

IOT BASED ARDUINO CNC FOAM CUTTING MACHINE

Submitted in partial fulfillment of the requirements for the award of Bachelor of
Engineering degree in Electronics and Communication Engineering

By

R.R.JAYASURYA (40130086)

K.T.KRISHNAN (40130119)



**DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
SCHOOL OF ELECTRICAL AND ELECTRONICS**

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(Deemed to be University)

Accredited with Grade "A++" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI,

CHENNAI - 600 119

APRIL - 2024



SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited "A++" Grade by NAAC | 12B Status by UGC | Approved by AICTE

www.sathyabama.ac.in

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **R.R.JAYASURYA (40130086)**, **K.T.KRISHNAN (40130119)** who carried out the project entitled **IOT BASED ARDUINO CNC FOAM CUTTING MACHINE** under my supervision from November 2023 to April 2024.



Internal Guide

Mr.V.KALIST,M.E



Head Of The Department

Dr.T.RAVI,M.E.,Ph.D.

Submitted for Viva voca Examination held on _____

Internal Examiner

External Examiner

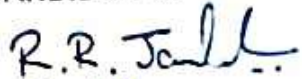
DECLARATION

We R.R.JAYASURYA (40130086) , K.T.KRISHNAN (40130119) here by declare that the Project Report entitled "IOT BASED ARDUINO CNC FOAM CUTTING MACHINE" done by us under the guidance of Mr.V.KALIST,M.E is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

DATE: 18.04.2024

PLACE: Chennai

SIGNATURE OF THE CANDIDATES

1. R.R.JAYASURYA 
2. K.T.KRISHNAN 

ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to **Board of Management of SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. We are grateful to them.

I convey my thanks to **Dr. N. M. NANDHITHA, M.E., Ph.D., Dean, School of Electrical and Electronics Engineering** and **Dr. T. RAVI, M.E., Ph.D., Head of the Department, Department of Electronics and Communication Engineering** for providing me necessary support and details at the right time during the progressive reviews.

I would like to express my sincere and deep sense of gratitude to my Project Guide **Mr.KALIST**, for his valuable guidance, suggestion and constant encouragement for the successful completion of my project work.

I wish to express my thanks to all Teaching and Non-teaching staff members of the **Department of Electronics and Communication Engineering** who were helpful in many ways for the compleion of the project.

ABSTRACT

In this modern era of automation and connectivity, integrating Internet of Things (IoT) with conventional machinery has become a prevalent approach to enhance efficiency and functionality. This paper presents the design and implementation of an IoT-based Arduino CNC (Computer Numerical Control) foam cutting machine. The proposed system leverages the capabilities of Arduino microcontrollers and IoT technologies to create a versatile foam cutting solution.

The CNC foam cutting machine is controlled by an Arduino board, which communicates with IoT devices over a network connection. This connectivity enables remote monitoring and control of the foam cutting process, providing real-time feedback and adjustments. Additionally, the system incorporates sensors to ensure precision and safety during operation.

The system enables remote monitoring and control through IoT devices, facilitating real-time adjustments and feedback on cutting parameters like speed and temperature. Integrated sensors ensure accuracy and safety during operation. Key features include remote accessibility via smartphones or computers, automated alerts for maintenance, and cloud integration for data storage and analysis. The user interface is designed for ease of operation and customization. This innovation promises enhanced productivity, safety, and versatility in foam cutting applications across industries like packaging and artistic design. Through this abstract, we highlight the potential of IoT integration with CNC machinery to revolutionize foam cutting processes, offering insights into design, implementation, and practical applications.

TABLE OF CONTENTS

CHAPTER NO	TITLE	PAGE NO
	ABSTRACT	v
	LIST OF ABBREVIATIONS	viii
	LIST OF FIGURES	ix
	LIST OF TABLES	x
1	INTRODUCTION	1
	1.1 OVERVIEW	2
	1.2 FORMULATION	3
	1.2.1 NEED OF THE PROJECT	3
	1.2.2 DEVELOPMENT	3
2	LITERATURE SURVEY	4
3	AIM & SCOPE	10
	3.1 AIM OF THE PROJECT	10
	3.2 FUTURE SCOPE	11
4	METHODOLOGY & ALGORITHM USED	13
	4.1 RESEARCH METHODOLOGY	13
	4.2 EXISTING METHODOLOGY	14
	4.3 PROPOSED METHODOLOGY	16
	4.4 HARDWARE REQUIREMENTS	19
	4.4.1 STEPPER MOTOR -NEMA 17	20
	4.4.2 A4988 STEPPER DRIVER	20
	4.4.3 ARDUINO CNC SHIELD	21
	4.4.4 ARDUINO UNO	22
	4.4.5 DC-DC CONVERTOR	23
	4.4.6 LIMIT SWITCH	24
	4.4.7 DC POWER SUPPLY	25
	4.4.8 MECHANICAL REQUIREMENTS	26
	4.5 SOFTWARE IMPLEMENTATION	27
	4.5.1 SOFTWARE TO GENERATE G CODE	27
	4.5.2 INKSCAPE	28

	4.5.3 GRBL LIBRARY	29
	4.6 PROGRESSION REVIEW	30
5	RESULT & DISCUSSION	35
	5.1 RESULT	35
	5.1.1 X & Y AXIS CALIBRATION PROCESS	35
	5.1.2 TEMPERATURE VARIATION & CURRENT	36
	5.2 IOT IMPLEMENTATION	42
	5.2.1 SHEDULING MAINTENANCE	43
	5.2.2 MACHINE UPTIME MONITORING	44
	5.2.3 IMPROVED WORKER SAFETY	44
	5.2.4 PRODUCT QUALITY CONTROL	45
	5.2.5 PREVENTATIVE MAINTENANCE	45
	5.3 PROBLEM DEFINITION	45
	5.4 PROBLEM IDENTIFICATION & TESTING	46
	5.5 WORKING	47
	5.6 SWOT ANALYSIS	48
	5.6.1 STRENGTH	48
	5.6.2 WEAKNESS	48
	5.6.3 APPLICATION	49
6	SUMMARY & CONCLUSION	50
	6.1 SUMMARY	50
	6.2 STANDARDS	51
	6.3 CONSTRAINTS	52
	6.4 TRADE-OFFS	52
	REFERENCE	51

LIST OF ABBREVIATIONS

UAV	UNMANNED AERIAL VEHICLE
CAD	COMPUTER-AIDED DESIGN
LOM	LAYERED OBJECT MANUFACTURING
XPS	EXTRUDED POLYSTYRENE FOAM
CNC	COMPUTER NUMERICAL CONTROL
IOT	INTERNET OF THINGS
GRBL	G-CODE REFERENCE BLOCK LIBRARY
GPIO	GENERAL-PURPOSE INPUT/OUTPUT
SPI	SERIAL PERIPHERAL INTERFACE
UART	UNIVERSAL ASYNCHRONOUS RECEIVER / TRANSMITTER
ADC	ANALOG-TO-DIGITAL CONVERTER
DAC	DIGITAL-TO-ANALOG CONVERTER
EPS	EXPANDED POLYSTYRENE

LIST OF FIGURES

FIGURE NO	FIGURE NAME	PAGE NO
4.1	RESEARCH METHODOLOGY	13
4.2	CNC MACHINE MECHANISM MODEL	15
4.3	BLOCK DIAGRAM OF CNC MACHINE	17
4.4	STEPPER MOTOR	20
4.5	STEPPER DRIVER	21
4.6	ARDUINO CNC SHIELD	22
4.7	ARDUINO UNO	23
4.8	DC-DC CONVERTOR	24
4.9	LIMIT SWITCH	25
4.10	DC POWER SUPPLY	26
4.11	DESIGN SETUP	27
4.12	3-D IMPLEMENTATION	28
4.13	2-D IMPLEMENTATION	28
4.14	INKSCAPE SIMULATOR-1	29
4.15	INKSCAPE SIMULATOR-2	29
4.16	GRBL LIBRARY	30
5.1	SIDE VIEW	38
5.2	FRONTAL VIEW	39
5.3	FOAM CUTTING ON PROCESS	40
5.4	FINAL RESULT	41

LIST OF TABLES

TABLE NO	TABLE NAME	PAGE NO
5.1	Y AXIS CALIBRATION PROCESS-1	35
5.2	Y AXIS CALIBRATION PROCESS-2	36
5.3	V, I & T MEASUREMENT	37

CHAPTER 1

INTRODUCTION

Different Foams are widely used in various industries like packaging, insulation, architectural, signage, decorations etc. for multiple applications. UAV Industry & Aeromodelling are industries in which different foam are extensively used for designing, prototyping, scaled model, manufacturing, pattern making etc. UAV Industry is an emerging industry from last decade with various applications in the field of surveying, surveillance, data acquisition, deliveries etc. UAV is booming globally & many start-ups are based around this technology. As it is still growing there is constant demand for development in UAVs to meet desired output, performance, and cost-effective solutions. In this process of development most of time is consumed by designing & making of model out of foam or in the cutting process

This foam cut determines the performance of the model in real life situations and also aids the designer in analysing problems & gives them parameters to reiterate the design. There is constant trial & error of the foam model to bring out optimum results. This process of making prototypes consumes lots of time & energy. Also, time is the most crucial aspect in research & development. This study aims towards the design of computer numeric control Foam cutter which will hasten rapid prototyping, save time, improve foam cuts, cost effective design. Foam cutting rapid prototyping and manufacturing machines are ideally suited to fulfill this niche because of their high speed, large working volumes and inexpensive working materials.

Thermal plastic foam cutting is the material removal process most commonly used in foam cutting rapid prototyping to shape or sculpt the plastic foam into desired shapes and sizes. The process is achieved by introducing a heat source generally a wire or ribbon which alters the physical properties of the plastic foam and allows low cutting forces to be achieved. In thermal plastic foam cutting the heat source is generated via Joule heating.

1.1 OVERVIEW

To reduce cutting time and increase its efficiency for current use in UAV industries, we had done a literature review, then we studied different mechanisms. We took references from various research papers. We designed our project through CAD modelling and using Auto CAD FUSION 360. After that, we did fabrications and assembling. We tested our models by cutting different foams to reduce errors and overcome their earlier limitations. We also reduced the overall cost so that small-scale manufacturing industries can also afford it. This process is suitable for mass production, to produce many identical parts, like fuselage or wings. Hobbyists that prefer to make their models at home with hand tools are usually limited to much simpler shapes that are obtained via bending plain Foam sheets around multiple cross-sectional elements.

Another method adopted is the layered object manufacturing (LOM) technique used for rapid manufacturing. They build their models from thick (approximately 30-100 mm) layers of XPS that were cut with the hot wire and glued together to form the intended object. Hotwire (heated with an electric current) must follow precisely contours of cross-sections which are achieved with templates glued on both sides of each layer; it needs skill and labour to achieve the desired result. The momentum research is an endeavour to fabricate a framework that can serve comparable requirements (yet not restricted to) of flying airplane modelers.

A member of RC Groups forum has made a numerically controlled hot wire cutter that uses diving Foam software for cutting long one-piece wings. Hans Seybold from Germany has made an NC hot wire cutter with 4 degrees of freedom. He used a unique mechanical layout where a bow with hot wire is positioned in space with 4 filaments of variable length controlled by 4 stepping motors. He likewise fostered a program to drive the bow along the ideal course which uses the plain content depiction of all directions of the shape. All information is available for free on the internet at Hot-wire cutter by Hans Seybold. Probably the most advanced technology is used in the Aero

Tetris Company located in Russia. They use a 6 axis NC machine which allows achieving an accuracy of 0,09-0,5 mm with wire inclination up to 165 degrees. During the cutting process speed and temperature are varied. The organization sells sets of Foam parts for building huge models.

1.2 FORMULATION

This research aims to overcome existing problem & to implement new methods

- To improve Precision & accuracy of foam cut using hot wire foam cutting
- Try to use open-source programs for controlling CNC foam cutter
- Try to make it cost-effective for hobbyist, designer
- Use easily accessible parts

1.2.1 NEED OF THE PROJECT

- To save time build time-prototyping for designer
- To make machine using accessible parts
- Easy to use machine based on open-source software
- To help UAV designer to design aircraft design with less expensive material like foam

1.2.2 DEVELOPMENT

To overcome and meet the objectives of the project. We had designed the machine from scratch using CAD software. This design will include 3d printed parts for motor mounting, frames, smooth rod for providing structural rigidity, threaded rod & Stepper motor mechanism for linear movement of Cutting tool i.e. hot wire. This complete assembly will be controlled using Micro controller and Stepper Drivers on G-CODE command generated using open-source software like wing g code generator software.

CHAPTER 2

LITERATURE SURVEY

TITLE : Design And Fabrication Of Arduino Controlled CNC Foam Cutting Machine

YEAR OF PUBLICATION : 2022

AUTHOR : Nihal Mankar, Yash Tiwari , Ankit Thakre , Pranay Bawankar

ABSTRACT : Most Foam Cutter Machines Are Likely CNC Machines. In The CNC Machine Cutting Process Done By A Hard Tool, Another Hand Laser Is Used. For Very Thin Material, There Was No Need For Hard Tool Bits And Lasers. Instead Of Tool Bits And Lasers, The Special Type Of Cutting Used In The Machine Is Named Hot Wire, Or A Special Type Of Resistance Wire (Nickel-Chromium Wire) Which Gets Heated When Electric Current Passes Through It. The Nickel-Chromium Wire Vaporizes And Melts The Foam When Electric Current Passes Through It. By Using This Technology, We Can Get Our Designated Shape And Size. Very Fine Thickness Can Be Achieved By This Technology For This Purpose It Is Employed In The Aerodynamic Events

PROBLEM STATEMENT : In the field of manufacturing and design, particularly where aerodynamic components and other precise foam-based products are concerned, there exists a challenge in achieving high precision and very fine thicknesses using traditional cutting methods. Conventional CNC machines utilizing hard tool bits and lasers may not offer the required accuracy or may cause material wastage and damage when dealing with very thin foam materials. There is a need for a cutting technology that can provide exceptional precision, minimal material wastage, and the ability to produce complex designs without compromising the material integrity of thin foam sheets.

TITLE : Design and development wire cutter CNC for Foam product

YEAR OF PUBLICATION : 2022

AUTHOR: Syahriza, U Aulia, L Muspika

ABSTRACT : Cutting Foam manually will result in inaccurate cutting and dissimilar shape. To upgrade the quality of the product, a Foam cutting machine which can cut automatically is needed. Thus, the aim of this research is to create a Foam cutting machine using CNC 2 Axis Wire Cutter which can cut the material according to the CAD drawing module, and accelerate the cutting process. The control system of the machine uses the Arduino UNO microcontroller. The cutting process is performed by sending G-Code file to the microcontroller through the Universal G-Code Sender software. Afterwards, the microcontroller sends a signal to activate the stepper motor, and it is generated actuator movement according to the drawing in G-code file. The optimal Foam cutting resulted by using CNC Wire Cutter with 0.2 mm nickel wire, 220oC, and 2 cm thickness.

PROBLEM STATEMENT : many Foam craftsmen rely on manual tools such as cutters and hot wires for shaping and creating decorations, safety goods, and other Foam-based products. This manual process includes time-consuming steps like measurements and sketches, which are critical for achieving the desired shapes and sizes. However, the manual cutting method poses significant challenges in terms of efficiency, precision, and the ability to fulfill a large volume of orders with diverse shape requirements. These challenges are exacerbated by the need for high concentration in sketches, measurements, and cuts, making the process labor-intensive and prone to errors. There is a pressing need for a solution that can enhance cutting precision, reduce production time, and accommodate varied design demands without compromising the quality of the final products.

TITLE : Design and Development of CNC Foam Cutter

YEAR OF PUBLICATION : 2021

AUTHOR : Dr. Abhinav P. Ninawe , Vijeet Khadilkar, Mohammed Muzammil ,

ABSTRACT : Cut quality of foam depend upon variable cutting parameters of hotwire which affects the cutting process to achieve the needed cut, precise and accurate cutting parameters are needed to be set this research is done to develop 4 axis computer-controlled machine to perform precise and accurate foam cutting using hot wire and to identify suitable cutting parameters to improve foam cutting. This CNC has two mutually perpendicular axes controlled using a motor and micro controller. This design will aid UAV designers, Aero- modeller & hobbyist for rapid prototyping of wings, fuselage & different shapes, also it has wide application in RC modelling, signage, scale model & props, etc.

PROBLEM STATEMENT : In the domain of rapid prototyping and production across various fields, including UAV design, aeromodelling, RC modelling, signage, scale models, and props, there exists a significant challenge in achieving precise and accurate cutting of foam materials. The quality of foam cutting is highly dependent on the control over variable cutting parameters such as temperature, speed, and wire tension. Traditional or less sophisticated cutting methods often fall short in providing the needed precision and accuracy, leading to potential material waste, inefficiency, and limitations in producing complex shapes and designs. There is a critical need for an advanced solution that incorporates a 4-axis computer-controlled mechanism designed specifically for foam cutting using hot wire technology. Such a solution should also aim to identify and optimize suitable cutting parameters to significantly improve the quality of foam cutting. This advancement would not only enhance the capabilities of professionals in creating detailed and intricate designs but also expand the possibilities in rapid prototyping and custom manufacturing applications.

TITLE : Study and Design of Arduino Based CNC Laser Cutting Machine

YEAR OF PUBLICATION : 2021

AUTHOR : Mohammad Nasir Khan, Ambuj Maheshwari, Himanshu Verma

ABSTRACT : For precise job manufacturing, system should possess good dimensional accuracy and surface finish. In applications like drilling, punching, marking, boring, tapping work piece is positioned firstly and then cutting tool performs its action while motion axes are kept stationary. In traditional approach for such applications, manufacturer uses highly expensive CNC machine for programming job cycle and executing the same. Big scale manufacturer can afford such highly expensive machines but for small scale mechanical job manufacturing industry we have to think of low-cost solution that can deliver high class output. In this project we are trying to propose low-cost design which gives similar functionality as that of high-cost CNC machine. By applying this machine in industry, it can acquire the multi generation brief time. In order to perform some operation which requires continuous cutting over a pre-defined curve, CNC machines are used as the traditional machines in the industry.

PROBLEM STATEMENT : The project seeks to bridge the gap between the advanced manufacturing capabilities of high-cost CNC machines and the financial constraints faced by small scale industries. Traditional CNC machines, while precise, demand significant investment and skilled operators, making them less accessible for smaller enterprises. This initiative aims to develop an affordable, low-cost CNC laser cutting machine controlled by Arduino, providing a cost-effective alternative with comparable functionality. By doing so, it intends to empower small scale manufacturers with the ability to perform detailed and precise manufacturing tasks such as cutting, engraving, and shaping, without the need for extensive financial resources or highly specialized skills. This solution promises to enhance productivity and competitiveness among small scale industries by making advanced manufacturing technology more accessible and manageable.

TITLE: The Development of CNC Hot Wire 3D Cutting Foam Tool

YEAR OF PUBLICATION : 2019

AUTHOR : Sugeng Dwi Riyanto , Saepul Rahmat , Muhammad Yusuf

ABSTRACT : Wedding decorations are considered incomplete without decoration. The decoration business must prepare a skilled and creative workforce and improve the artistic creation skills of employees to provide several choices of decorating styles to clients. The material that was recently used in decorations is Foam. The purpose of this research is to design a CNC machine to get good results and neatly cut Foam using a hot wire. This research also contributes to solving problems with Foam cutting usually a problem with detailed and complicated work that can be solved automatically using a CNC machine. Tool hardware design requires Bluetooth connection, driver to the stepper motor, driver A4988 to CNC shield, and step down to the heating wire. Software design includes uploading GRBL firmware, creating G-code using Inkscape Software, and connecting Android applications to CNC machines. The result shows that for 2-dimensional foam cutting with 1cm thickness, the best results are obtained in the range voltage of 7.4-8.5V.

PROBLEM STATEMENT : The wedding decoration industry relies heavily on skilled artisans and creative designs, with foam emerging as a popular material. This research addresses this by designing a CNC machine with a hot wire for precise and automated cutting. The project encompasses hardware and software development, including Bluetooth connectivity and G-code generation. Experimental results reveal optimal cutting parameters for 2D and 3D foam cutting, highlighting the machine's efficacy. Ultimately, this research aims to streamline Foam cutting processes, enhancing decorative options and efficiency in the wedding decoration industry.

TITLE : Design and Fabrication of Compact CNC Hot Wire Foam Cutting Machine

YEAR OF PUBLICATION : 2017

AUTHOR : Sanjay S N , Sidhvin D M , Sachin Hegde , K P M Unni Krishnan

ABSTRACT : Hotwire acting is a commonly used method to cut various types of foam in different shapes and sizes. Cut quality of foam depend upon variable cutting parameters of hotwire which affects the cutting process to achieve the needed cut, precise and accurate cutting parameters are needed to be set this research is done to develop 4 axis computer-controlled machine to perform precise and accurate foam cutting using hot wire and to identify suitable cutting parameters to improve foam cutting. This CNC has two mutually perpendicular axes controlled using a motor and micro controller. This design will aid UAV designers, Aero- modeller & hobbyist for rapid prototyping of wings, fuselage & different shapes, also it has wide application in RC modelling, signage, scale model & props, etc. this will save time, increase productivity and quality of cuts.

PROBLEM STATEMENT : The problem statement for this research project is to address the need for precise and accurate foam cutting using hot wire technology. The cut quality of foam depends on various cutting parameters, requiring precise settings for optimal results. The aim is to develop a 4-axis computer-controlled CNC machine capable of achieving precise cuts in foam, while also identifying suitable cutting parameters to enhance the cutting process. This machine targets applications in UAV design, aeromodelling, RC modelling, signage, scale model production, and more, promising to save time, increase productivity, and improve the quality of cuts in various foam materials and shapes.

CHAPTER 3

AIM & SCOPE

3.1 AIM OF THE PROJECT

The aim of a CNC foam cutting machine is to automate and improve the precision, efficiency, and versatility of foam cutting processes. The primary objectives include:

- **Precision Cutting:** Achieve high levels of precision and accuracy in cutting foam materials to meet design specifications and quality standards consistently.
- **Efficiency:** Increase productivity by automating the cutting process, reducing manual labor, and minimizing material waste through optimized cutting paths.
- **Versatility:** Enable cutting of foam materials into various shapes, sizes, and designs to fulfill diverse application requirements across industries such as packaging, insulation, arts and crafts, and construction.
- **Flexibility:** Adapt to different foam materials, thicknesses, and densities, allowing for the production of customized foam products tailored to specific needs.
- **Scalability:** Accommodate the production of small-scale prototypes as well as large-scale batches of foam products efficiently, allowing for scalability according to demand.
- **Integration:** Integrate with CAD/CAM software systems to translate digital designs into precise cutting instructions and optimize tool paths for efficient foam cutting.

- **Ease of Use:** Provide user-friendly interfaces and controls, allowing operators to set cutting parameters, load designs, and monitor the cutting process with ease.
- **Safety:** Implement safety features to protect operators and prevent accidents during the cutting process, such as emergency stop mechanisms and enclosure systems.

Overall, the aim of a CNC foam cutting machine is to streamline foam cutting operations, improve product quality, and enhance production efficiency across various industries that utilize foam materials.

3.2 FUTURE SCOPE

The scope for an IoT-based Arduino CNC foam cutting machine is extensive, offering numerous possibilities for enhancing functionality, connectivity, and user experience. Here are some key aspects of its scope:

- **Remote Monitoring and Control:** Implementing IoT capabilities allows users to monitor the machine's operation remotely and control it through a web or mobile interface. This feature enables real-time monitoring of cutting processes, status updates, and adjustments to cutting parameters from anywhere with an internet connection.
- **Data Logging and Analysis:** Incorporating IoT sensors enables the collection of data related to cutting parameters, machine performance, and material usage. This data can be logged and analyzed to identify patterns, optimize cutting processes, predict maintenance needs, and improve overall efficiency.
- **Automated Workflow Management:** IoT integration facilitates automation of workflow management tasks such as job scheduling, material inventory

tracking, and order management. This automation streamlines operations, reduces manual intervention, and enhances productivity.

- **Machine Health Monitoring:** IoT sensors can monitor various aspects of machine health, including temperature, vibration, and power consumption. Continuous monitoring allows for early detection of anomalies or potential issues, enabling proactive maintenance and minimizing downtime.
- **Enhanced User Experience:** IoT features can enhance the user experience by providing intuitive interfaces, interactive dashboards, and personalized settings. Additionally, remote troubleshooting and support functionalities can be integrated to assist users in resolving issues quickly and efficiently.
- **Scalability and Customization:** The IoT-based Arduino CNC foam cutting machine can be designed with scalability and customization in mind, allowing for the integration of additional sensors, actuators, and features as needed. This flexibility ensures that the machine can adapt to evolving requirements and accommodate specific user preferences.

Overall, incorporating IoT capabilities into an Arduino CNC foam cutting machine expands its functionality, improves efficiency, and enhances user satisfaction, making it a valuable tool for various industries and applications.

CHAPTER 4

METHODOLOGY & ALGORITHM USED

4.1 RESEARCH METHODOLOGY

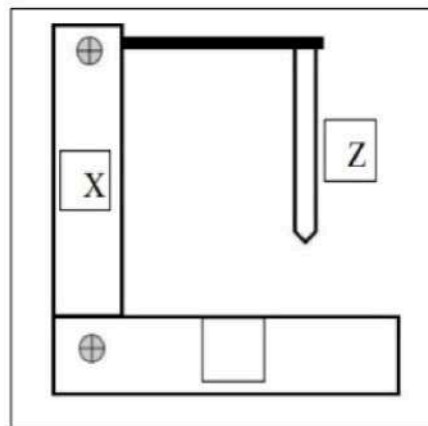


Fig:4.1: Research Methodology

There are 3 movements of using 3 CD ROMs. The horizontal movement(X) i.e. forward & backward movement is provided by the lower CD Rom. The 2nd CD Rom is mounted between the 2 columns which provide side movements(Y) i.e. left and right hand side movements. The spindle which is mounted on the 3rd CD Rom provides vertical movement (Z) for feed of tool. If the G-Code is successfully sent and the hot wire heating process achieves the desired temperature, the machine proceeds to the X and Y axis motor control process. This involves precisely controlling the movement of the cutting tool along the X and Y axes to execute the design with accuracy. However, if any issues arise during the G-Code processing or the hot wire heating process, the machine loops back to address and resolve these concerns before proceeding further. Once the X and Y axis motor control process is successfully completed, the programming process commences. This stage focuses on optimizing the machine's performance by finetuning the parameters and instructions to enhance cutting

precision and efficiency. Finally, the motor is thoroughly tested to ensure it operates smoothly and effectively, meeting the desired performance standards.

This systematic and iterative process ensures that each step is meticulously executed, and any potential issues are promptly addressed. By adhering to this carefully orchestrated workflow, the CNC-based Foam cutting machine maximizes its capabilities and produces high-quality, precise cuts in line with the intended design. After the testing of the motor, the microcontroller takes charge of adjusting the DC-DC converter to ensure that the voltage and temperature applied to the hot wire are precisely as intended. This critical adjustment guarantees optimal performance and safety during the foam cutting process. The microcontroller's role extends further as it generates an output signal that regulates the current flowing through the hot wire. This controlled current, achieved through the DCDC converter, is then utilized in the foam cutting process.

As a result, the hot wire becomes the instrument through which the foam material is expertly shaped and sculpted. Simultaneously, the Nema 17 stepper motors responsible for controlling the movement along the X and Y axes receive commands from the microcontroller. These precise instructions dictate the motion required to achieve the desired cuts and patterns on the foam material. The synchronized coordination between the microcontroller, DC-DC converter, hot wire, and Nema 17 stepper motors ensures a seamless and efficient cutting process, yielding remarkable results.

4.2 EXISTING METHODOLOGY

The proposed machine can be introduced as a CNC hot wire foam cutter. It has two pairs of vertical and horizontal arms attached. This pair of vertical arms hold the cutting tool i.e. hot wire at a certain distance. These vertical arms are mounted on horizontal arms which are controlled using a stepper motor. Motor speed and feed rate of the cutting tool is controlled using a microcontroller through G codes. Proposed machine

intends to save the time of maker, give them quality cuts, to bring out suitable cutting parameter for foams.

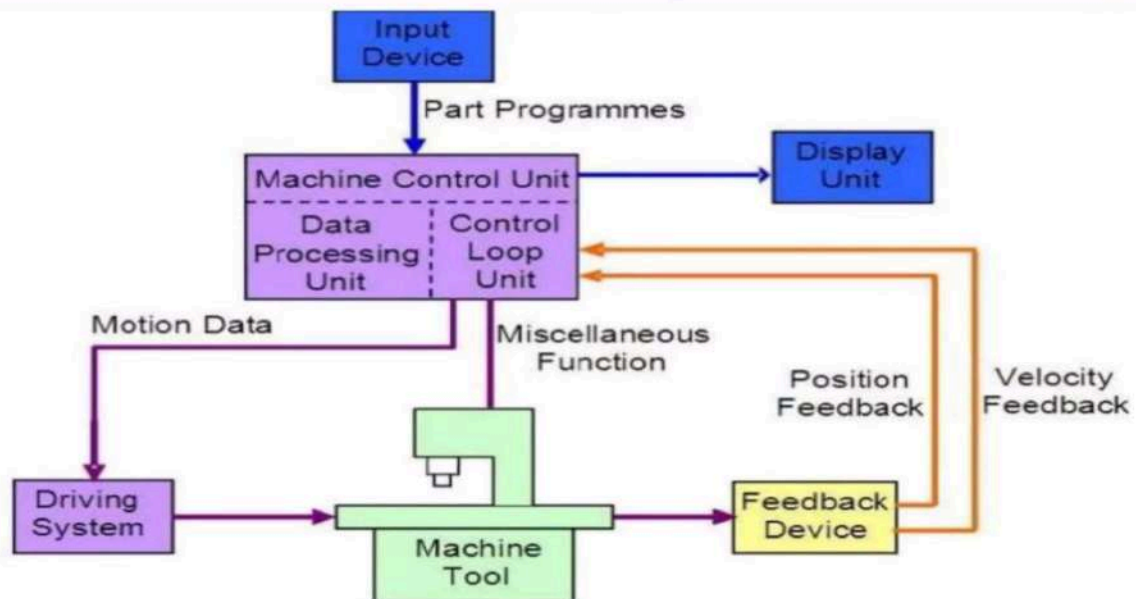


Fig:4.2: CNC machine mechanism model

The principle of CNC (Computer Numerical Control) revolves around using computerized systems to control and automate the operation of machinery and equipment, particularly in manufacturing and machining processes. CNC technology is based on the integration of computers, software, and machinery to achieve precise and efficient control over various industrial operations. The key principles of CNC include:

Computer Control: CNC systems are driven by computer programs, also known as CNC programs or G-code. These programs contain a series of instructions that dictate the movements, operations, and parameters of the machine.

Numerical Representation: CNC uses numerical data to define and control movements and operations. Coordinates and measurements are expressed in numerical values, which the computer interprets and translates into physical actions.

Automation: CNC machines operate with a high degree of automation. Once a CNC program is created and loaded, the machine performs the specified operations with minimal human intervention.

Precision and Accuracy: CNC technology enables precise and accurate control over movements and machining operations. The ability to program and execute complex sequences with tight tolerances leads to consistent and high-quality results.

Flexibility and Versatility: CNC systems are versatile and adaptable. By modifying the CNC program, different parts or products can be produced on the same machine, making it well-suited for batch production and rapid prototyping.

Complex Geometries: CNC machines can produce intricate and complex shapes that would be challenging or impossible to achieve manually. They can perform 3D milling, contouring, drilling, and threading operations with ease.

Reduced Human Error: CNC systems significantly reduce the risk of human errors that can occur in manual operations. Once programmed correctly, the machine executes tasks consistently and accurately.

Remote Control and Monitoring: Some CNC systems allow for remote control and monitoring, enabling operators to manage multiple machines and production processes from a central location.

Rapid Production: CNC technology enables faster production cycles compared to traditional manual methods, leading to increased productivity and shorter lead times.

Tool and Material Optimization: CNC machines can optimize tool usage and material utilization, reducing waste and costs.

4.3 PROPOSED METHODOLOGY

The Proposed machine is nearly same as the existing CNC machine but in the existing method a person should be present there manually to monitor the process for errors but we have included ESP 32 cam for mobile monitoring. We can monitor for error

from a remote place and can turn off the machine using your mobile or computer using the IOT cloud. For seamless error internet connection should be present.

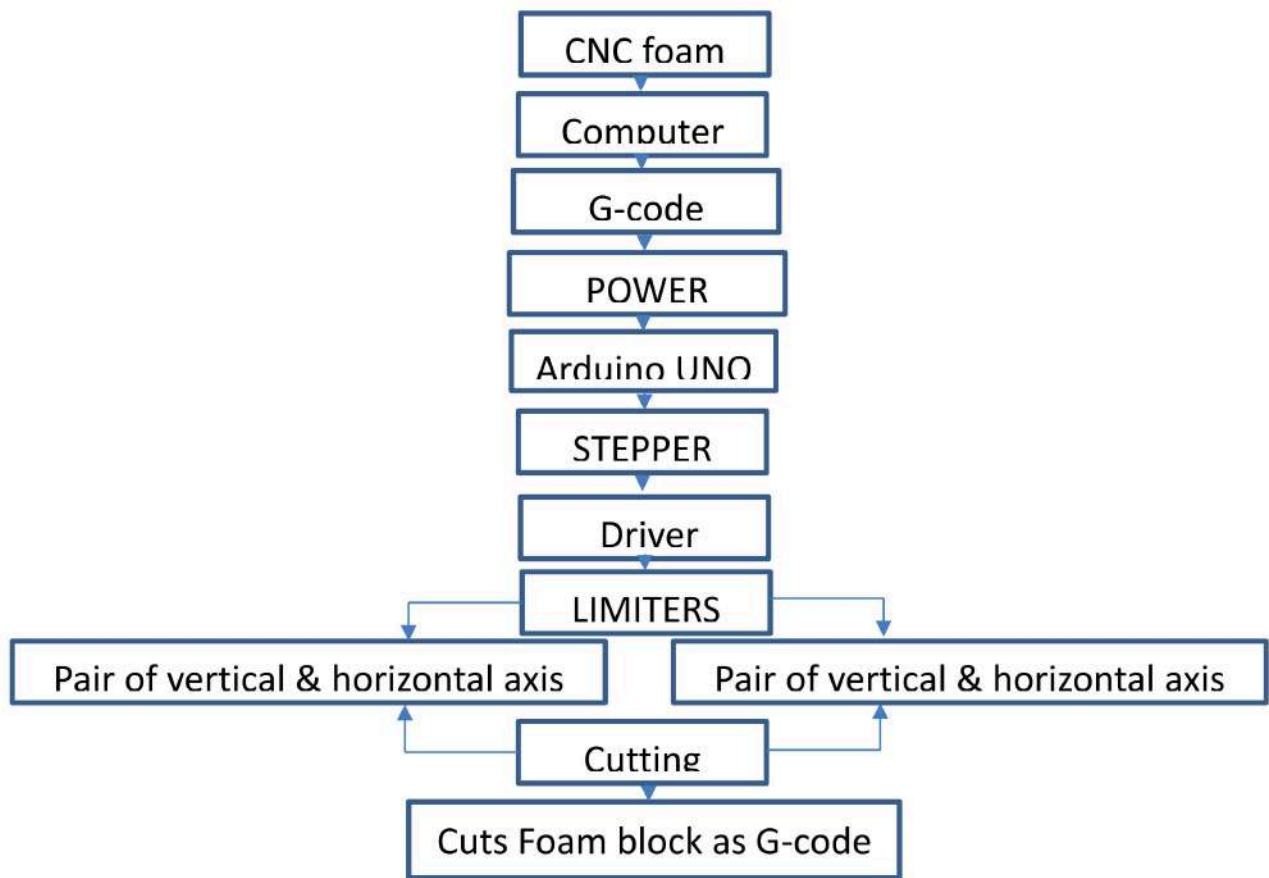


Fig:4.3: Block diagram of CNC machine

Proposed design will consider 4 axes defined as XYUZ to control feed rate of the tool. X and U are horizontal and YZ vertical. This is important for design software which needs the correct letters assigned to generate the g-code. More on this later, depending on the software there are a few ways to assign this. This is a motor and shaft driven mechanism in which Stepper motors are coupled to threaded rod on which a carriage will be mounted to hold the vertical axis with the same motor & shaft mechanism with supporting aluminum profile attached to it. It is a 4 Axis machine with two sets of mutually perpendicular axes separated by a certain distance. Hotwire will be held by two vertical arms which can move in all four directions. This hotwire will be in constant tension with the help of a spring attached to one of the vertical

arms. Tensioning is done to keep hot wire tight through the cutting process & prevent any unwanted errors in cutting process & prevent any unwanted errors in cutting process. Below is figure of this mechanism.

Left gantry is XY and Right gantry is UZ here is pair of horizontal & vertical arm blue part in Image are 3d printed carriage and mount for holding motor, aluminium extrusion Stepper motor used for this design is Nema 17 with 4.8 kg cm torque, 1.5 A rated current & 1.8° angle i.e. 200 steps. Threaded rods used are of 8mm diameter with 1.5 mm pitch. This mechanism is sufficient enough to achieve controlled feed rate for the tool. Stepper motor gives precise positioning which meets the primary need of this design. This complete assembly & structure of cnc machine is made using 3d printed parts & Aluminium extrusion as shown in figure. This design is made in cad software.

The material to be cut is just soften under the point of melting because it is thermoplastic material, after that the cutting is done. The surface of the cut and kerf-width is affected by the changing of the velocity and the diameter of wire even if it was small. Many researchers have studied the cutting process of polymers and the effective parameters on it. Harmanpreet & Manpreet Singh studied the effect of parameters for the polymer cutting process on material removal rate and kerfwidth also the optimization of the machining process. Ranjeet et al made investigation in ablation process for the Expanded Polystyrene (EPS) rapid prototyping to predict and calculate the kerfwidth and surface roughness (Ra) with mathematical model. Kiril & Jesper proposed a novel thermoelectro-mechanical model for hotwire cutting of EPS foam and predicts the stress, voltage and temperature of wire during cutting of EPS foam. In addition, find relation between kerfwidth and the cutting angle as measured from the horizontal direction. Namrata & Sathyan investigated the factors responsible for the bowing phenomenon via a series of experiments involving variations in current and wire feed rate, build more precise prototypes, kerf width is also examined, Further more finding noval way to predict the influence of gases in bowing has been analyzed and quantified.

Numerically controlled foam cutter had to be able to cut intricate shapes out of foam material such as extruded polystyrene by using 3D virtual model, also find novel mathematical model to predict the kerfwidth, and empirical relationship is established to predict the surface roughness (Ra) of the sliced surface by performing regression analysis. Ahn et al studied the Influence of process parameters on the surface Jroughness in hotwire of variable lamination manufacturing (VLM-S) for EPS foam such as cutting angle and compositions of expandable polystyrene EPS, the apparatus is fouraxis automatic cutter and the specimen is thin foam.

While in my study, parameters differsand the device is 2D axis CNC. with any thickness of foam can be cut. P. Gallina et al studied the hot wire with 2D robotic system to cut polystyrene plates with accurate force control which is delayed reference control (DRC) with time delay: (tT) ,T the time delay calculated online, while my study is about 2D CNC machine and different parameters to reach optimum conditions of cutting without considering of time. The objective of this paper is to obtain the optimum cutting conditions for hotwire cutting process, and study the effects of these parameters on the process.

4.4 HARDWARE REQUIREMENTS

Hardware components in electronics are the physical building blocks essential for device functionality. Integrated circuits (ICs) house numerous electronic components on a single chip, including transistors and resistors, enabling complex operations in a compact form. Capacitors store and release electrical energy, stabilizing voltage levels. Inductors resist changes in current flow, crucial for filtering and signal processing. Diodes allow current flow in one direction, pivotal for rectification and signal modulation. Resistors regulate current flow and voltage levels within circuits. Printed circuit boards (PCBs) provide a platform for component integration and electrical connections, serving as the foundation of electronic devices.

4.4.1 STEPPER MOTOR - NEMA 17

Stepper motors are precise electromechanical devices used in various applications, converting digital pulses into mechanical motion. They operate in discrete steps, providing accurate positioning control without feedback mechanisms. These motors offer high torque at low speeds, making them ideal for applications requiring precise control, such as 3D printers, CNC machines, robotics, and automated systems.



Fig:4.4 : Stepper motor

Stepper motors come in various types, including bipolar and unipolar, each with unique characteristics and suitability for different tasks. With their simplicity, reliability, and cost-effectiveness, stepper motors play a crucial role in modern automation, powering movements in countless devices across industries worldwide.

4.4.2 A4988 STEPPER DRIVER

Stepper drivers are essential components in controlling stepper motors, translating digital signals into precise mechanical motion. These drivers regulate the flow of electrical current to the motor coils, ensuring accurate steps and smooth operation. They offer features like microstepping, allowing finer resolution and smoother movement. Stepper drivers come in various types, such as bipolar and unipolar, each suited for specific motor configurations. With advanced features like current control and overheat protection, stepper drivers optimize motor performance and reliability.

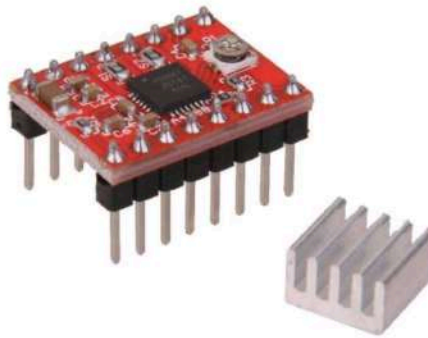


Fig:4.5 : Stepper driver

They find widespread use in CNC machines, 3D printers, robotics, and automation systems, providing precise control and enhancing overall system efficiency and performance. Stepper drivers play a vital role in managing stepper motor operation by converting digital signals into precise movement. These drivers ensure smooth motion, control current flow to motor coils, and optimize performance with features like microstepping. They're crucial for various applications like CNC machines, robotics, and 3D printers, enhancing efficiency and accuracy.

4.4.3 ARDUINO CNC SHIELD

The Arduino CNC Shield is a specialized expansion board designed to interface with Arduino microcontrollers, facilitating the control of CNC (Computer Numerical Control) machines. It acts as an interface between the Arduino board and external components such as stepper motors, limit switches, and spindle controllers, enabling precise and automated control of CNC operations. The Arduino CNC Shield is a specialized expansion board designed to interface with Arduino microcontrollers.

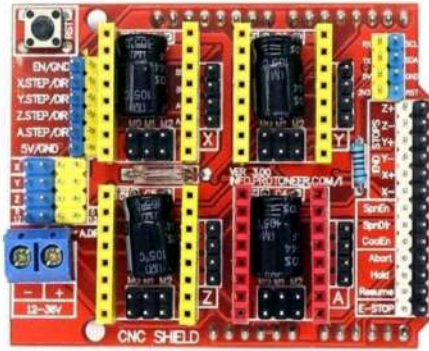


Fig:4.6 : Arduino CNC shield

The Arduino CNC Shield is a specialized expansion board designed to interface with Arduino microcontrollers, facilitating the control of CNC (Computer Numerical Control) machines. It acts as an interface between the Arduino board and external components such as stepper motors, limit switches, and spindle controllers, enabling precise and automated control of CNC operations. The Arduino CNC Shield is a specialized expansion board designed to interface with Arduino microcontrollers.

Equipped with stepper motor drivers, the shield can control multiple stepper motors simultaneously, enabling precise movement along multiple axes. With its affordability, and compatibility with Arduino ecosystem, the Arduino CNC Shield empowers users to create and experiment with CNC projects easily making it versatile and adaptable for different CNC applications.

It simplifies the development process by providing a standardized interface for connecting and controlling CNC peripherals, enabling hobbyists, makers, and professionals to build custom CNC machines efficiently.

4.4.4 ARDUINO UNO

The Arduino Uno is a popular microcontroller board based on the ATmega328P chip. It features digital and analog input/output pins, allowing for versatile interfacing with sensors, actuators, and other electronic components. With its simple yet powerful

design, the Arduino Uno is widely used in hobbyist projects, educational settings, and professional prototyping. It supports the Arduino Integrated Development Environment (IDE), simplifying code development and uploading.



Fig:4.7 : Arduino UNO

The Arduino Uno is a versatile microcontroller board designed for easy prototyping and DIY electronics projects. Powered by the ATmega328P microcontroller, it features 14 digital input/output pins, 6 analog input pins, and a USB connection for programming and power. It supports a wide range of sensors, actuators, and shields, expanding its capabilities for diverse applications. With its open-source nature and extensive community support, beginners and experts alike can leverage its simplicity and flexibility to create interactive projects, from simple LED blinking to complex robotics. Its affordability and accessibility make it a popular choice for learning and experimentation in the world of electronics.

4.4.5 DC-DC CONVERTER

A DC-DC converter is an electronic device that transforms a direct current (DC) input voltage into a different DC output voltage. It operates by controlling the flow of electrical energy through semiconductor switches like transistors or diodes. By adjusting the switching frequency and duty cycle, it regulates the output voltage to match the desired level. DC-DC converters find widespread use in portable electronic devices, telecommunications equipment, automotive electronics, and renewable

energy systems. They offer advantages such as compact size, high efficiency, and precise voltage regulation, making them indispensable for powering electronics in various applications where stable and efficient power delivery is crucial.



Fig:4.8 : DC-DC Converter

It regulates voltage by adjusting duty cycle or pulse width modulation. These converters are essential in various applications where voltage transformation is needed, such as power supplies, battery charging, and renewable energy systems. They come in different topologies like buck, boost, and buck-boost, each suited for specific voltage conversion requirements. With their ability to step up or step down voltages efficiently, they play a crucial role in powering diverse electronic devices and systems.

4.4.6 LIMIT SWITCH

A limit switch is an electromechanical device used to detect the presence or absence of an object, typically at the end of a motion range. When activated by physical contact with an object, it sends a signal to control circuits to stop, start, or change the operation of machinery.

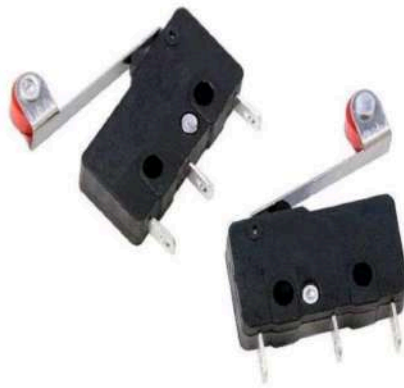


Fig:4.9: limit Switch

Limit switches are widely used in industrial automation, robotics, and machinery safety systems to provide accurate position feedback and prevent overtravel or collisions. They come in various configurations, including lever, roller, and proximity types, offering versatility and reliability in diverse applications requiring precise and reliable position sensing.

4.4.7 DC POWER SUPPLY

A DC power supply is an electronic device that converts alternating current (AC) voltage from a mains power source into direct current (DC) voltage suitable for powering electronic circuits and devices. It regulates voltage and current output to provide stable and reliable power to connected loads. DC power supplies come in various types, including linear and switched-mode power supplies, each offering different characteristics and efficiency levels.



Fig: 4.10 : DC power supply

They are essential components in electronics laboratories, manufacturing, telecommunications, and automotive industries, where a stable and precise DC power source is required for testing, prototyping, and operation of equipment. Modern DC power supplies feature adjustable voltage and current limits, overvoltage and overcurrent protection, and digital interfaces for remote control and monitoring. With their versatility, reliability, and wide range of applications, DC power supplies are indispensable tools for engineers, technicians, and hobbyists working with electronic circuits and systems. Stabilized DC power supplies can be divided into two types depending on the output method: constant voltage power supplies and constant current power supplies. In constant-voltage power supplies, the output voltage is controlled so that it remains constant even if the power supply load changes. On the other hand, constant-current power supplies are controlled so that the output current remains constant.

4.4.8 MECHANICAL REQUIREMENTS

- 6x 20x20mm 500mm T-slot Aluminum Profiles
- 4x 10mm Linear Rails Rods
- 6x T-slot profile corner brackets
- 50x M5 nuts for T-slot Profiles
- 6x Linear bearings 10mm
- GT2 Belt + Tooth Pulley + Idler Pulley

- 2X Bearing 5x16x5mm spacer set
- Spring assortment set
- Hot Wire

4.5 SOFTWARE IMPLEMENTATION

The CNC system uses G Code to control or automate the movement of tools & axis. To understand this G code firmware is uploaded on a microcontroller. Firmware will interpret the G code and generate a control signal for .This modification can be done using a compiler of microcontroller i.e.,Arduino ide or using user Interface software made for this CNC foam cutter.

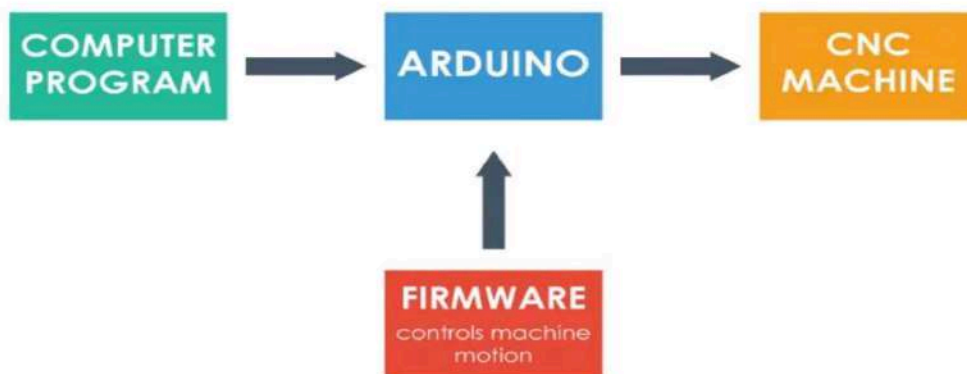


Fig:4.11 : Design setup

4.5.1 Software to generate G code

As this design of machine primarily aims towards cutting of wings & UAVs parts. There are few free software or sites available online to generate G code as per the given wing geometries. In this program it needs the inputs like

- Aerofoil of wing in .dat file format
- Set foam block size that will be cut
- Feed rate of tool

- On the basis of these inputs G code is generated in. ngc or .nc format depending upon software being used.

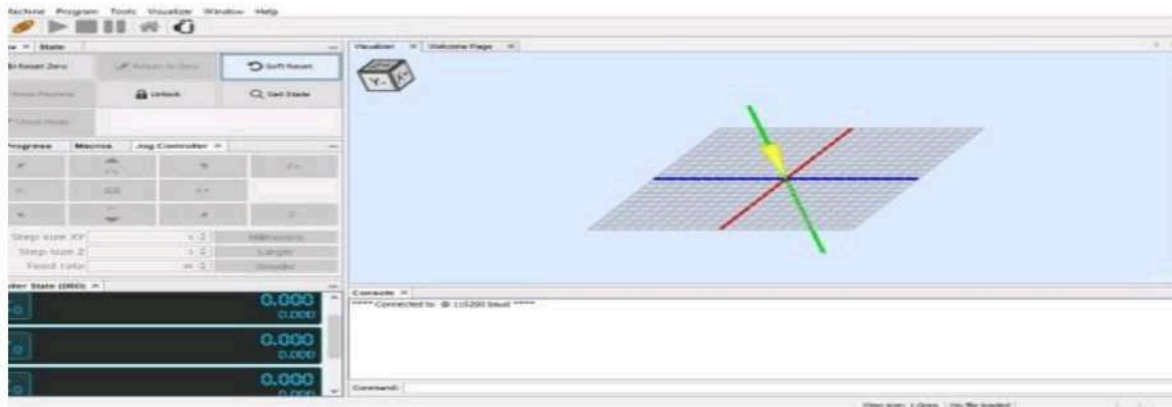


Fig: 4.12 : 3-D Software implementation



Fig: 4.13 : 2-D Software implementation

4.5.2 INKSCAPE

Inkscape is a free and open-source vector graphics editor used for creating and editing scalable graphics such as logos, illustrations, diagrams, and artwork. It provides a comprehensive set of tools for drawing, manipulating shapes, and adding text, colors, gradients, and effects.

Inkscape is a program for creating and editing vector graphics. It is the ideal tool for drawing logos and icons, creating (animatable) graphics for websites, for composing

posters and flyers, or for making patterns for use with cutting machines and laser engravers. It is also a good choice for drawing short comics, making art, building user interface mockups and making or editing diagrams created by other software. People use it for fun projects, such as map-making, creating birthday cards, painting on eggs, 2D game graphics and for many, many more purposes.

Key features of Inkscape include bezier curves, pen and pencil tools, path editing, layers, and object transformations. It also supports extensions and plugins, allowing users to enhance functionality and automate tasks. Inkscape's user-friendly interface and extensive documentation make it accessible to both beginners and experienced graphic designers, artists, and illustrators. Additionally, being open-source, Inkscape benefits from community-driven development and regular updates, ensuring continued improvement and innovation in vector graphics editing.

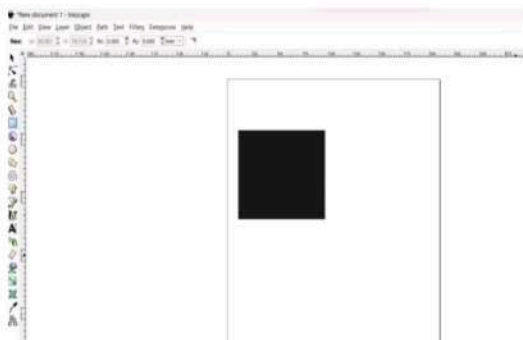


Fig: 4.14 : Inkscape simulator-1

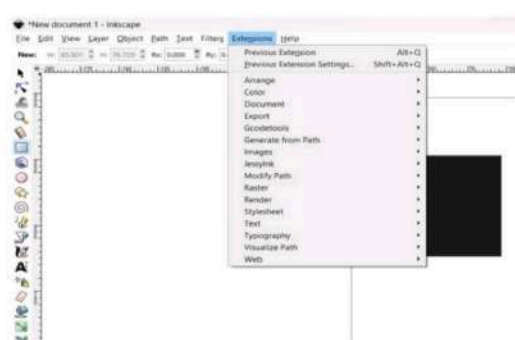


Fig: 4.15 : Inkscape simulator-2

4.5.3 GRBL LIBRARY

GRBL is an open source software or firmware which enables motion control for CNC machines. We can easily install the GRBL firmware to an Arduino and so we instantly get a low cost, high performance CNC controller. The GRBL uses G-code as input, and outputs motion control via the Arduino. The controller is written in highly optimized C utilizing every clever feature of the AVR-chips to achieve precise timing and asynchronous operation. It is able to maintain up to 30kHz of stable, jitter free control pulses. It accepts standards-compliant g-code and has been tested with the output of

several CAM tools with no problems. Arcs, circles and helical motion are fully supported, as well as, all other primary g-code commands. Macro functions, variables, and most canned cycles are not supported, but we think GUIs can do a much better job at translating them into straight g-code anyhow.



Fig: 4.16 : GRBL library

4.6 PROGRESSION REVIEW

Step 1: Disassembly DVD/CD Drives

First step to start building this CNC machine is to disassemble two DVD/CD drives and take off them the stepper motors. Use the screwdriver to open them and take off them the rails. Next step is to choose our base for this CNC machine. Finally we will

need to find something to attach the one of the stepper-rails vertically to our construction.

Step 2: X and Y axis

In this step X axis is attached to two plastic parts that we took from remaining 'garbage' stuff. We cut it to fit the construction. This is an easy procedure. Just make sure to put the Y axis straight to CNC base and the X axis vertically in 90 degree.

Step 3: The Z axis

That's the most difficult part of our construction. You will need something to attach it on X axis, a flat surface. On that surface you will attach the servo motor and the pen base. Pen (or pencil) must be able to move up and down with the help of servo motor. Servo motor must be able to move up and down the pen.

Step 4: Paper base

Now you will have to attach a wood (or plastic) surface on Y axis (5x5cm will be fine). On this you will put the paper piece to print your texts or images. Remember, printing area is 4x4cm

Step 5: The Circuit

Now that we have our construction ready, it's time to build the circuit and test stepper motors (X and Y axis). Watch the above image with breadboard circuit schematic. Steppers motors wiring is something that needs patient. On next step you will find a 'testing' code for x and y axis. If your steppers don't work properly you must find correct working combination by changing the cables between them and the L293D IC

On mine CNC , X axis motor connection are: L293 A: Pins 1 and 3 & B: 2 and 4, but on Y axis motor connection are A: 1 and 2 & B: 3 and 4

Step 6: Testing X and Y axis movement

Here is the X and Y axis testing code embedded using code bender For X axis: For Y axis: If you see any movement here that means that the stepper motors wiring is correct! if you don't, try to change the cables.

Step 7: Uploading the CNC code

Here is the main CNC code embedded using code bender In this part you will see your pen goes up. If don't, change pen Up and pen Down variables that controlling the servo motor. Press the "Run on Arduino" button and program your board from your browser!

Step 8: The GCTRL program

Now we are ready to print our first image! To do this we will use the gctrl.pde processing program. This program sends 'G code' images to the CNC plotter. What is G code? G code is a file with X,Y and Z coordinates. Header of this file is set to: M300 S30.00 (Servo down) G1 X10.00 Y10.00 F2500.00 G1 X20.00 Y10.00 F2500.00 M300 S50.00 (Servo up) Download Processing from here, now download and open GCTRL.pde application. Click the "play" icon/button to start the program. ~Watch the above image~ Now press 'p' and select your Arduino serial port. Press 'g' and select the 'drawing g code' file

Step 9: Make your own G code file

To make g code files that are compatible with this CNC machine you have to use the Inkscape. Inkscape is professional quality vector graphics software which runs on Windows, Mac OS X and Linux. It is used by design professionals and hobbyists worldwide, for creating a wide variety of graphics such as illustrations, icons, logos,

diagrams, maps and web graphics. Inkscape uses the W3C open standard SVG (Scalable Vector Graphics) as its native format, and is free and open-source software. Download and install Inkscape from here (Important: download 0.48.5 version) Now you need to install an Add-on that enables the export images to g code files. This add on can be found here with installation notes. Setup Inkscape for first use Open the Inkscape, go to File menu and click "Document Properties". See the 1st image above and make the changes, make sure to change first to "cm". Now close this window. We will use the area within 4 to 8 cm. See the 2nd image above.

How to print texts Put text, change font to Times New Roman and size to 22. Now click on cursor icon and center the text like the 3rd image above. Select Path from menu and "Object to Path". How to print images This is more difficult than texts. Images must have a transparent background. Drag and drop the arduino logo image (download it from files) in Inkscape. Click ok to the next window. Now you have to re-size the image to fit our printing area, see the 4th image above. Click Path from menu and "Trace Bitmap". Make changes as the 5th image above. Click ok and close the window. Now, move the gray scale image, and delete the color one behind it. Move the grey image to the correct place again and click from Path menu "Object to path". Export as g code Final, go to file menu, click save as and select g code. Click ok on next window. That's it! Ready to go! Use the gctrl.pde app to print the g code file on your new Arduino CNC Plotter.

We have supply the current in Arduino with USB DATA cable to transfer Data from Computer to Arduino Board Here we have used 3 Stepper Drivers to supply the G codes in Sequence to the stepper motors. Arduino will be mounted on CNC shield. CNC shield will be distributing the Current in the command of Arduino. CNC shield will be converting the command of G codes in digital pulse by Stepper motor. In X direction Stepper motor will be move left and Right ,Y direction stepper motor will be move in front and back direction, Z direction Stepper motor will be move in Up and down. We have made much difficult design via using this machine. The accuracy of this machines result is very high. So we have used in industry to reduce the cost of design printing and maintain accuracy level. Drafting and Scaling of CNC Plotter machine is very

precious. The research involved in developing this CNC-based foam cutting machine employs a comprehensive range of experimental methods to ensure its successful creation. Through meticulous design, manufacturing, assembly, and testing processes, the researchers have dedicated themselves to perfecting every aspect of the machine. Their unwavering commitment to excellence and relentless pursuit of innovation have resulted in a remarkable technological advancement that promises to revolutionize the way Foam is cut and shaped. This preliminary research phase provides valuable insights and knowledge that inform the subsequent stages of the process. Following the literature study, the mechanical and electronic design process takes place, wherein the intricate details of the machine's components and circuitry are meticulously planned and engineered. Once the design phase is complete, the mechanical and electronic assembly process ensues, during which the various parts and components are carefully integrated to bring the machine to life.

CHAPTER 5

RESULT & DISCUSSION

5.1 RESULT

5.1.1 *X and Y Axis Calibration process*

Voltage and temperature regulation play a vital role in the CNC-based foam cutting machine, specifically in controlling the temperature of the hot wire. The regulation process involves careful calibration of voltage and current to achieve the precise and optimal temperature required for the foam cutting process. Table 1.1

Table 5.1: *Y Axis Calibration Process - 1*

Y AXIS CALIBRATION PROCESS				
Stepper motor	Micro Stepping	Pulley Teeth	Belt Pitch	Result
Deg/step: 1.8	Pulse/step: 16	Pulley teeth: 16	Pitch: 2	Steps/mm: 100
Steps/rev: 200	Pulse/rev: 3200		mm/rev: 32	mm/step: 0,01

With the number of pulley teeth set at 16 and a belt pitch of 2 pitches, the stepper motor is configured with a default step angle of 1.8 degrees per step and a microstep setting of 16 pulses per step. These specifications are crucial in calibrating the X axis of the machine. Through careful calibration and testing, the results indicate that the machine achieves a precision of 100 steps per millimeter in its X axis movement. Next one, Table 2. shows the Yaxis calibration process on a NEMA 17 stepper motor.

Table 5.2 : Y Axis Calibration Process - 2

Y AXIS CALIBRATION PROCESS				
Stepper motor	Micro Stepping	Pulley Teeth	Belt Pitch	Result
Deg/step: 1.8	Pulse/step: 16	Pulley teeth: 20	Pitch: 2	Steps/mm: 80
Steps/rev: 200	Pulse/rev: 3200		mm/rev: 40	mm/step: 0,0125

With the number of pulley teeth as many as 20 teeth and belt pitch as many as 2 pitches, the default condition of the stepper motor is 1.8 deg/step with the number of micro steps as many as 16 pulses/step. Based on the default specifications of the machine components used, the Y-axis calibration results are 80 steps per mm

5.1.2 Temperature Variation & Current

Taking hot wire temperature measurement data based on voltage (V) and current (A) on the device using multimeter. Table 3. shows the minimum voltage used at 1.3 V obtained hot wire at 27°C temperature and maximum voltage used is 10.1 V on the grounds. If the voltage is greater than the maximum voltage, it will cause the hot wire (nikelin wire) smoldering which will then cause the cutting results to be less precise and offset will be large so that the measurement error will also increase and the cutting results are not maximum.

Table 5.3: *V, I & T Measurement*

Measurement		
Voltage (V)	Current (A)	Hot Wire Temperature (°C)
1,3	0,00	27
2,2	0,00	27
3,1	0,07	31
4,1	0,15	38
5,1	0,23	52
6,1	0,29	76
7,1	0,38	85
8,1	0,47	104
9,1	0,56	170
10,1	0,67	190

In this study, there are results and analysis of the trial system testing of foam cutting machine based on CNC 2 Axis using Hot Wire:



Fig:5.1: Side view

The detailed portrayal presented in Figure 5.1 provides an extensive view of the assembly process of the Arduino CNC foam cutting machine from a side-angle perspective. By presenting the machine from this viewpoint, viewers can develop a comprehensive understanding of its functionality and operational intricacies, leading to a deeper appreciation of its engineering excellence and craftsmanship. Furthermore, this visual representation serves as a valuable resource for in-depth analysis and address any issues that may arise during foam cutting operations. Whether for assembly guidance or performance optimization, aiding users in achieving optimal results and efficiency in CNC foam cutting endeavors. optimal results and efficiency in CNC foam cutting endeavors.



Fig 5.2: Frontal view

The Fig 5.2, portraying the fully assembled Arduino CNC foam cutting machine, offers a meticulous portrayal of the system's frontal aspect. It meticulously showcases the intricate interplay of components and the structural arrangement. From this vantage point, observers gain a comprehensive understanding of the machine's design, encompassing the placement of stepper motors, the precise positioning of the cutting wire, the solidity of the frame, and the seamless integration of electronic elements. This detailed visual insight enables enthusiasts and practitioners alike to grasp the machine's inner workings, facilitating comprehension of its operational intricacies. Moreover, the figure serves as a crucial reference point for assembly procedures, providing clear guidance on component placement and wiring configurations.

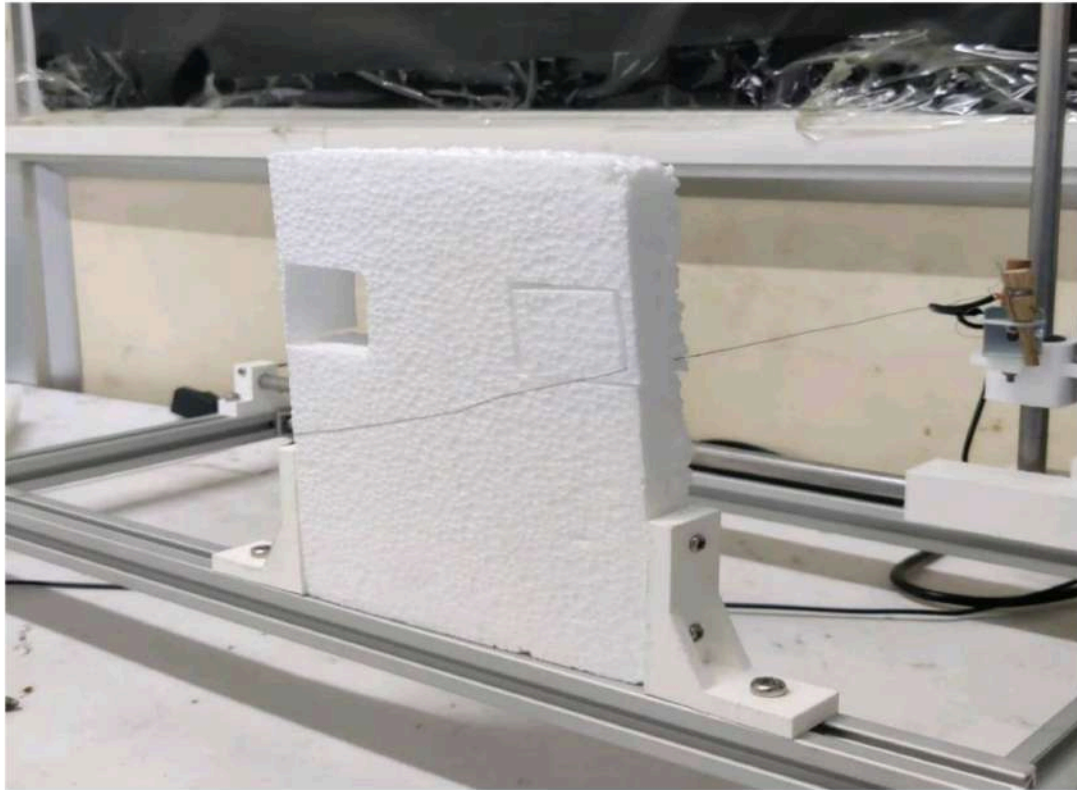


Fig 5.3: Foam cutting on process

The aforementioned Fig 5.3 offers a detailed portrayal of the ongoing foam cutting process, showcasing the utilization of a nichrome wire to meticulously carve thermacol material into a square-shaped 2D block. This visual representation provides a vivid depiction of the intricacies involved in foam cutting, highlighting the precise application of heat to shape the thermacol material. The nichrome wire, renowned for its exceptional heat-resistance and conductivity properties, facilitates efficient heat transfer to the foam, enabling controlled and precise cutting. By capturing this pivotal moment in the cutting process, Fig 5.3 affords viewers a comprehensive understanding of the CNC machine's capabilities and the sophisticated techniques employed in foam fabrication. This insightful depiction not only showcases the machine's precision but also underscores the craftsmanship and technological innovation that has been and inherent in the foam cutting processes.

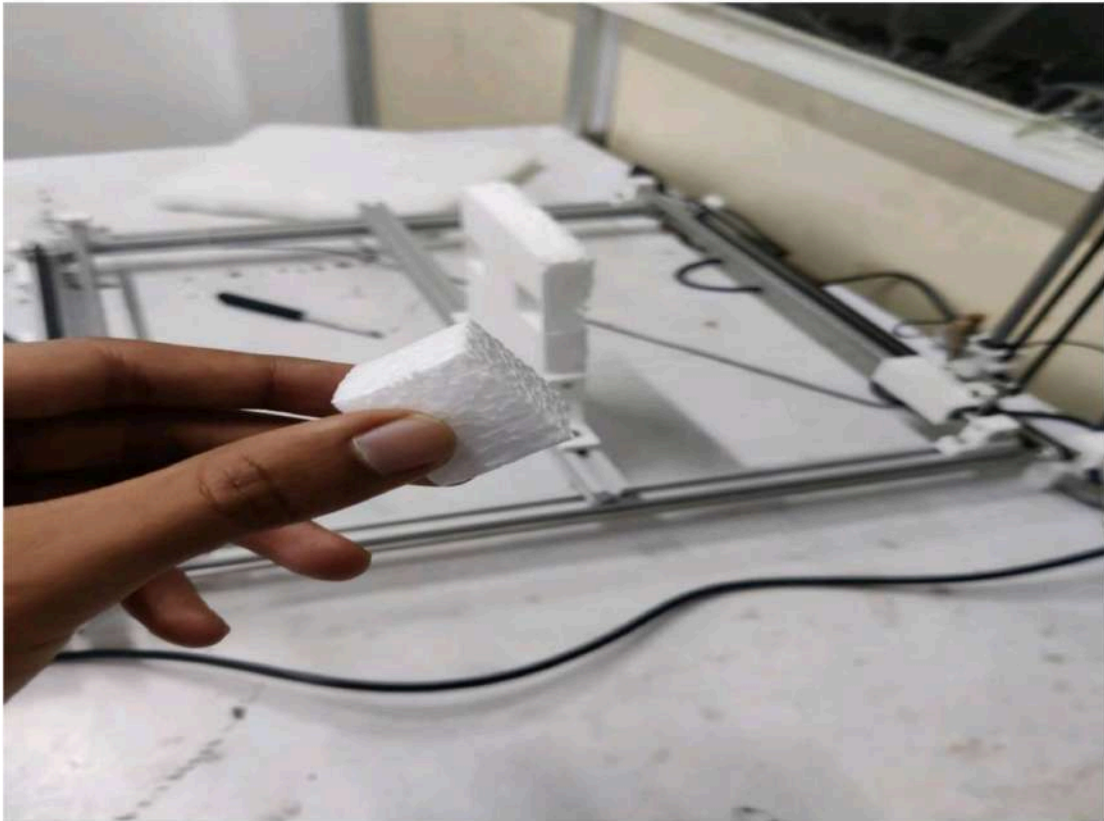


Fig 5.4: Final result

The Fig 5.4, titled "Foam cutting on process," offers a captivating portrayal of the foam cutting procedure in action. This visual representation vividly illustrates the intricate process of transforming a square-shaped 2D block into its final, sculpted form. By showcasing the ongoing foam cutting operation, the image captures the essence of precision and accuracy inherent in CNC foam cutting machines. It provides a compelling insight into the transformative nature of the cutting process, highlighting the machine's remarkable ability to execute complex designs with finesse and efficiency. Through this depiction of the square-shaped block as it evolves during the cutting process, Fig 5.4 offers valuable insights into the capabilities of CNC foam cutting machines and underscores the craftsmanship involved in their operation. This visual representation serves as a testament to the technological innovation and precision engineering that drive foam fabrication processes, showcasing the potential of CNC machines to produce intricate and refined foam-based designs.

5.2 IOT IMPLEMENTATION

The implementation of IoT enables the use of CNC machine monitoring solutions, on a larger scale IIoT creates machine-to-machine interaction that results in automated operations and less manual intervention. Sensors embedded on CNC machines measure different parameters and share them to a platform from where the condition and functioning of the machines can be effectively supervised. The ESP32 is a versatile microcontroller developed by Espressif Systems, widely used for IoT (Internet of Things) applications due to its integrated Wi-Fi and Bluetooth capabilities.

- **Dual-Core Processor:** The ESP32 features a dual-core processor, offering higher processing power and multitasking capabilities compared to single-core microcontrollers. This makes it suitable for handling complex IoT applications and tasks.
- **Wi-Fi Connectivity:** Integrated Wi-Fi connectivity allows the ESP32 to connect to wireless networks, enabling communication with other devices and the internet. It can be used for data transmission, remote monitoring, and control in IoT projects.
- **Bluetooth Connectivity:** In addition to Wi-Fi, the ESP32 also supports Bluetooth connectivity, making it suitable for applications such as Bluetooth Low Energy (BLE) sensors, beacons, and wearable devices.
- **Low Power Consumption:** The ESP32 is designed to operate efficiently on low power, making it suitable for battery-powered IoT devices. It features various power-saving modes and optimizations to prolong battery life.
- **Rich Peripheral Set:** The ESP32 offers a rich set of peripherals including GPIO pins, SPI, I2C, UART, ADC, DAC, and more, providing flexibility for interfacing with sensors, actuators, and other external devices.

- **Security Features:** It includes hardware-based security features such as Secure Boot, Flash Encryption, and cryptographic accelerators, ensuring secure communication and data protection in IoT applications.
- **Development Environment:** The ESP32 can be programmed using various development environments including the Arduino IDE, Espressif IDF (IoT Development Framework), and MicroPython, making it accessible to a wide range of developers.
- **Applications:** The ESP32 is suitable for a wide range of IoT applications including home automation, smart agriculture, industrial automation, environmental monitoring, wearable devices, and more.

Overall, the ESP32 is a powerful and versatile microcontroller platform that enables developers to create innovative IoT solutions with ease.

Its combination of processing power, connectivity options, low power consumption, and rich peripheral set makes it a popular choice for IoT projects of all scales.

5.2.1 Scheduling Maintenance

From IOT based CNC machine monitoring, they can, therefore, track the condition of machines at all times from a distance. This remote and real-time monitoring helps the person-in-charge of the machines to schedule a CNC for inspection or repairs. Alternatively, they can also configure their CNC machines to send alerts or notifications to operators whenever machines deem themselves due for tuning or maintenance. In other words, the machine will raise red flags about complications such as a rise in temperature, increased vibrations, or tool damage.

5.3.2 Machine Uptime Monitoring

Capabilities of IoT based CNC solutions are not only limited to remote monitoring and scheduled maintenance for CNC machines. By using IoT systems and leveraging its real-time alert feature, factories can now reduce their machine downtime and increase overall equipment effectiveness. Alerts shared by machines can be used to take proactive measures and sudden breakdown of tools or any other component of a CNC machine. We provided an exact same solution to one of our clients by configuring our IoT energy monitoring solution for their CNC machines. Before the implementation, the client was having trouble with the subsequent breakdown of their machines. Our IoT solution helped them to gain a clear insight into the running hours of their CNC machines, which in turn gave them an accurate idea of how they were utilizing their production time. Similarly, a machine uptime monitoring solution can be used for a series of CNC machines to not only improve their functioning but also to improve machine to machine synchronization in an industrial establishment and achieve operational excellence.

5.2.3 Improved Worker Safety

For a larger implementation, the technology of IIoT can also be used to reduce manual efforts, or in other words, remove the potential of workers' injury from the equation of a factory's operation. The mutual communication between machines will result in a better understanding between different electromechanical devices, which in turn will lead to automatically-driven and less labor-dependent operations in a factory.

Many companies are already working towards the development of smart robots and machines that can perform pre-programmed tasks and respond to the ongoing needs of CNC machines to reduce the burden of standard operation from the manual workforce. Other than decreasing injuries in the workshop, this will also help in reducing material wastage and improving the efficiency of machines, which in turn will result in increased production of accurate components in less time duration.

5.2.4 Product Quality Control

With the IoT working in conjunction with CNC machining efforts, companies can outfit each and every part produced with a tiny sensor that connects it to a larger network. This makes it easier not only to track the products throughout any subsequent shipping and assembly efforts, but also to recognize and address production errors. If sensors detect a defect, the machining process can be halted if necessary until it's sorted out.

5.2.5 Preventative Maintenance

Preventative maintenance is one of the most cited benefits of the IoT in manufacturing, and it is certainly a factor where CNC machining is concerned as well. As Particle put it, the IoT allows for real-time, remote condition monitoring – not only of products, as described above, but of the machines themselves. With CNC machining mechanisms essentially left alone to produce orders, IoT-connected sensors can make sure that they are doing so adequately, alert management to any issues, and even give advance notice of any general maintenance or upkeep needs.

5.3 PROBLEM DEFINITION

The available Arduino controlled CNC machines are having only 2 axis movement. The structure is weak and can machine foam only. The problem definition for an IoT-based Arduino CNC foam cutting machine involves addressing several key challenges and opportunities:

- **Limited Connectivity:** Traditional CNC foam cutting machines lack connectivity features, making it difficult to monitor and control the cutting process remotely. This restricts the flexibility of foam cutting operations.
- **Manual Monitoring and Control:** Operators often need to manually monitor the cutting process and adjust parameters as needed, leading to inefficiencies and potential errors. This manual intervention also limits the scalability of foam cutting operations.

- **Data Management and Analysis:** There is a lack of real-time data collection and analysis capabilities in traditional foam cutting machines. This hinders the ability to optimize cutting parameters, predict maintenance needs, and improve overall efficiency.
- **Limited Automation:** Traditional foam cutting machines lack automation features, requiring manual intervention for job scheduling, material inventory tracking, and order management. This results in increased labor costs and reduced productivity.
- **Safety Concerns:** Foam cutting machines pose safety risks, especially when operating in industrial environments. Lack of real-time monitoring and safety features can lead to accidents and injuries.
- **Environmental Impact:** Inefficient foam cutting processes can result in material wastage, energy consumption, and environmental pollution. There is a need for more sustainable and eco-friendly foam cutting solutions.

5.4 PROBLEM IDENTIFICATION AND TESTING

Two major parameters that are responsible for the smoothness of cut and their accuracy are the temperature of the hot wire and the feed rate in mm/s. The temperature of the hot wire is regulated using a variable power supply, which acts as a cutting tool for foam. The current-carrying wire will vaporize the foam. Feed Rate is the speed of a cutting tool i.e. the hot wire at which it is moving; this is controlled using a stepper motor via G code & microcontroller. In the cutting process, a hot wire heated by passing current is directed through a block of foam. The wire is heated at 200°C, as polystyrene foam melts at around 200°C, but attains its flowing state at 100°C. This heated wire vaporizes the foam at the cutting location. This slightly melts the surface of the foam & leaves an open gap at the cut location. This gap is called a kerf. The width or thickness of the kerf depends upon the cutting temperature and cutting speed. It varies

with variations in temperature and cutting speed. Kerf is directly proportional to temperature and cutting speed. Kerf can be controlled using the CNC system implemented in this project.

Testing was done to find out Kerf's width. It is the width of the gap between foam parts that are separated by the cut. From Testing it is pointed out that the kerf width value varies with the amount of time and current supplied to the wire. Kerf values vary with the thickness of cutting wire for the proposed model.

5.5 WORKING

We have supply the current in Arduino with USB DATA cable to transfer Data from Computer to Arduino Board Here we have used 3 Stepper Drivers to supply the G codes in Sequence to the stepper motors. Arduino will be mounted on CNC shield. CNC shield will be distributing the Current in the command of Arduino. CNC shield will be converting the command of G codes in digital pulse by Stepper motor. In X direction Stepper motor will be move left and Right ,Y direction stepper motor will be move in front and back direction, Z direction Stepper motor will be move in Up and down.

The system used by Arduino Uno as the process is to control the stepper motor and Bluetooth connection . In designing a 3-axis CNC machine control system, several processes are Arduino Uno and CNC Shield are turned on with a power supply, then to the input section the G-code file is transferred to Android, then with the help of the Android Controller GRBL application it can transfer it to Arduino via Bluetooth, after that Arduino processes commands and then transmits commands to CNC Shield, The CNC Shield shares these commands with the installed motor drivers. The G-code file is transferred to Android, and with the help of the Android Controller GRBL application, it can transfer to Arduino via Bluetooth. After that Arduino processes the command and then transmits the command to the CNC Shield, the CNC Shield divides the command to the installed motor driver, Then the driver runs and controls the stepper motor with a limit switch as a movement limiter.

5.6 SWOT ANALYSIS

Swot Analysis evaluates Strengths, Weaknesses, Opportunities, and Threats related to a business or project. It helps identify internal strengths and weaknesses, as well as external opportunities and threats, aiding in strategic planning and decision-making.

5.6.1 STRENGTH

- CNC machines can be used continuously 24x7 throughout the year and only need to be switched off for occasional maintenance.
- CNC machines are programmed with a design which can then be manufactured hundreds or even thousands of times. Each manufactured product will be exactly the same.
- Less skilled/trained people can operate CNC machines unlike manual lathes / milling machines etc. which need skilled engineers.
- CNC machines can be updated by improving the software used to drive the machines
- Training for correct use of CNC machines is available through the use of 'virtual software'. This software is like a computer game that allows the operator to practice using the CNC machine on the screen of a computer.
- Modern design software allows the designer to simulate the manufacture of his/her idea. There is no need to make a prototype or a model. This saves time and money.

5.6.2 WEAKNESS

- The machine runs in a slow pace and generates excess heat which causes the heat sink to be heated quickly.
- A slight error may remain on the image file after it has been plotted due to one side of the Y-axis fixed to the moving part and the other end is free to move.
- The Z-axis is not very rigid so it causes slight vibration

5.6.3 APPLICATION

- CNC foam cutter is suitable to carve EPS foam molds, wood molds and other non-metal molds, especially for car molds, ship molds, aviation molds or train molds. The machine also specializes in processing good foam products in other industries, such as sculpture, decoration, packaging and furniture industries..
- Foam architecture detail covered with strengthening nets and stuccoes are becoming very popular, due to their light weight, easy assembly, precision of realization, price and the fact that they are environmentally friendly.
- There is no machines as useful as a Hot wire CNC foam cutters when building fair stalls and film or theatre decorations. Its speed and cutting precision allow creating every set and stage design in short time and without spending a lot of money.
- In medical field they are use in various components as EKG pads, Medical mattresses and furniture padding, Examination table padding, Foam for medical equipment, Sponges for cleaning instruments and Orthopedic braces.
- The fabrication of foam products and solutions for cleaning applications are Magic cleaning products with Melamine, Sponges with cellulose foam, Hand sponges, Sponge mops, Auto care products and Polishing Pads.
- The fabrication of foam products and solutions for construction applications are Expansion joint materials, Chinking foams, Closure strips, Roof Venting and Gutter guards
- The fabrication of foam products and solutions for specialty packaging are Gun case inserts, Instrument, Computer end caps and Multi- layer containers.
- The fabrication of acoustical foam products and solutions are Foam baffles, Noise cancellation products, Speaker grills and Cabinet Damping.

CHAPTER 6

SUMMARY & CONCLUSION

6.1 SUMMARY

In this paper we have presented the concept of a low cost three-axis mini CNC plotter. The existing CNC machines are of high cost, difficult to maintain and requires highly skilled operators. Our CNC plotter overcomes these problems. It is of low cost and easy to control and there is no need of highly skilled operators. It can be used for long hours at a stretch which is not possible in existing ones. It is hoped to extend this work for future development. Design of this CNC foam cutter Machine will be feasible & cost effective for makers or hobbyists. This design can be made with easily accessible parts & components. Open-source software used for G code generation will be an additional benefit to save time & cost of development.

This design will resolve challenges & will be a solution for accuracy, precision, for situations were constant This machine cut foam Material used for cutting trials was vinylbenzene (thermacol). completely different power input & completely different cutting speed were modified in G codeThe surface texture on a sample cut with constant current changes reckoning on the cutting force gift at that position. High cutting forces lead to a wavy surface. Low non-zero cutting forces give the smoothest surface because the wire shears the adjacent liquified plastic filling within the cell boundaries. once cutting forces area unit zero the wire is sufficiently hot to soften the froth previous the wire resulting in a granular surface texture because of discriminatory melting at the cell boundaries.

This cutting force & temperature may be controlled by finding out properties of fabric & exploitation feedback system. UAV is rising technology in Asian country and Aeromodelling is hobby of all time. These field uses foams as for prototyping, production, mildew creating of recent model. move amateur and makers.

6.2 STANDARDS

The NIST Cybersecurity Framework provides adaptable guidelines for improving cybersecurity risk management. Applied to IoT-enabled CNC foam cutting machines, it involves assessing risks, managing assets, implementing security controls like access restrictions and data encryption, and continuously monitoring for threats. In case of incidents, having a robust response plan is crucial, involving isolation of compromised devices and swift recovery procedures. Collaboration among stakeholders ensures comprehensive security measures. By adhering to these principles, manufacturers can enhance the security posture of CNC foam cutting machines, reducing the likelihood of cyber threats impacting their operation and safety.

ANSI B11 series of standards, established by the American National Standards Institute (ANSI), delineates safety requirements for diverse machinery, encompassing CNC machines. These standards offer comprehensive guidelines for safeguarding operators, mitigating risks of accidents, and ensuring workplace safety. They address various aspects such as machine design, installation, operation, maintenance, and personnel training. Specific standards within the series cover different types of machinery, including milling machines, turning machines, and machining centers, each tailored to address the unique hazards associated with these machines. By adhering to ANSI B11 standards, CNC machine manufacturers and users can implement robust safety measures, such as emergency stop controls, protective barriers, interlocking mechanisms, and ergonomic design principles. Compliance with these standards not only enhances workplace safety but also fosters confidence among operators and regulatory authorities regarding the reliability and integrity of CNC machine operations.

6.3 CONSTRAINTS:

Despite the project's innovative aspirations, several constraints posed challenges throughout the development process. One significant constraint was the limited availability of resources, including time, funding, and technical expertise. With strict deadlines and budget constraints, we had to make strategic decisions regarding resource allocation and task prioritization to ensure project completion within the specified timeframe and budgetary constraints. Additionally, the project faced constraints related to hardware and software compatibility, requiring meticulous planning and thorough testing to ensure seamless integration and functionality. Furthermore, constraints related to regulatory compliance and safety standards necessitated careful consideration and adherence to established guidelines to mitigate potential risks and ensure user safety. Moreover, environmental constraints, such as space limitations and power consumption requirements, influenced design decisions and system configurations. Despite these challenges, proactive management and creative problem-solving strategies enabled us to navigate these constraints effectively and deliver a successful project outcome.

6.4 TRADE-OFFS:

In the development of our project, we encountered several trade-offs that involved balancing competing objectives and considerations. One trade-off was between performance and cost, where we opted for cost-effective components that met the project requirements while keeping expenses within budget. Another trade-off was between complexity and simplicity, as we aimed to design a system that was user-friendly and easy to operate while still offering advanced functionality. Additionally, we faced trade-offs between customization and standardization, opting for a modular design that allowed for flexibility while ensuring compatibility and interoperability. Overall, these trade-offs were carefully evaluated to achieve the optimal balance between competing priorities and constraints in our project.

REFERENCE

- [1] Hadley Brooks, David Aitchison, "A review of state-of-the-art large-sized foam cutting rapid prototyping and manufacturing technologies", *Rapid Prototyping Journal*, Volume 16 Issue 5, 2010, pp. 318-327.
- [2] Hadley Brooks, "Plastic Foam Cutting Mechanics for Rapid Prototyping and Manufacturing Purposes", University of Canterbury, Christchurch, New Zealand, 2009.
- [3] Luka Ivanovskis, "Four Axis Hot-Wire Foam Cutter Controlled by Mindstorms EV3", Saimaa University of Applied Sciences Faculty of Technology, Lappeenranta, 2017.
- [4] Sanjay S N, Sidhvin D M, Sachin Hegde, K P M Unni Krishnan, "Design and Fabrication of Compact CNC Hot Wire Foam Cutting Machine", *International Journal of Science and Research (IJSR)*, 2017.
- [5] Sulkowski W W Nowak K Sulkowska A Wolinska A Bajdur W M Pentak D Mikula B 2009 Study of the Sulfonation of Expanded Polystyrene Waste and of Properties of the Products Obtained *Pure Appl.Chem* 81 2417-2424
- [6] V.K. Pabolu and K.N.H. Shrinivas, "Design and implementation of a three - dimensional CNC machine", *Int. J. Computer Science and Engineering*, vol. 2, pp. 2567-2570 2010.
- [7] Plastic Foam Cutting Mechanics for Rapid Prototyping and Manufacturing Purposes. s.l. : Engineering: Theses and Dissertations [1828], Vols. University of Canterbury, New Zealand.
- [8] A review of state-of-the-art large-sized foam cutting rapid prototyping and manufacturing technologies. Aitchison, Hadley Brooks and David. s.l. :

Department of Mechanical Engineering, Vols. University of Canterbury, Christchurch, New Zealand.

- [9] I. Nae and T. Andrei, "Designing and building a CNC router using stepper motors", Serial Technical, vo. LXII, pp. 55-62, 2010 .

Pahole, L. Rataj, M. Ficko, S. Klancnik, S.Brezovnik, M.Brezocnik, and J. Balic, "Construction and evaluation of low cost table CNC milling machine",

RE-2022-227374-plag-report

ORIGINALITY REPORT

16%

SIMILARITY INDEX

11%

INTERNET SOURCES

8%

PUBLICATIONS

9%

STUDENT PAPERS

PRIMARY SOURCES

1

i-scholar.in

Internet Source

3%

2

sist.sathyabama.ac.in

Internet Source

2%

3

www.rame.org.in

Internet Source

<1%

4

vpmpme.files.wordpress.com

Internet Source

<1%

5

repository.sustech.edu

Internet Source

<1%

6

www.biz4intellia.com

Internet Source

<1%

7

alkej.uobaghdad.edu.iq

Internet Source

<1%

8

jartel.polinema.ac.id

Internet Source

<1%

9

www.coursehero.com

Internet Source

<1%