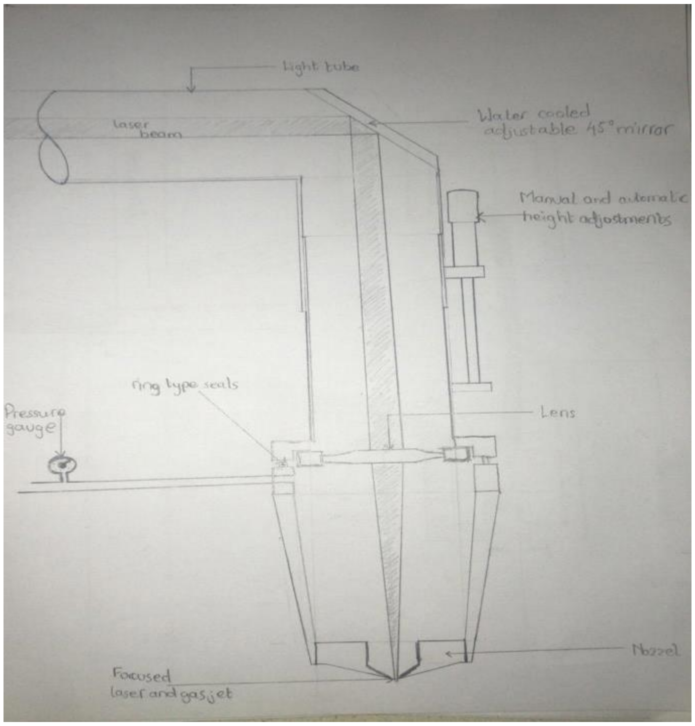

Figure 10

3.5.4 Air Cooling Dryer and Filter

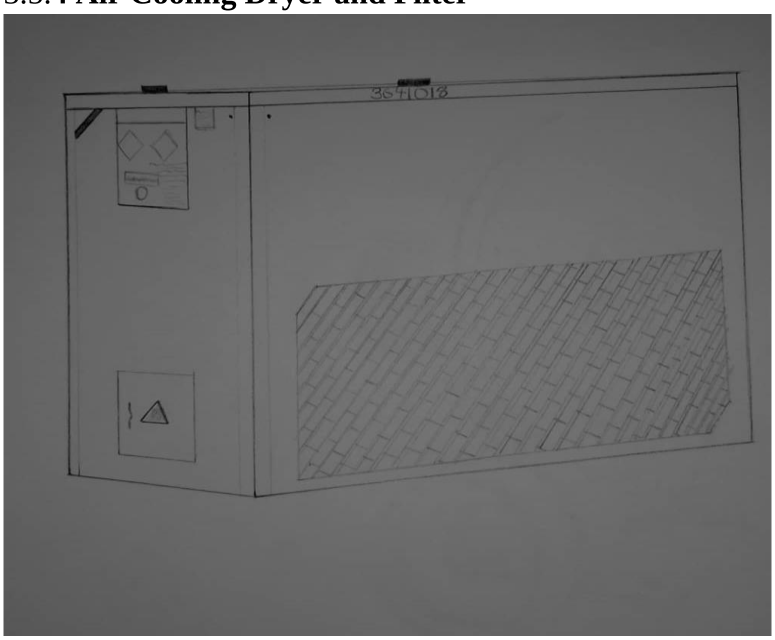

Figure 11

3.5.5 **Exhaust Dust Collector**

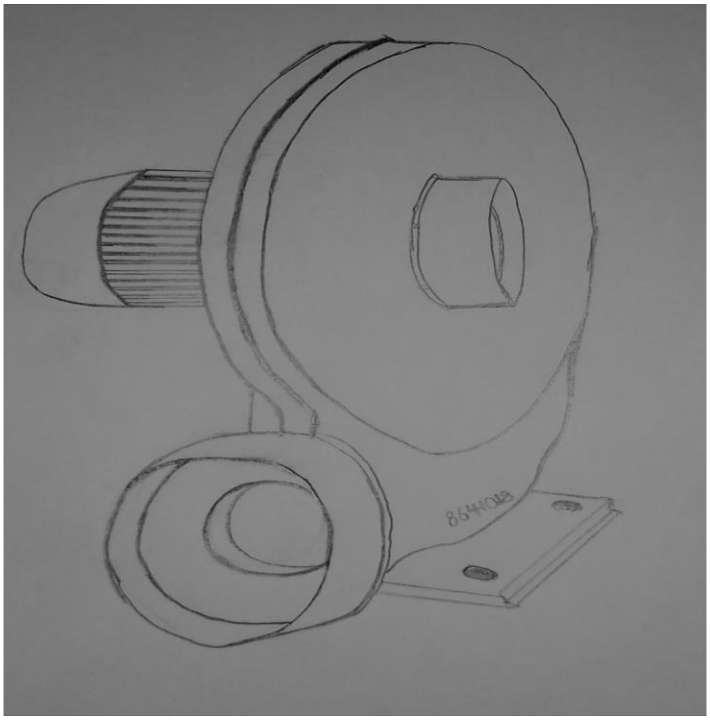

Figure 12

3.5.6 **Air Compressor Gas Storage Tank**

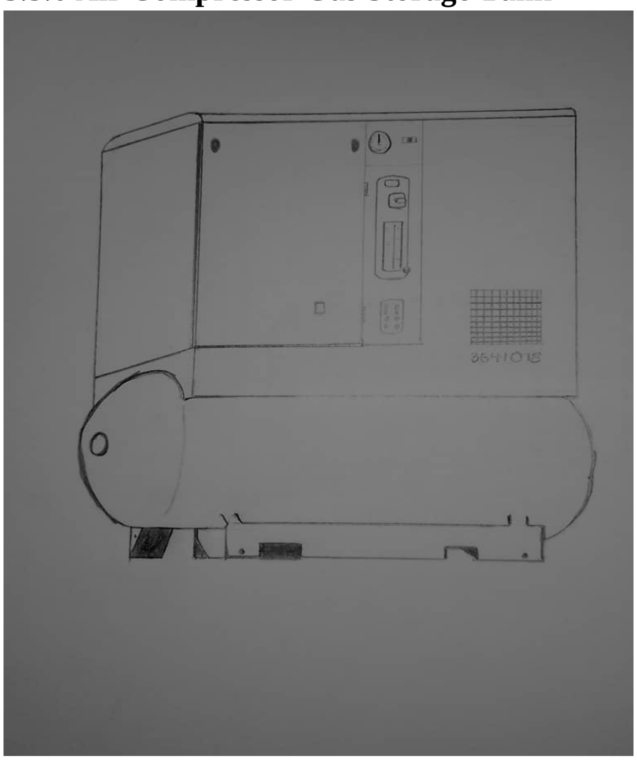

Figure 13

3.5.7 Voltage Stabilized Power Supply

Laser generator is the core "power source" of laser equipment, just like car engine

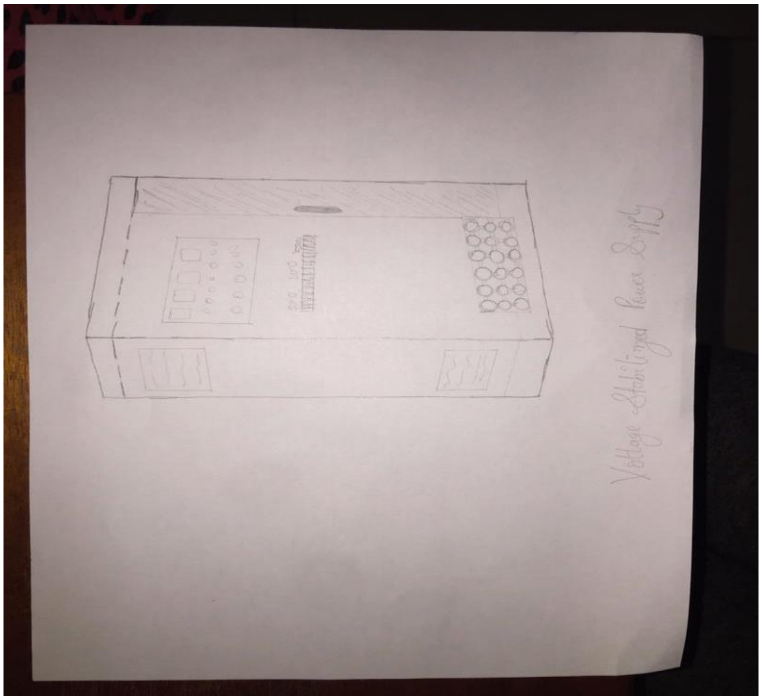

Figure 14

3.5.8 CNC System

The control system is the dominant operating system of the fiber laser cutting machine, which mainly controls the machine tool to realize the movement of the X, Y, and Z axis, and also controls the output power of the laser. Its quality determines the stability of the operation performance of the fiber laser cutting machine. Through software control, the cutting effect can be improved.

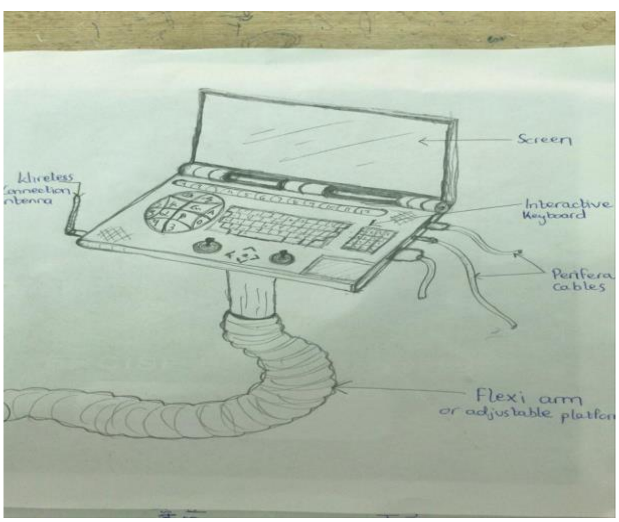

Figure 15

3.6 The Block Diagram of the Laser Cutting Machine

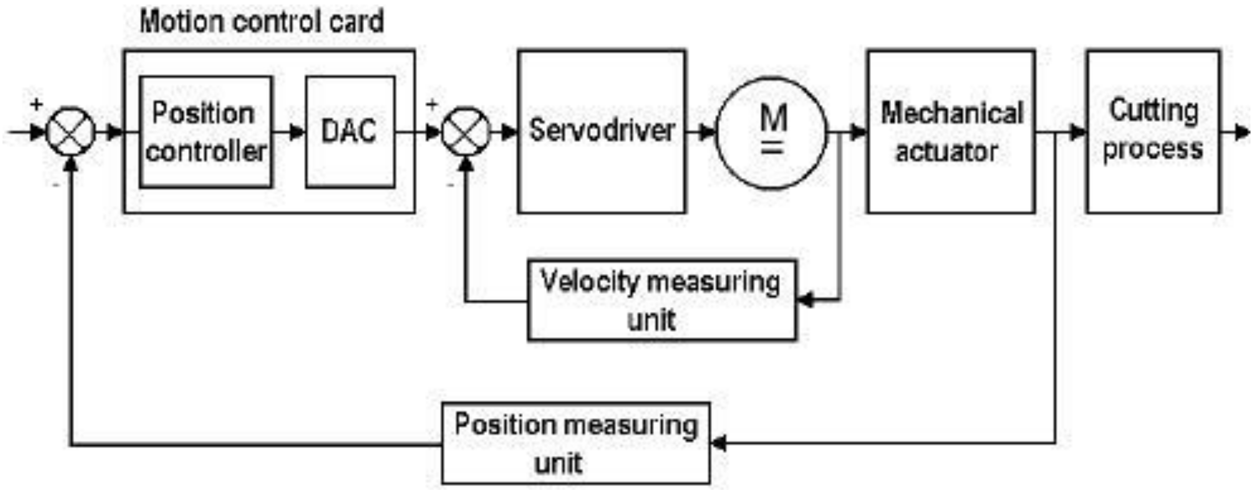

Figure 16

3.6.1 Transfer Function Calculation

A transfer function also known as system function or network function is a mathematical equation relating the output of a system to its input. The transfer function provides information which specifies the behavior of a system.

Reduction of the block diagram yields:

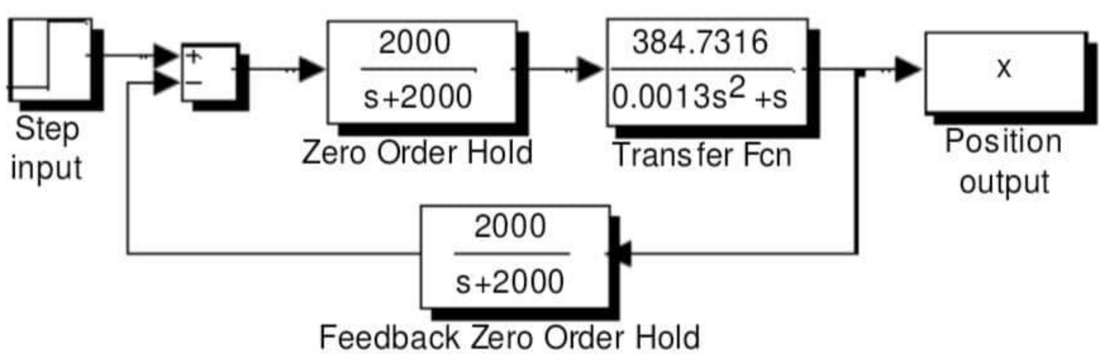

Figure 17

$$\frac{C'(S)}{D(S)} = \frac{\frac{2000}{s+2000} \times \frac{384.7316}{0.0013s^2+s}}{1+(\frac{2000}{s+2000} \times \frac{384.7316}{0.0013s^2+s} \times \frac{2000}{s+2000})}$$

$$\frac{C'(S)}{D(S)} = \frac{\frac{769463.2}{(s+2000)\times(0.0013s^2+s)}}{1+(\frac{2000}{s+2000} \times \frac{384.7316}{0.0013s^2+s} \times \frac{2000}{s+2000})}$$

$$\frac{C'(S)}{D(S)} = \frac{\frac{769463.2}{(s+2000)\times(0.0013s^2+s)}}{1+(\frac{1538926400}{(s+2000)\times(s+2000)\times(0.0013s^2+s)})}$$

$$\frac{C'(S)}{D(S)} = \frac{769463.2\times(s+2000)}{0.0013s^4+6.2s^3+9200s^2+4\times10^6s+1538926400}$$

3.6.2 Checking for the stability of the laser cutting machine

Using Routh Hurwitz criterion to test for stability
Equate the denominator to 0 to find the poles.
This finally yields:

S^4	0.0013	9200	1538926400
S^3	6.2	4000000	0
S^2	8361.3	1538926400	0
S^1	2858868.4	0	0
S^0	1538926400		

Since the sign convention along the s-column is constant, all the e roots are on the left half-plane. Therefore, the system is stable

CHAPTER FOUR

IV. SIMULATION / RESULTS

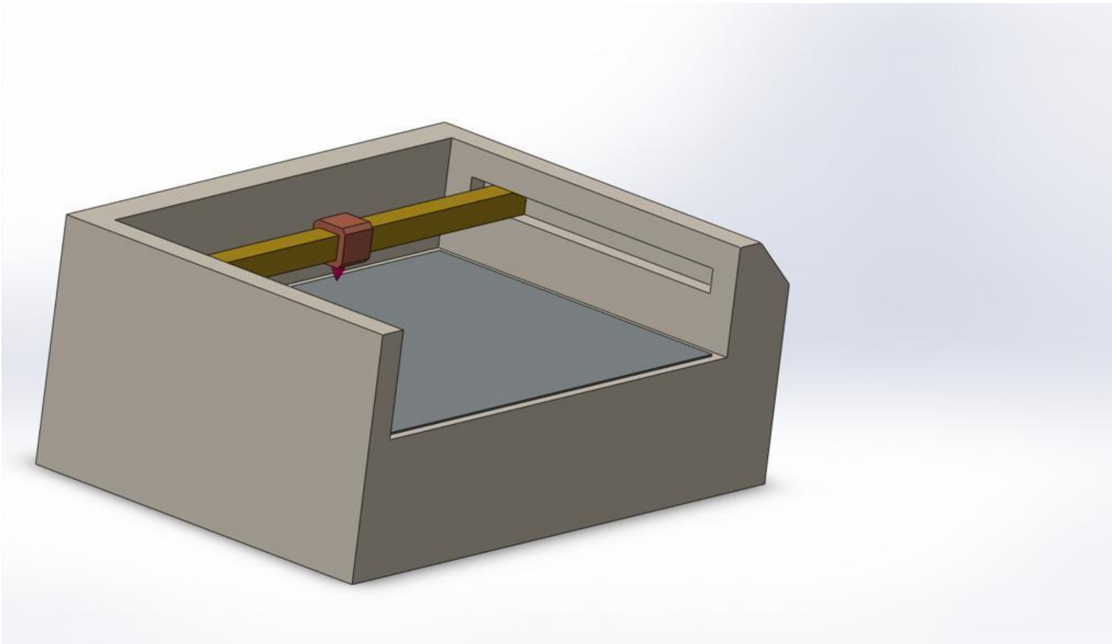

Figure 18

CHAPTER FIVE

V. CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSION

From both the Routh criterion, it can be inferred that the system is stable. The stability of a system relates to its response to inputs or disturbances. A system which remains in a constant state unless affected by an external action and which returns to a constant state when the external action is removed can be considered to be stable.

5.2 RECOMMENDATIONS

The right frequency must be selected depending on the metal to be cut.

Reference

https://en.wikipedia.org/wiki/Laser_cutting

https://www.google.com/search?q=how+to+design+an+automated+laser+cutting+machine&client=opera&hs=zu5&source=lnms&tbm=isch&sa=X&ved=2ahUKEwiv0vKAjI_vAhV2VRUIHdDAqEQ_AUoAXoECAIQAw&biw=1326&bih=658#imgrc=-Vh81WwA688DQM&imgdii=izoTk5CGVZRcuM

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