AUTOMATED CUTTING MACHINE

A final year project report

Presented to

SCHOOL OF MECHANICAL AND MANUFACTURING ENGINEERING

Department of Mechanical Engineering

NUST

ISLAMABAD, PAKISTAN

In Partial Fulfillment

of the Requirements for the Degree of

Bachelors of Mechanical Engineering

by

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ABSTRACT

This report covers the progress of the design and fabrication of an Automated Cutting Machine. Our main objective with regards to this project was to design a machine that was capable of cutting fabrics, leathers and other thin material as per the design or drawing specifications provided by the user/consumer in the form of a drawing on a software (vector plot, sketches etc.). This entailed the procurement, manufacturing and assembly of a gantry capable of supporting and handling the movement of the cutting tool in a two dimensional plane, alongside the linkage of this with a computerized software and user interface allowing for the input of the required designs. With this project we aim to manufacture an affordable and lightweight portable cutting machine at a cost significantly lower than that currently available locally.

PREFACE

A requirement of our degree of Bachelors in Mechanical Engineering is the successful completion of our Final Year Project which encompasses the design and fabrication of a working prototype of something relating to and utilizing all the skills and concepts learned in the past 4 years. As such this report aims to track and document the progress and the final results and conclusions gleaned from our project, in this case “Automated Cutting Machine”. It provides an in-depth analysis of the literature review carried out prior to the project review, the design used and its calculations, and the specifications and reasons for the various parts and equipment used. Our project group consisted of 3 people with each student working to his strength and collaborating in order to produce the working prototype. All 3 members worked to the limit of their abilities in order to ensure that the resulting project meets the required deliverables and expectations.

ACKNOWLEDGMENTS

There are several people among us without whom this project and report would never have been possible and their contributions towards us and this project are invaluable.

First we would like to thank our supervisor and mentor Dr. Hussain Imran, who guided us throughout this project, offering help and advice where necessary and suggesting new approaches and methods when we were stuck. His cooperation was vital in the completion of this project. We would like to also thank the faculty and staff of SMME, and NUST for their guidance and services provided for this project.

On a final note our friends and family deserve special mention for supporting us throughout this project and believing in us and for helping us in whatever way possible and providing assistance even though it was not their own project.

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ABBREVIATIONS

CNC Computer Numerical Control

SME Small and Medium Enterprise

EDM Electrical Discharge Machining

NEMA National Electrical Manufacturers Association

DC Direct Current

IC Integrated Circuit

CAD Computer Aided Design

NOMENCLATURE

$C = Circumference$

$r = radius$

$SPR = steps\ per\ revelotion$

$mW = milli\ Watt$

$mm = millimeter$

$kg = kilogram$

CHAPTER 1

INTRODUCTION

Background

The manufacturing industry of Pakistan, as in most other countries, consists of a large portion of products that are produced with either partial or complete help of cutting. These industries include, but are not limited to, textile, metal removal and fabrication, tanneries and woodworks among others. However, most of the small and medium manufacturing enterprises (SMEs) utilize manual labor and traditional manual cutting machines. These, apart from significantly lowering production rates and volume, also result in allowance of errors and reduce accuracy and quality of the final product produced. All this has led to a decline in many of the mentioned industries as we are unable to produce high quality products at competitive prices.

Our Project

In order to combat these issues our project is to build an automated cutting machine or more precisely, a CNC cutter. This automated process will solve the issues relating to accuracy and repeatability as well as quality, since it will not be subject to variation as in the case of manual labor. Apart from this, it will reduce the labor cost significantly and in turn the product cost. Currently, most of the CNC machines that are available are foreign made and expensive, which is why most SMEs are unable to afford them. In regards to this are aim is to design and fabricate a high quality CNC cutter that is cheaper than what is currently available in the market.

CNC

CNC or Computerized Numeric Control essentially consists of automated tools that run through encoded commands which are programmed within the command module. CNC uses Computer Aided Manufacturing in addition to Computer Aided Design programs to design parts [1]. The CNC machine movement is along multiple axis, such that the plane x-y while the depth is covered by the tool in the z-axis. In order to get accurate movements, stepper motors are used that divide the rotation into small steps to provide accuracy and smoothness in motion. The CNC programs basically produce output in a form that can be transferred to the machine and interpreted using microprocessors, this allows us to control the CNC operations.

Types of CNC

There are various types of CNC machines available, which are determined by the type of tool used, whether it is stationary or not and the type of operation being carried out.

CNC Laser Cutting Machine

This method employs the use of a laser for its cutting operations. It works in the principle guiding the output of a laser with the aid of optics onto a focused point, and this focused beam cuts the materials by means of either melting vaporizing or burning the material. A CNC is used to direct either the material or the laser unit as per the requirements.

CNC Electric Discharge Machine

EDM uses an electrical charge for cutting operations, the current discharge between the electrodes cuts the required material with a fluid acting as the dielectric. The two electrodes being used are classified as tool electrode and work piece electrode. Sinker EDM and Wire EDM are the two main types of this machine.

CNC Water Jet Cutting Machine

A high velocity water jet is used to perform cutting in this type of CNC machine. Water can also be used in the form of a mixture with sand or other substance to slice the part or component. This method is useful when the part cannot bear high temperatures.

CNC Lathe Machine

These are highly similar to CNC milling machines in operation, control specifications and languages it operates upon. The major difference here is that in this case the tool remains stationary while work piece rotates instead.

CNC Plasma Cutting Machine

Plasma Cutting uses a plasma torch to cut parts or components. This works by using high velocity gas blown through a nozzle, usually compressed air, such that there is an electric arc being produced inside the nozzle to the surface. The gas is turned into plasma in this way which is sufficiently hot to melt the component at the point of cutting and fast enough so that the molten material blows away.

CNC Milling Machine

In this the work piece is stationary while the tool rotates. These translate programs in order to move tool to various depths and locations. Most of these utilize G-code while some also use the language created by the manufacturers them.

Summary

It can be seen that our project scope has a lot of application within the local industry, namely the SMEs. There are a variety of cutting tools and methods that can be applied in our proposed CNC machine, and a widespread literature review was carried out to determine the approach most feasible and practical.

CHAPTER 2

LITERATURE REVIEW

Prototype Design

Our prototype is a scale model of the CNC machine developed to depict the implementation of our concept and understanding. While carrying out our literature review, after carefully studying and analyzing our requirements and deliverables as well as the various techniques and types of cutting machines that can be manufactured feasibly we narrowed down our prototype design to two options.

In the first option the design consists of machine frame made primarily from wood and aluminum such that the base and stand is made of wood while tooling operations will be carried out through movement of the mounted aluminum frame. The cutting tool is mounted on the aluminum frame, having motion capability in x, y and z axis. This will allow the CNC to perform 3 dimensional cutting i.e. planar cutting with depth definition. The motion of the frame and tool is carried out using stepper motors, one to provide motion for each axis. The Microcontroller (Arduino Uno) is used with motor driver (L298, A4988, DRV8825) to control the motion of the stepper motors. The mounted aluminum frame is supported by two steel rods, while two screwed rod support the z and x axis movement of the mounted tool through rotation thus giving accuracy and smoothness of motion. A Soildworks model for this design can be seen below (Figure 1).

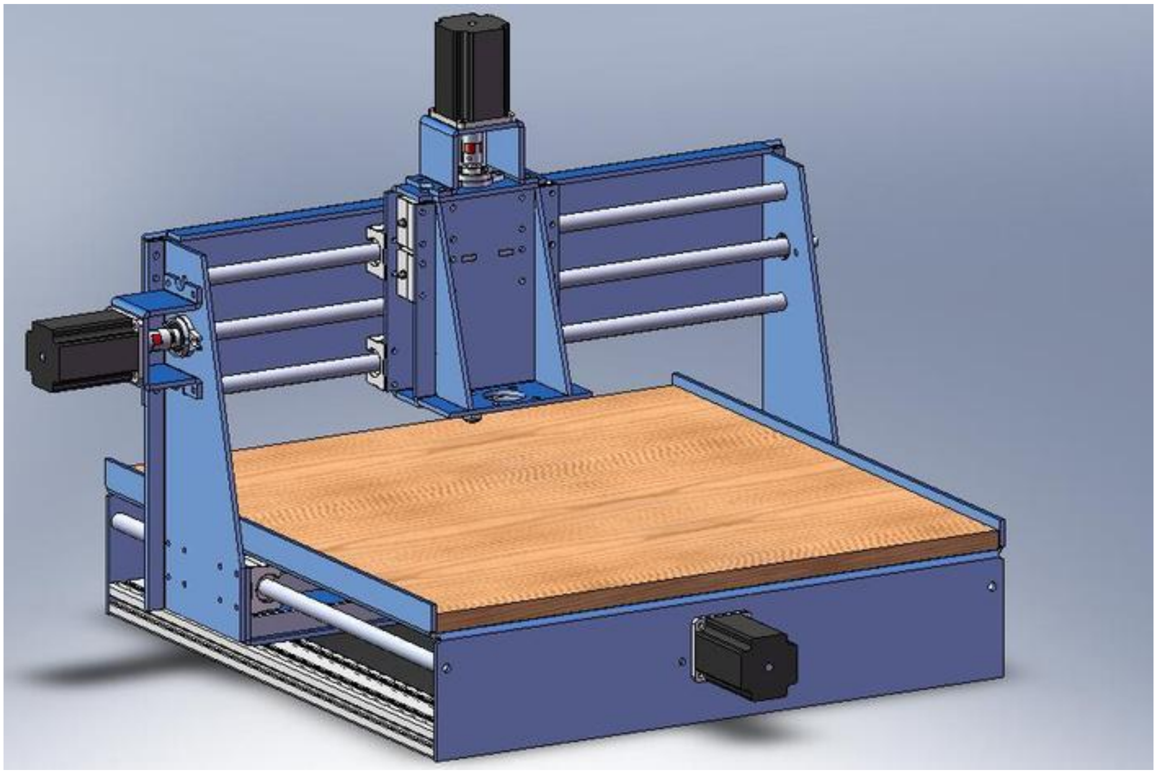


Figure 1: Proposed CAD model of prototype - 2

The second alternative Prototype basically consists of machine frame made primarily from aluminum and acrylic, such that the gantry is made of lightweight aluminum rods while the mounting for the motors and the laser module would be made of acrylic. The cutting tool is mounted on the aluminum frame, having motion capability in x, y and z axis. This will allow the CNC to perform 3 dimensional cutting i.e. planar cutting with depth definition. The motion of the frame and tool is carried out using 3 stepper motors (NEMA 17), one to provide motion for the X axis and the other two to provide identical motion in the Y axis. The Microcontroller (Arduino Nano) is used with motor driver (L298, A4988, DRV8825) to control the motion of the stepper motors. The mounted laser module is supported by acrylic plates while the movement will be carried out by the rotation of the timing belt mounted upon the coupler of the motors. A Soildworks model for this design can be seen below (Figure 2). This covers the manufacturing and assembly portion of the project.

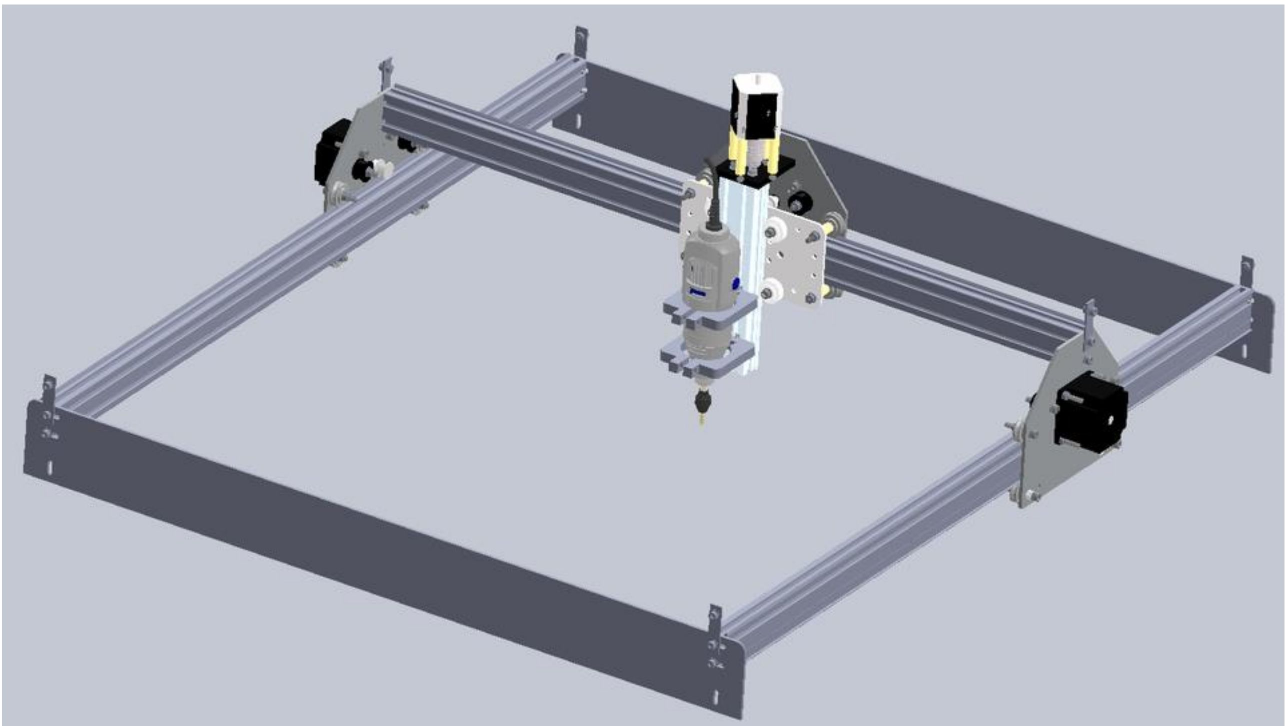


Figure 2: Proposed CAD model of prototype - 2

The programming and computerized aspect is covered through the microcontroller and software linkage. This is can be done by several methods which shall be discussed later, which allows us to use software to input cutting shape. These software convert this shape to G-code and Arduino software converts this code to give motion command through the driver to stepper motors.

Parts and Equipment

The CNC machine consists of the following major parts also mentioned are the names of available equipment:

- Stepper Motors (NEMA 17 / NEMA 23)
- Stepper Motor Driver (L298, A4988, DRV8825)
- Microcontroller (Arduino Uno/Nano)
- Rollers
- Timing Belts
- CNC Tool (for cutting, drilling)
- Computer Software

Stepper Motor:

A stepper motor is a DC motor that divides the rotation into several equal steps such that motor positioning can be controlled and stopped at any one of these steps. Bipolar and Unipolar motors are the two main types of stepper motors [2]. The pulses received as input are converted to precisely defined increments in the rotor positions, this allows the movement of the rotor through fixed angles.

A microcontroller is generally used to energize the electromagnets around the rotor. Each rotation angle of the motor is called a step and it is produced when one of the electromagnets is energized, attracting the gear’s teeth. These teeth due to the attraction get offset from the next electromagnet. Similarly, when the next magnet is turned on switching the first one off, the gear again rotates with a fixed angle. This process keeps on repeating to give equal rotation of the motor for a given number of steps to complete circular motion of the motor.

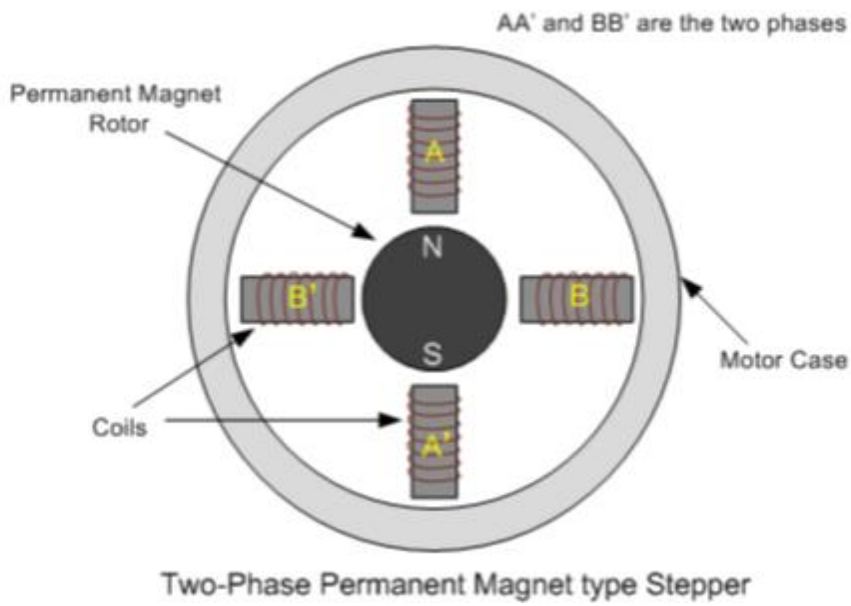


Figure 3: Stepper Motor schematic - 2

Bipolar motors are preferred over unipolar motors due to their greater power to weight ratio. The reason for this is the arrangement of the windings, unipolar motors are less efficient as the amount of wires is doubled giving half the output as compared to bipolar [3].

The stepper motor is used instead of other available motors due to the following advantages:

- Simple Design and construction
- Low maintenance

- Low cost
- Low speed with high torque at startup
- Ruggedness
- Less likely to stall or slip

Using the stepper motors has some downsides as well, some of them are:

- Dedicated control circuit is necessary
- Less torque at higher speeds
- More current used as compared to DC motors

Stepper Motor Driver:

Stepper motors can draw currents up to 2A, it cannot be directly connected to a microcontroller. For this purpose an isolator circuitry is needed that protects the microcontroller from high currents of stepper motor. In market, many driver ICs are available. One of the most popular IC for driving the stepper motor is L298 dual H-bridge IC. It is to be noted that L298 by itself cannot drive a motor but instead relies on a microcontroller to send control signals to the motor [4]. An alternate to using a microcontroller with stepper motor is to use an IC designed specifically for driving a stepper motor. These are Allegro's A4988 and TI's DRV8825. All of these IC still require some sort of control signals from a microcontroller, but being application specific, are easier to implement and handle. Moreover, from the literature review it was found that heating issues are expected with increased loads in case of using L298 and A4988. It is possible that this will be verified during the testing phase.

Computer Software

To generate G-codes from a drawing, an extension HSM Express can be used in SolidWorks. It is not a very widely used software for CNC machine operation. HSM basically converts the 2D drawing into a series of commands that are understood by all CNC machines called G-codes. We specify the depth of the cut and from this point, our Arduino code will process the G-code and convert the code into motor rotation according to the speed and feed-rate that was previously specified.

Another approach is to use the software Mach3. It is the most widely used software for CNC machine operation. Mach3 can use a simple computer as a CNC machine controller, it is a very powerful tool to be used as CNC control program [5]. Mach3 can process G-codes in most of the Windows PC available and can control the operation of the machine. It is an easy to use software that can take G-code input and read CAD drawings to generate G-codes as well.

One other approach is to use the Arduino with a GRBL/Benbox compatible CNC shield. In this method the software firmware is flashed on the Arduino which is mounted on the CNC shield according to the pin layout diagram. Using this technique the software is able to communicate with the motors without any complex G-Code reading programs and can translate the drawing into motor movement to give the desired shape.

Summary

Extensive literature review has provided us with the necessary information and knowledge to further carry out our project and move it into the fabrication stage. Having learned about the advantages and disadvantages of each approach we are now well placed to judge which is better and should be implemented. An in depth analysis of the various techniques that we can use for our software linkage has provided us with a variety of options, from which we shall chose the option that is most feasible to us.

CHAPTER 3

METHODOLOGY

Early Stage and Planning

The early stage of the project consisted of background study of CNC machine and its working mechanism. We are interested in both the design of the router frame as well as the CNC controller board. CNC machines are a common commodity of even small scale industries all around the world because of the comfort they provide to the operators and workers, and the high speeds they give to perform every job. Unfortunately, CNC machines have not made their presence known in the Pakistani small and medium scale industries. This is particularly due to the high cost of these machines. This is why we are interested in making a smaller scale CNC router which is inexpensive and can be easily operated by less skilled operators. The controller boards are quite expensive too and are rarely manufactured in Pakistan. The imported controller boards, however, do provide better performance, but are very hefty on the price. So, it was decided to concentrate efforts on selecting an affordable and quality Controller Board as well to keep the overall cost low while not compromising on the desired accuracy and operational capabilities.

Work Breakdown Structure

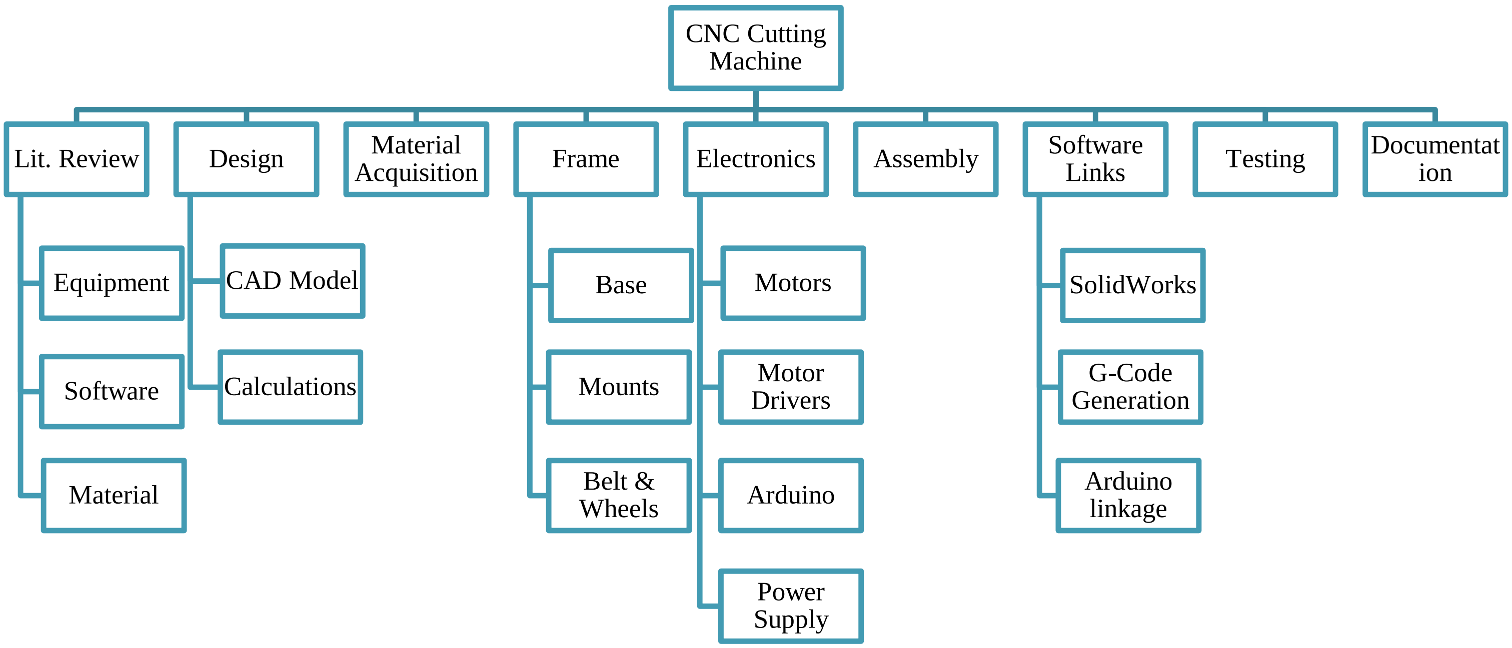


Figure 4: Work breakdown structure for the project - 3

Gantt Chart

Figure 5: Partial Gantt chart - 3

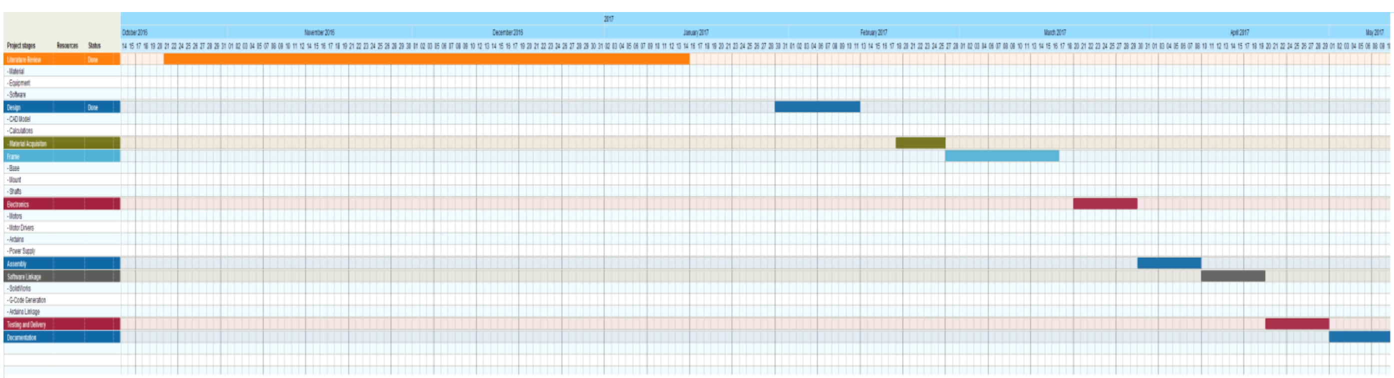


Figure 6: Complete Gantt chart - 3

Open Source Project Study

Some open source DIY CNC projects were studied. This study provided us with the necessary information to start building our own router. We studied designs of several different CNC projects that were available to us on online forums. The components that were essential to the project were determined by the help of these online forums. The functionalities of each available components were understood in detail. Since there are more than one components available in the market of different ratings and sizes, we discovered and finalized which ones were suitable for our project and why were they suited for our project. For example, to control the movement of the tool stepper motors (NEMA 17) are used, and the projects we studied provided a design to get the best performance out of a stepper motor. Methods to control the stepper motor were reviewed and the best method was selected that put the motor and the whole circuit at the least amount of risk.

Computer Software Selection

To generate G-codes from a drawing, an extension HSM Express can be used in SolidWorks. It is not a very widely used software for CNC machine operation. HSM basically converts the 2D drawing on SolidWorks into a series of commands that are understood by all CNC machines called G-codes. We specify the depth of the cut and the extension gives an accurate G-code for the whole drawing. From this point, our Arduino code will process the G-code and convert the code into motor rotation according to the speed and feed-rate that was previously specified in the G-code.

Another approach is to use the software Mach3. It is the most widely used software for CNC machine operation. Mach3 can use a simple computer as a CNC machine controller, it is a very powerful tool to be used as CNC control program. Mach3 can process G-codes in most of the Windows PC available and can control the operation of the machine.

It is an easy to use software that can take G-code input and read CAD drawings to generate G-codes as well.

The most viable approach however, was to use the Arduino with a GRBL/Benbox compatible CNC shield. In this method the software firmware is flashed on the Arduino which is mounted on the CNC shield according to the pin layout diagram. Using this technique the software is able to communicate with the motors without any complex G-Code reading programs and can translate the drawing into motor movement to give the desired shape.

Engineering Approach

The material selection for the prototype is done based on how different parts are being utilized. Keeping in mind our design requirements, availability of resources, skill in the market and the financial cost of the parts, we decided upon the second design option, the reasons for which are as explained. The gantry is to be made of aluminum rods so as to keep the machine lightweight and portable. The moving mount of the motors and the laser module is to be made of acrylic. This will allow us to have a light weight mount since strength is not a priority in this case as the weight of the motors and the laser is not much while the rest of the parts such as the small wheels and belts have negligible weight. The lightweight moving mount thus helps in reducing the load to be moved by the stepper motors, allowing less heat generation, less energy loss and less danger of damage or failure. One of the other reasons for choosing to make the gantry and the railings from aluminum, and the mounts from acrylic is its easy availability in the market. Aluminum rods are readily available here with similar types being used in the railings for curtain thus allowing us ease of access in addition to them being cheap on account of that we would require only a small amount and its weight would be less. Similarly in the case of acrylic, it is readily available within the local markets and can easily be cut into the required shapes and is comparatively very cheap and lightweight when put against aluminum or mounts of other metals.

The movement of the tool is carried out using stepper motors with timing belts. Stepper motors can divide the full motion into several equal steps and can be controlled to operate and hold at any one of these steps. The timing belts provide smooth and unhindered motion in the axis based on its rotational movement.

The drivers are used based on load handling and respective heat generation, for this purpose the literature review allowed us to know that L298 has a lesser load handling capacity than A4988 and DRV8825.

Material and Equipment Selection

After extensive literature review and market survey according to our requirements we finalized the equipment and the material to be used in this project. First of all we decided to use the second design. The gantry will be made of aluminum rods in order to provide a lightweight and portable body thereby providing ease of access in using it. In addition it was decided that in order to keep the load on the motors as minimum as possible the mounting and moving panels were to be made of acrylic and we would use two motors in the Y axis as it will also have to bear the additional weight of an aluminum rod.

NEMA 17 was decided in favor of NEMA 23 since due to our lightweight structure and the use of two motors in the Y axis direction, the motors would not require much power in order to move the laser panel. Moreover, NEMA 17 is much lighter in weight than NEMA 23. This would allow us to in turn save costs and make the project feasible in terms of being cost effective and lightweight.

The cutting tool that we decided upon was a laser cutter. This decision was arrived upon by studying the different methods and their feasibility. Laser cutting allows us the precision required in order to successfully cut the material as per the requirement since its cutting diameter is very small as compared to other cutters and its focus and intensity can also be manually adjusted for different materials and different types of operations (cutting, engraving & etching etc.).

Calculations

Table 1: NEMA 17 Required Data -3

NEMA 17 MOTOR DATA	
STEPPER STEPS/REV	200
STEP ANGLE	1.8°
MICRO STEPPING	8
WEIGHT	0.3 kg
POSITIONAL ACCURACY	±5%

- Radius (coupler)

$$r = 0.25\ inch = 6.35\ mm$$

- Circumference

$$C = 2\,\pi\,r = 1.57\ inch = 39.9\ mm \approx 40\ mm$$

- Steps/Rev

$$SPR = 200\ x\ 8 = 1600\ steps/rev$$

- Distance/step

$$C/_{SPM} = \ ^{40}/_{1600} = 0.025\ \ mm/step$$

These calculations show the accuracy available within our working parameters. The machine is accurate up to 0.025 mm and each step has that degree of control.

Summary

The literature review has allowed us to understand the project, and research work is almost complete. We have finalized which approach we are going to undertake and have outlined the reasons why we believe it is the best and most viable approach. The parts that will be used have also been finalized keeping in mind our requirements and demands and the most feasible option for software linkage and user interface has been selected as explained above. Now the project has moved to the development phase where we are working on procurement and frame construction. We have planned and scheduled the activities to complete the project in time and will keep on making minor changes based on when and if the problems and issues are encountered during the development phase.

CHAPTER 4

RESULTS

This section deals with the results and outcomes of the project. It is, however, necessary to consider the aims and objectives set for this project first. The project was undertaken with specific objectives in mind, which were developed after considerable literature review and market. Moreover, the project aims to provide technical support to small and medium enterprises, therefore, demands of the market were also kept in mind while setting objectives for the project.

The project aim was to design and manufacture a 2D cutting machine to fulfill the requirements of small and medium enterprises currently employing manual techniques. The machine must be capable of cutting fabrics and thin leather. It should be light weight and portable. The cost must be lower than the imported machines currently available in the market so that small industries can easily afford it. Lastly, easy to use control software must be integrated to control operations and there should be a proper easy to use user interface.

Keeping the above mentioned points in mind, then it can be summarized that the following outcomes were achieved compared to our goals and objectives at the start of this project as explained in detail.

Project Specifications

- **2000mW Laser Cutting Module**
  Keeping in view the cutting requirements and market availability we obtained a 2000mW laser. This would provide us with the necessary power in order to provide the cutting capability that we decided at the start of the project, namely to be able to cut fabrics.

- **65 x 50 cm Working Area**
  The working area was set twice the size of the low cost imported machines currently available in the market. This is so that the machine can be employed in diverse operations in small industries allowing for a wide range of material sizes that can be cut.

- **NEMA 17 Stepper Motors**
  Stepper motors used for accurate positional control of machine movement. This type of project requires precise movement in order to produce the required cut, since any delay or unwanted movement would cause the cutting to degrade and as such waste the product material since a wrong cut would render the entire work piece useless. As such these motors provide the necessary accuracy and precision in terms of movement.

- **Accuracy of up to 0.025 mm**
  With precision of paramount importance as mentioned beforehand we calculated that according to the specifications of the motors that we would be using we would get an accuracy of up to 0.025 mm. This is a very highly accurate distance thereby ensuring that the cut matches the exact requirements of the customer and the design provided.

- **Software and User Interface**

  In order to translate the provided drawing in to G-Codes and the subsequent translational movement of the motors we used an open source software for this conversion. We flashed this software on to the Arduino and this provided us with the required user interface allowing us to interact with it. Within this user interface we could manually draw various things such as shapes etc. Other than this this interface is also capable of receiving input in the form of drawings such as sketches, vector plots and jpeg image files. The interface also allows for different forms of cutting with each provided a different type of cut suited for different types of applications. The first type is the “outline method” whereby it moves the laser (tool) along the outline of the sketch or image provided only. This is a fast method and is best suited for sketches that have little or no detail within them such as names. However this is a slightly less accurate method and not suitable for images with detail. This brings us to the second type which is the “by line method” in which it would break the image into a series of infinite parallel lines, and then trace the laser along each line in order successively, firing pulses where required. This is a slower method but highly accurate and provides great detail in the cut, with the details with the boundary of the image also being etched or carved.

Project Capabilities

- **2 Dimensional Laser Cutting Machine**

  2 Dimensional machine movement with laser cutting. This ensures smooth cutting as there is no direct contact of cutting surfaces. Moreover, the material being cut is not distorted because of contactless cutting. The accuracy achieved using stepper motor is 0.025mm per step which fulfils the given objectives for this product.

Figure 7: Completed CNC Laser Cutter - 4

- **Cutting Capabilities**

  This machine is capable of cutting and engraving a variety of things. It can both cut and engrave fabric, paper, rexine and cardboard. This is capable by manually adjusting the power of the laser in order to suit your requirements and keeping in mind the material being cut. Cutting speed can also be varied using computer software based on the material being cut. A picture of the sample material that we cut using this can be seen below.

Figure 8: Sample materials that can be cut - 4

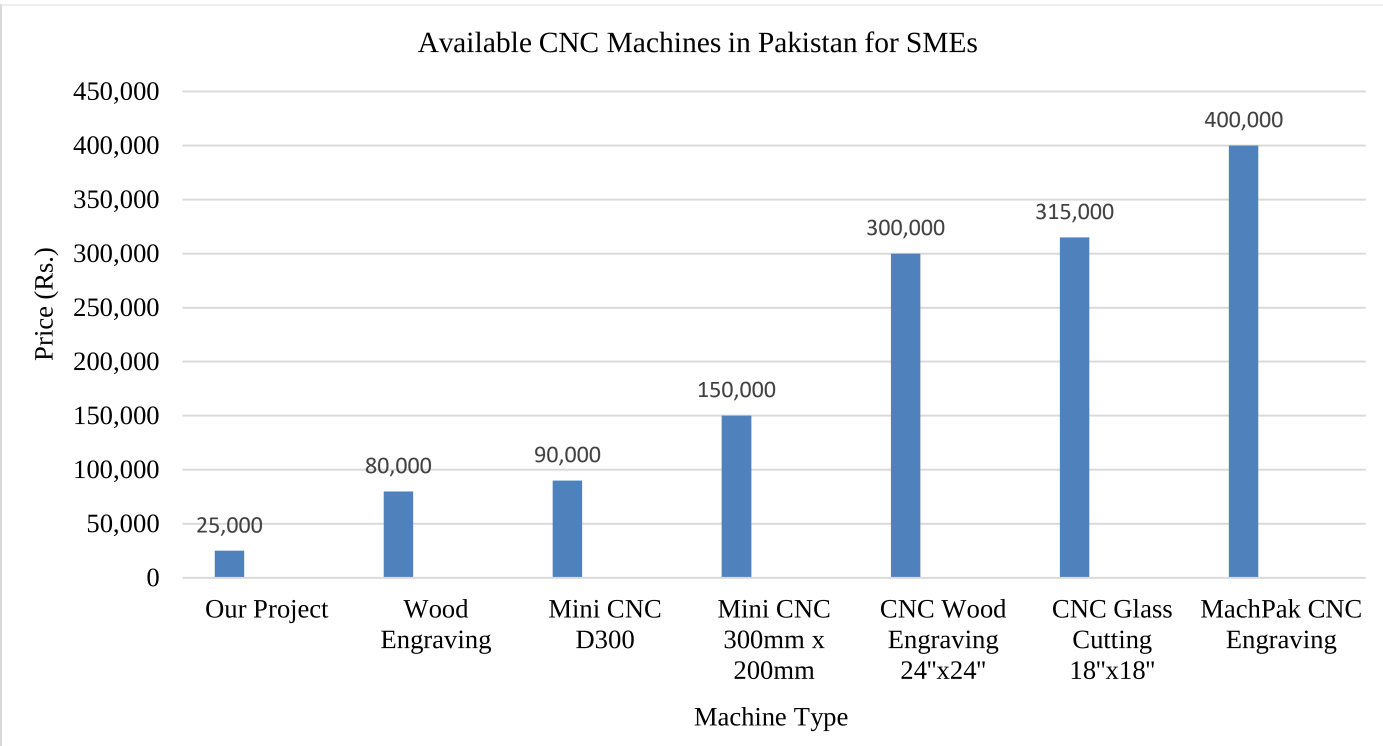
- **Engraving Capabilities**

  Engraving of wood, acrylic and leather. Engraving can be customized by varying cutting speed and laser power. The depth of engraving can be adjusted using these two variables.

- **Low Cost**

  The cost of the machine is considerably low as compared to the imported machines currently available in the market. This increased affordability and its comparatively small size and weight allows it to be the ideal machine to be used in small and medium enterprises. The cost of the machine is around Rs. 25,000.

Table 2: Price comparison of different locally available CNC machines - 4



- **Lightweight and Portable**

  In order to be employed in small industries, it is necessary that the machine be portable and lightweight. Therefore, aluminum gantry is used with acrylic supports. This use of lightweight material has ensured that the machine weighs as little as 3 kg, easily being capable of being lifted and carried around by a single person of average build. Another significant advantage within our project is its capability to be easily disassembled and the reassembled. Our simplified design and the use of screws instead of welding to hold the parts together ensures that the project can easily be disassembled and taken apart into its various individual components with the help of only a screwdriver and the right Allen key within 10-15 min, while it can also be reassembled back together within the same time frame. This makes its transportation over long distances comparatively much easier and convenient for the user as compared to the other machines that are much more bulky and heavier.

Industrial Applications

- **Applications in Small and Medium manual industries**

  Our machine has a lot of application in the industrial sector especially in the domain of the Small and Medium Enterprises. These businesses are usually unable to afford expensive investments and most of the cutting work is done manually. Our low cost machine ensures that it is a viable option for them while its automated feature accuracy means that work will both be sped up and increased in the quality of cut and finish. Affordability, ease of use, portability and accuracy make this machine an ideal option to be employed in the small scale cutting industry of Pakistan.

- **Textile and fabric cutting industry**

  The laser is capable of cutting fabric in any given shape using software interface. Laser module of 2000mW is powerful enough to easily cut through fabrics and textiles. The software setting allow us to also produce different demands on design and we have the option to explore this venture as well. Various small scale fabric producing industries can use this machine to achieve precision and repeatability in production.

- **Paper and Vinyl cutting industry**

  Paper and vinyl can also be cut in any given shape using the laser module on the machine. The power of the laser must be brought down in this case as these materials are quite thin for the given laser module. There is a danger of the base material being damaged if the power is not controlled in case of thin materials.

- **Wood, acrylic and leather engraving industry**

  Wood, acrylic and leather can be engraved in any shape as well as any text using the software. Due to greater thickness, a 2000mW laser module cannot cut through these materials, however, engraving on these materials can easily be done.

- **Product customization – souvenirs, personalized items**

  The machine can also be used for home-based and entrepreneurial ventures. Customized products with texts, logos can be made. This include wallets, key chains, bags, covers etc. The accuracy of the machine allows beautiful engraving on these products which can be sold in the market. We tried and successfully engraved custom names on the wallets of our friends. The result can be seen in the photo below as shown. This proves that this option can further be explored and made into a successful business venture.

Figure 9: Sample of customized product - 4

Summary

In conclusion we can state that the objectives that we set out with and started this project with, namely the creation of a two dimensional cutting machine with low cost and various industrial applications, were successfully accomplished. Our project is capable of cutting a wide variety of fabrics as well as paper and do so as per the requirement of the consumer. However its main asset is its low cost, just around Rs 25,000 which is comparatively lower than those currently available in the market, and it being lightweight and easily portable making it the ideal option for application within the SME sector of Pakistan.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

Conclusion

CNC cutting as a technique is a highly accurate form of cutting and allows for a great degree of variation within this level of accuracy. However in Pakistan this method has struggled to take form as many local industries, particularly those of the small and medium level, are reluctant to try this technique, mainly because of issues arising from its cost and availability. With these things in mind we decided that for our final year project that we would build a CNC cutting machine. For this purpose we defined and started with a core set of objectives and aims that would guide us throughout the project. Chief among these objectives was the fabrication of a CNC cutting machine capable of cutting fabrics in a 2 dimensional plane that would be low cost and a feasible option for the SMEs within Pakistan, especially in comparison to the imported material. Another objective was for the project to have a wide scope of application with regards to the industries currently present within Pakistan, and for the project to have a positive impact on the general community and benefit our nation in some way or the other. With this in mind we started our project and after an in-depth literature review we analyzed different approaches and equipment and decided that the gantry and mounts would be made of aluminum and acrylic respectively to keep it light and that the tool to be used would be a laser due to its accuracy and the software and user interface would be an open source software compatible with a CNC shield to convert G-Codes into movement. In comparison to these aims we managed to achieve all of them and some more. Our project was capable of using laser cutting in a 2D plane with an accuracy of up to 0.025 mm, and was achieved in a budget of just over Rs./- 25000, which is significantly cheaper than those currently available within Pakistan as illustrated by table 2. It was extremely lightweight, weighing in at just 3 kilograms and highly portable. It consisted of a fully compatible user interface and had numerous applications in the industry such as fabric cutting, souvenir customization and other things.

Recommendations

There are several ways in which this project can be further improved and carried forward. First of all one of the simplest and most straight forward steps that can be taken is to use a laser of a higher power rating. Our laser was only 2000 mW and as such was only able to engrave and etch thick materials such as wood. A laser of higher power such as 6000 – 8000 mW would be capable of cutting through material such as wood and acrylic. Another addition that can be done is to incorporate the addition of variation within the z-axis, allowing for control over the depth of our cut. This would allow us to further expand our capabilities by increasing our scope of work with regards to the industrial applications. The tool can also be changed in order to facilitate different types of cutting and the various types of material to be cut.

Limit switches can also be incorporated within this project allowing us to define the end points of the machine and letting it operate in Cartesian co-ordinates. This will further enable us to add a feedback system whereby we will be able to exactly the position of the tool is and how many turns the motor has gone through. This means that operating conditions could be monitored and any variations adjusted for automatically. The software can also be upgraded such that it is also capable of taking input in the form of G-Codes or a CAD drawing directly.

Lastly our main recommendation is that this project should be carried on further as a business venture with its various applications in the industry. We have already customized various products for our friends such as their wallets and we believe that given the chance we can develop this into a sustainable business idea and model.

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APPENDIX I: NEMA 17 MOTOR SPECIFICATIONS

- Common Ratings

Step angle: 1.8 degrees

Positional Accuracy: 5%

Number of Phase: 2

Temperature Rise: 80 ^{o}C

Rotor Inertia: 54 gcm^2

Dielectric Strength: 500 VAC

Insulation Resistance: 100 Mohm

Ambient Temperature: -10 to 50 ^{o}C

Insulation Class: B

Weight: 0.3 kg

- Specifications

Table 3: NEMA 17 Specifications

Holding Torque	Rated Current/Phase	Phase Resistance	Rated Voltage	Phase Inductance
0.45	2.0	1.1	2.2	2.6

APPENDIX II: CONTROL CIRCUIT SCHEMATIC

The control circuit creates the connection between the software (interface) and the hardware (motors, laser) of the machine. The control circuit consists of the following components:

- Arduino Uno (Microcontroller)
- A4988 (Motor Driver)
- CNC Shield

Together, these components link the software to the movement of the motors and laser operation. Thus, the machine can be controlled. The control circuit is connected as shown below:

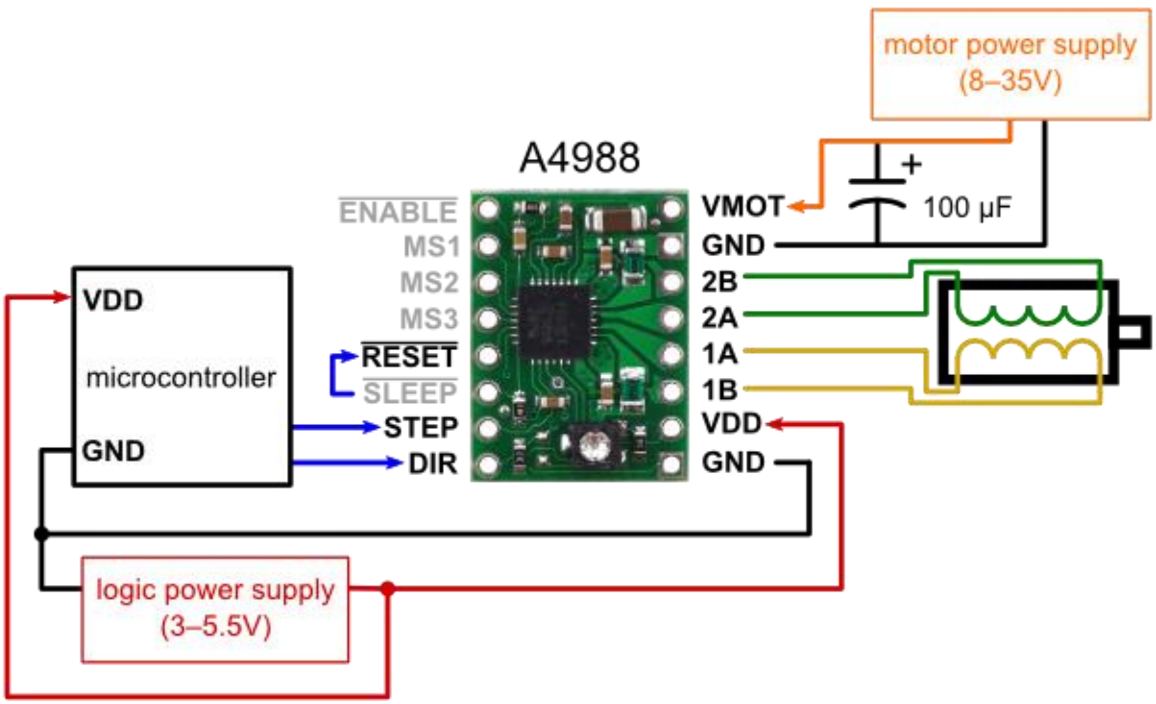

Figure 10: Control Circuit Schematic