RV Educational Institutions ®
RV College of Engineering ®

Autonomous Institution Affiliated to Visvesvaraya Technological University, Belagavi

Approved by AICTE, New Delhi, Accredited By NAAC, Bengaluru And NBA, New Delhi

Go, change the world

DEPARTMENT OF MECHANICAL ENGINEERING

Development Of IOT Controlled Module for Electrochemical Discharge Machining Application

MINOR PROJECT REPORT

Submitted by

RITHWIK SHANKAR RAJ ***1RV19ME087***

Under the Guidance Of

Prof. Jinka Ranganayakulu

Assistant Professor

Dept. of Mechanical Engineering

RV College of Engineering, Bengaluru - 560059

In partial fulfillment for the award of degree of

Bachelor of Engineering in

Mechanical Engineering 2020-2021

ABSTRACT

‘’The motivation for this project was to design and develop an IOT controlled module for Electro-chemical Discharge Machining application that can be used for micro machining of non-conducting material such as glass. The goal was to micromachining the workpiece, and to control the machining through IOT, which involves the utilization of Arduino U no R3 along with other components like stepper motors, Arduino Uno, IR sensor, Node MCU, Bluetooth modules, etc.’’

‘’The machine was successfully demonstrated during the presentation on 04/08/2022. The movement of the stages have been carried out by remote control and also by the use of G-Codes. The machining of the workpiece has been carried out using the ECDM process. Very fine machining of components can be carried out with the provision for slow feed rates for increased surface finish and quality.’’

‘’This machine concept can be commercially used or implied in making industrial products. The apparatus has been tested for different feed rates and fine holes have been successfully machined on the workpiece. The apparatus can be further extended for machining of micro-channels for microfluidic devices and MEMS which find extensive use in biomedical and electronics industries. The programming software used in making the code is Arduino IDE codes and C language.’’

TABLE OF CONTENTS

SCOPE

In this project it is aimed to develop an IOT controlled module for electrochemical discharge machining that can be operated remotely using mobile phone network. This machine has been programmed to perform machining of non-conducting, brittle, hard and low-machinable engineering materials. The power module has been developed using Arduino as a platform. The setup has been developed to perform machining of components and can be controlled remotely. Sensors have been used to achieve this objective. The construction of the machine circuit is comprehensive and compact. The idea proposed in this project is to repurpose and retrofit the Electrochemical Discharge Machining setup. A power module has also been developed and IOT has been implemented to provide live feedback of the operating conditions and to facilitate remote control of the machine. Electrochemical Discharge Machining can be used for a wide range of applications including microfluidics, machining of non-conducting materials like glass, ceramics, etc. Microfluidic devices have a large application in the medical and bio-technological industry: They are widely used in procedures such as flow cytometry, PCR amplification, DNA analysis, separation and manipulation of cells, and cell patterning.

‘

Motivation

Market Motivation: Micro-machining is in high demand in the market. Electrochemical Discharge Machining (ECDM) is a highly efficient method for the production of high-quality components especially in the domain of biochemistry, biomedicine and electronics.

Industrial Motivation: Electrochemical Discharge Machining can be used to machine non-conducting materials like glass, ceramics, etc. The fine speed and feed control can be used to machine workpieces and components for Micro-Electromechanical Devices (MEMS) and Microfluidics applications. Incorporating IOT can also assist in monitoring the operating conditions and can facilitate remote and indirect control of the machine.

Research Motivation: ECDM method can be used for accurately machining non-conducting materials like quartz, glass, composites, ceramics etc. Microfluidics is an important research application wherein the microfluidic devices can be manufactured accurately using the ECDM method.

Societal motivation: Microfluidic devices have a large application in the medical and bio-technological industry: They are widely used in procedures such as flow cytometry, PCR amplification, DNA analysis, separation and manipulation of cells, and cell patterning.

Knowledge Motivation: During execution of the project, students learn about Arduino-uno IDE, AF Motor library, new ping library, Infrared Sensor library, CNC codes, Toolpath Generation, Gears and machine design, thermocouple and temperature measurement libraries, use of Bluetooth modules, IOT control applications, etc.

Environmental Motivation: ECDM method is a very effective method for machining non conducting materials. The waste generated is very minimal and is not hazardous. It is much more efficient and less harmful to the environment than other forms of non-traditional machining operations like chemical machining.

Literature Review

Reference	Contribution	Scope for research work
Baoyang Jiang, Jun Ni: `MICRO-MACHINING OF GLASS USING ELECTROCHEMICAL DISCHARGE ASSISTED CUTTING', Proceedings of the ASME 2016 International Manufacturing Science and Engineering Conference MSEC2016 June 27-July 1, 2016, Blacksburg, Virginia, USA MSEC2016-8759	Glass is a hard-to-machine material with vast industrial application. Electrochemical discharge machining (ECDM) is a non-traditional machining technology that has shown potential for effective glass machining. This work provides results of extensive research on the micro-machining of glass using the ECDM process and focuses on parameters such as material removal rate, surface finish and geometric accuracy.	Micro-machining of glass using ECDM has several parameters that need to be considered. Material removal rate, surface finish and geometric accuracy differ for various cases. The required accuracy for a workpiece can be determined by varying these parameters.
Liu Y, Zhang C, Li S, Guo C, Wei Z. Experimental Study of Micro Electrochemical Discharge Machining of Ultra-Clear Glass with a Rotating Helical Tool. Processes. 2019; 7(4):195.	Sets of experiments were carried out to investigate the machining localization of ECDM with a rotating helical tool on ultra-clear glass. This paper discusses the effects of machining parameters including pulse voltage, duty factor, pulse frequency and feed rate.	The pulse voltage, duty factor, pulse frequency and feed rate are important parameters involved in the machining of the glass workpiece. The result of the paper can be used to set optimum values of these parameters for machining the glass workpiece in the setup.
Wansheng Zhao, Mo Chen, Weiwen Xia, Xuecheng Xi, Fuchun Zhao, Yaou Zhang, Reconstructing CNC platform for EDM machines towards smart manufacturing, Procedia CIRP, Volume 95, 2020, ISSN 2212-8271	CNC is important for controlling the ECDM process. This paper gives an overview of the layout and setup of the structure of CNC for EDM	The CNC layout for the ECDM set up can be adapted from the paper. Further for automation and optimisation of the CNC setup IOT and other software components such as Deep Learning can be incorporated move. In such a way the robot works

Research Objectives

- Develop the circuits and related hardware and software components for the purpose of machining a workpiece using Electrochemical Discharge Machining by incorporating IOT
- Re-purpose the existing setup and carry out tests for machining glass workpieces

Main Objectives of the Project

1. Re-purpose and retrofit Electrochemical Discharge Machining Setup
2. Develop power module circuitry for the ECDM setup
3. Development of IOT controlled module for tool feed, rotation and work table movement.
4. Preliminary experimentation to validate the developed IOT enabled ECDM module

REPORT ORGANIZATION

CHAPTER 1 INTRODUCTION

CHAPTER 2: DEVELOPMENT OF CIRCUITS AND INITIAL SETUP

CHAPTER 3 PROJECT METHODOLOGY

CHAPTER 4 EXPERIMENTAL SETUP

CHAPTER 5 RESULTS AND DISCUSSION

CHAPTER 6 CONCLUSION AND FUTURE SCOPE

Chapter 1: Introduction

1.1 OVERVIEW

It is a complex combination of Electrochemical machining (ECM) and Electric Discharge machining (EDM). The ECDM process involves melting and chemical etching of the workpiece due to high electrical energy discharged on the tip of the electrode during electrolysis. One is the tool electrode, which is used to produce desired machined shape, and the other is the counter electrode or auxiliary electrode made as anode. The workpiece and counter electrode (anode) are immersed in an electrolyte solution. Electrolysis starts when a voltage is supplied by a direct current (DC) power source between the tool electrode and counter electrode.

The schematic diagram for Electrochemical Discharge Machining is as shown in Fig 1.1:

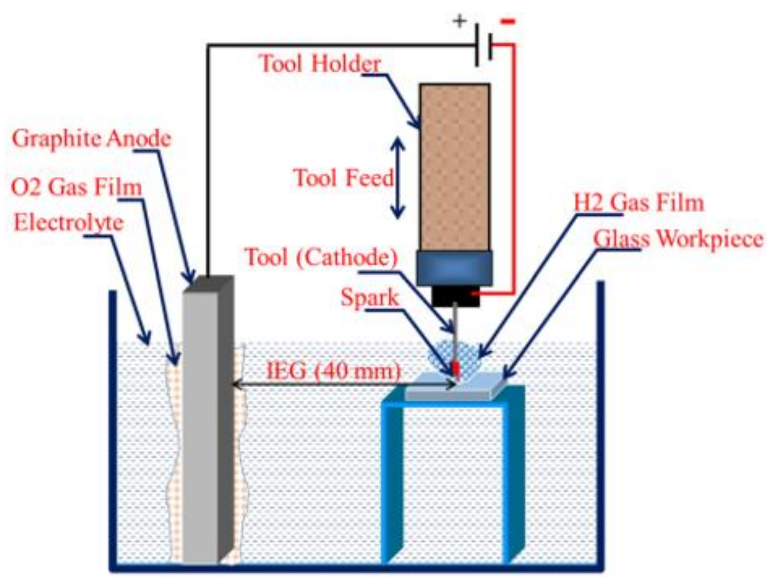

Fig 1.1 Schematic of ECDM setup

1.1 PRINCIPLE OF ELECTROCHEMICAL DISCHARGE MACHINING

Electrochemical Discharge machining (ECDM) process combines the principle of both ECM and EDM. The tool (generally cathode) and the anode (which is very large in comparison with tool diameter) are dipped in aqueous solution of the electrolyte. When DC is applied electrolysis takes place. The electrolytic reactions take place at the electrodes when the voltage at the inter-electrode gap of the machining zone increases beyond the required value.

Reactions at cathode result in the production of hydrogen due the chemisorption of water molecules on the electrode surface (Volmer's reaction) and by desorption either by Heyrovsky reaction which is an electrochemical reaction or by Tafel reaction which is a chemical reaction.

M + H_2O + e^- → M-Hads + OH^- (Volmer reaction)

M-Hads + M + H_2O + e^- → 2M + H_2 + OH^- (Heyrovsky reaction)

M-Hads + M-Hads → 2M + H_2 (Tafel reaction)

The reactions at anode for oxygen evolution

$2H_2O \rightarrow O_2 + 4H^+ + 4e^-$ (Acidic electrolyte solution)

$4OH^- \rightarrow O_2 + 2H_2O + 4e^-$ (Alkaline electrolyte solution)

When the voltage is increased, owing to the small dimension of the tool compared to anode, current density at the tool tip increases leading to the formation of a bubble layer around the electrode. When critical voltage is reached the bubbles coalesce into a gas film around the tool electrode. When sufficient potential difference is created between the gas film and the gas-film-electrode interface, electrical discharges occur between the interfaces.

The voltage-current characteristics of water decomposition, which directly relates the discharge phenomenon is shown in Fig 1.1.

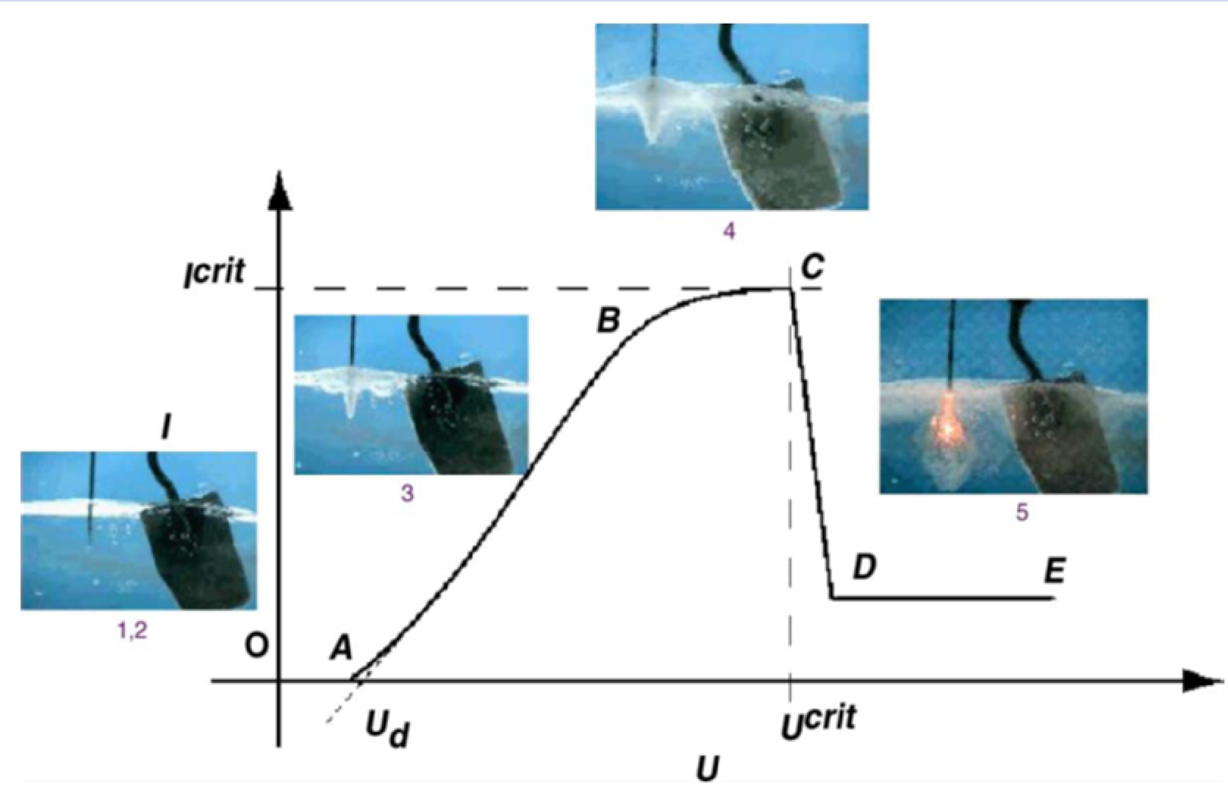

Fig 1.2 V-I characteristics of spark discharge

The electrochemical discharge is classified into five regions based on the stationary current:

1. Thermodynamic and over-potential Region:

Here the voltage supplied is less than decomposition potential Vd. Hence no current flows between the electrolytes and no significant electrolysis occurs.

2. Ohmic region AB:

As voltage is increased, current increases nearly linearly with it. Decomposition of water into hydrogen and oxygen starts, leading to the evolution of bubbles and beginning of formation of the bubble layer.

3. Limiting current region BC:

Limiting value of mean current, I, is reached and is almost constant in this region. Bubbles start evolving in larger sizes and the bubble layer is formed. The limiting current region ends when the voltage reaches Vcrit.

4. Instability region CD:

Beyond critical voltage Vcrit the current drops very rapidly with increase in terminal current. A gas film is formed around the working electrode and the electrolyte resistance diverges.

5. Electrochemical discharge region DE:

Due to the formation of the gas film the working electrode is completely isolated from the electrolyte. Electrochemical discharges take place through the gas film and are used for machining.

1.2 MECHANISM OF MATERIAL REMOVAL FOR GLASS

During electrochemical discharge machining of borosilicate glass, sublimation of the glass surface occurs leading to the etching of the majority of the surface by OH^- radicals, reduction in viscosity of glass at the zone of electrochemical discharges due to local heating and formation of microcracks. The temperature at the machining zone is determined by:

- Spark intensity
- Movement of electrolyte in the machining zone
- Gap between the work-piece and electrode

The chemical reaction occurring with ECDM with glass work-piece and NaOH electrolyte is shown in the schematic diagram given in Fig 1.3. Sodium ions (Na^+) and Hydroxide ions (OH^-) are adsorbed on the glass surface, which leads to breakage if Si—O—Si bond and changed into Si—O—Na bond. The Sodium bond (Na—O) is weaker than the Silicon bond (Si—O). Due to this the binding force of -Na—O- in Na_2SiO_2 is weak, making the Na_2SiO_2 weak so that it is easily broken by electrochemical discharges and easily soluble in water. Hence the material can be melted and machined by the thermal energy in electrochemical discharges.

The chemical reaction is represented by the following equation:

$SiO_2 + 2NaOH$ à $Na_2O\text{-}SiO_2 + H_2O$

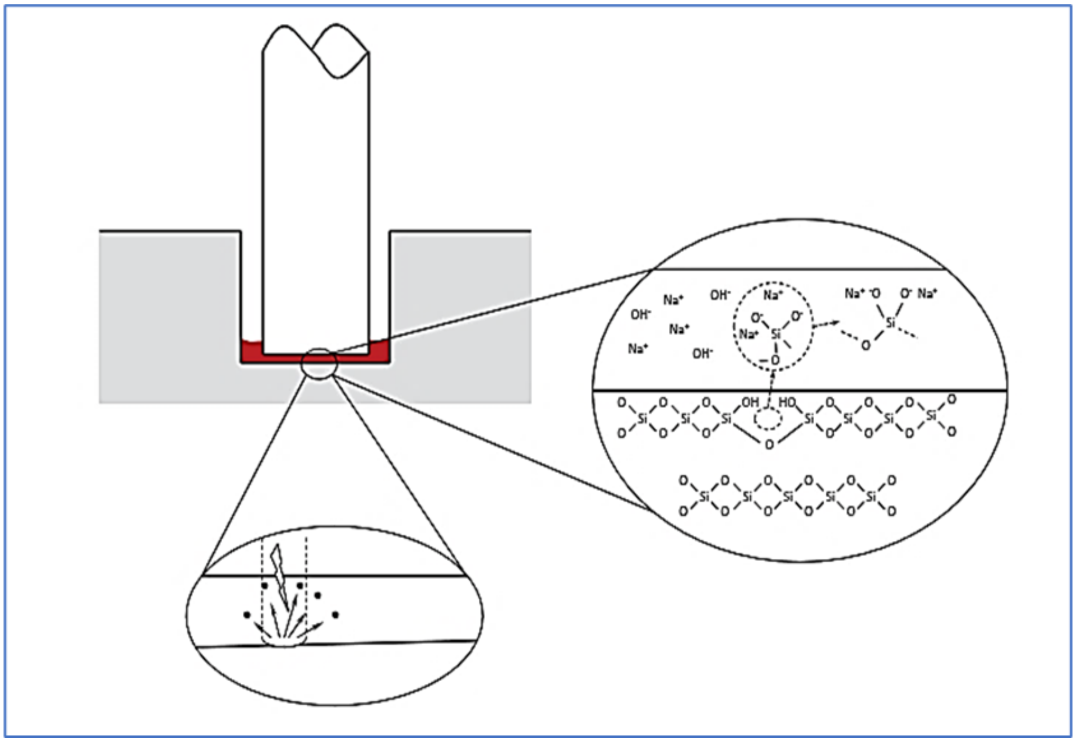

Fig 1.3 Schematic of machining mechanism of glass

Chapter 2: Development Of Circuits And Initial Setup

2.1. OVERVIEW OF COMPONENTS USED

2.1.1. Arduino Uno:

Arduino UNO is a microcontroller board based on the ATmega328P as shown in Fig 2.1. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button.

Fig 2.1 Arduino UNO ATmega328P

2.1.2. Node MCU:

The NodeMCU ESP8266 development board comes with the ESP-12E module containing the ESP8266 chip having Tensilica Xtensa 32-bit LX106 RISC microprocessor as shown in Fig 2.2. This microprocessor supports RTOS and operates at 80MHz to 160 MHz adjustable clock frequency. NodeMCU has 128 KB RAM and 4MB of Flash memory to store data and programs. Its high processing power with in-built Wi-Fi / Bluetooth and Deep Sleep Operating features make it ideal for IoT projects.

NodeMCU can be powered using a Micro USB jack and VIN pin (External Supply Pin). It supports UART, SPI, and I2C interface.

Fig 2.2 Node MCU

2.1.3. Stepper Motors:

NEMA 17 is a hybrid stepping motor with a 1.8° step angle (200 steps/revolution) as shown in Fig 2.3. Each phase draws 1.2 A at 4 V, allowing for a holding torque of 3.2 kg-cm. NEMA 17 Stepper motor is generally used in Printers, CNC machines and Laser Cutters.

This motor has six wires, connected to two split windings. Black, Yellow, Green wires is part of first winding while Red, White and Blue is part of second winding.

Fig 2.3 NEMA-17 Stepper Motor

2.1.4. Thermocouple (MAX 6675):

The MAX6675 performs cold-junction compensation and digitizes the signal from a type-K thermocouple. The data is output in a 12-bit resolution, SPI-compatible, read-only format as shown in Fig 2.4. This converter resolves temperatures to 0.25°C, allows readings as high as +1024°C, and exhibits thermocouple accuracy of 8 LSBs for temperatures ranging from 0°C to +700°C. The MAX6675 is available in a small, 8-pin SO package

Fig 2.4 MAX 6675 cold junction thermocouple

2.1.5. 20 x 4 LCD Display:

This is a 20x4 Arduino compatible LCD display module with high speed I2C interface as shown in Fig 2.5. It is able to display 20x4 characters on two lines, white characters on blue background. This I2C 20x4 LCD display module is designed for Arduino microcontroller. It is using I2C communication interface, with this I2C interface, only 2 lines (I2C) are required to display the information on any Arduino based projects. It will save at least 4 digital / analog pins on Arduino. All connectors are standard XH2.54 (Breadboard type).

Fig 2.5 20 x 4 LCD Display

2.1.6. DC Motor:

DC Motor is used for driving the spindle of the ECDM setup. The motor is shown in Fig 2.6.

Fig 2.6 DC Motor

2.1.7. Arduino CNC Shield:

Arduino CNC shields provide an Arduino microcontroller with the power necessary to drive stepper motors and run all the other functions that contribute to a CNC machine's operation as shown in Fig 2.7. Depending on the shield, this could include end stops, spindle speed control, and probing. It utilizes an Arduino Uno and requires a 12-36 volt power supply to drive the motors. It runs the common GRBL Arduino CNC firmware. It can support up to four plug-in stepper motor drivers, this shield has the ability to clone an axis.

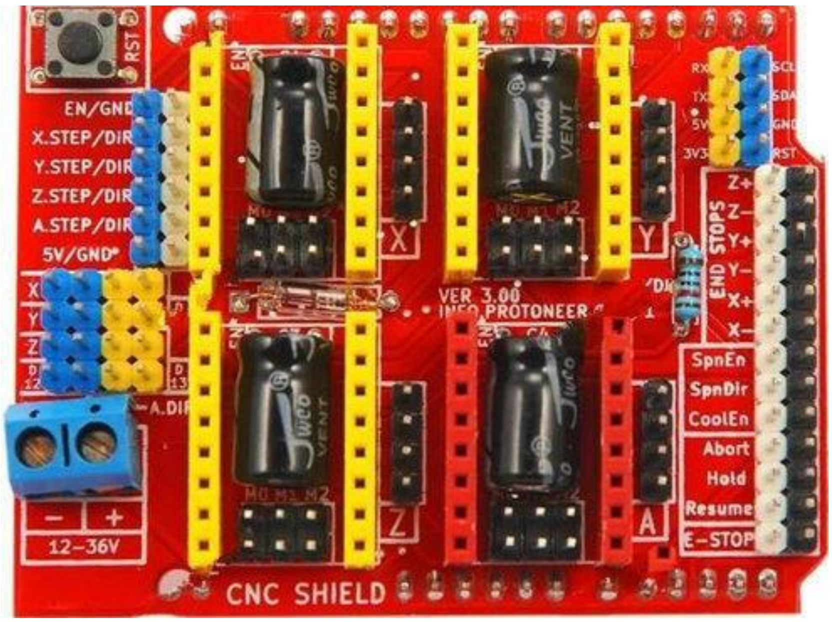

Fig 2.7 Arduino GRBL CNC Shield

2.1.8. Bluetooth Module (hc05):

HC-05 Bluetooth Module is an easy to use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup as shown in Fig 2.8. Its communication is via serial communication which makes an easy way to interface with controller or PC. HC-05 Bluetooth module provides switching mode between master and slave mode which means it able to use neither receiving nor transmitting data.

Fig 2.8 hc05 Bluetooth module

2.1.9. Cooling Fan:

The cooling fan is used to remove the heat generated in the power module set up. The fan is as shown in Fig 2.9

Fig 2.9 Computer cooling fan

2.1.10. IR Sensors:

IR Sensor has been used to calculate the speed of rotation of the spindle (Fig 2.10). The speed of the shaft is measured in RPM and is displayed in the LCD display.

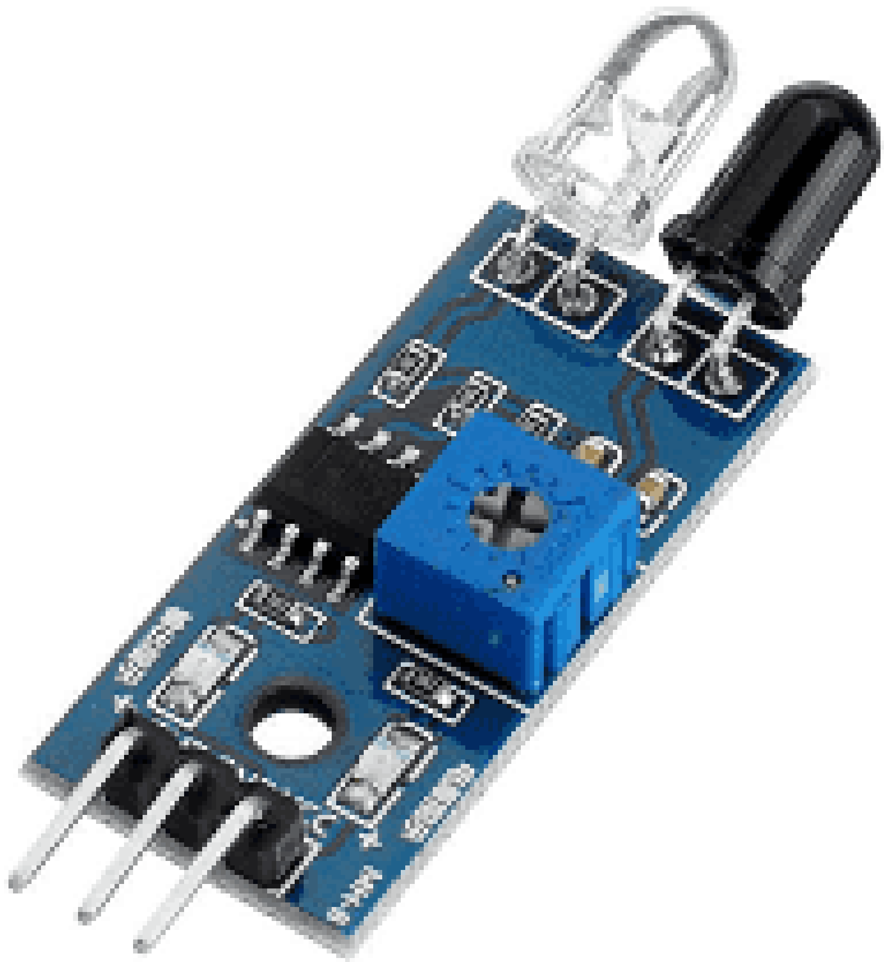

Fig 2.10 IR Sensor

2.1.11. Joystick:

A joystick has been used to control the movement along the vertical axis (Fig 2.11).

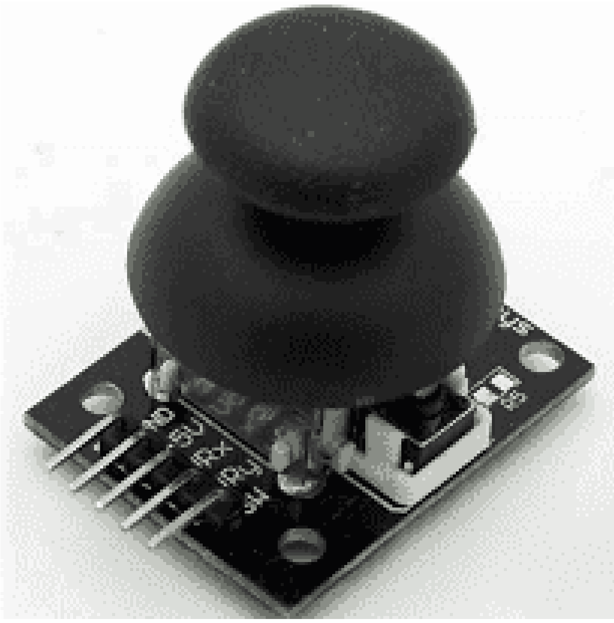

Fig 2.11 Joystick

2.1.12. Potentiometer:

A potentiometer is used for controlling the rotational speed of the spindle as shown in Fig.

Fig 2.12 Rotary potentiometer control

2.2. OVERVIEW OF THE PRE-EXISTING ECDM SETUP

The pre-existing setup of the ECDM apparatus is as shown in Fig 2.13 and Fig 2.14. The ECDM setup shown in the figures operates manually and does not include IOT control. The process parameters of the machining process are not visible and thus there is a huge limitation in accurate machining of non-conducting materials like glass.

The main objectives of this project are to refurbish and retrofit the pre-existing ECDM setup and to incorporate IOT control in order to facilitate indirect control of the machine and to provide a platform for the viewing of the process parameters such as pulse frequency, enclosure temperature and rotational speed of the spindle.

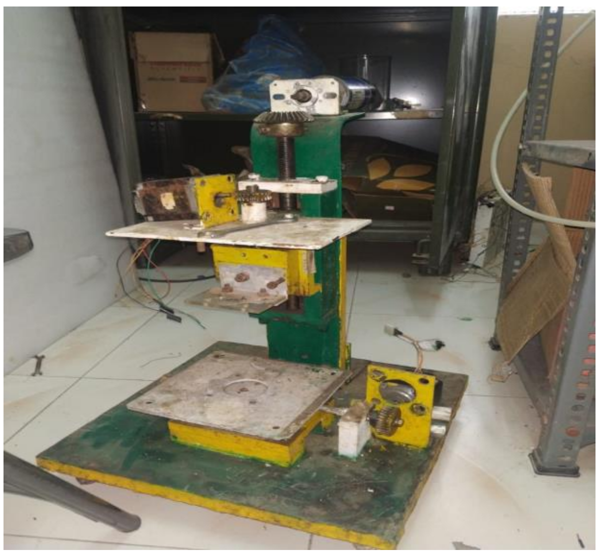

Fig 2.13 Manual controlled ECDM machine

Fig 2.14 Circuitry of pre-existing setup

Chapter 3: Project Methodology

In the development of the ECDM setup an extensive literature survey has been carried out. The detailed layout of the project methodology followed is as shown in Fig 3.1. The components for the circuit have been selected for the power module as per the results and conclusions of the papers studied as a part of the literature review process. The development of the circuitry for the power module and the IOT control system is the next step in the project methodology.

The components of the circuit are assembled and are connected to the refurbished existing ECDM setup. The Arduino code is developed for the power module and the IOT control and it is compiled. The errors are debugged and it is ensured that there are no errors. After this in the testing phase the circuit parameters are varied until the desired result is obtained. Once the code has been finalized it is then uploaded to the Arduino UNO boards.

Trial runs have been conducted for machining a glass workpiece. The main objective is to machine fine holes in the glass workpiece using the ECDM process. The machining process was carried out fir different feed and speed rates. The holes were successfully machined on the glass workpiece using ECDM process.

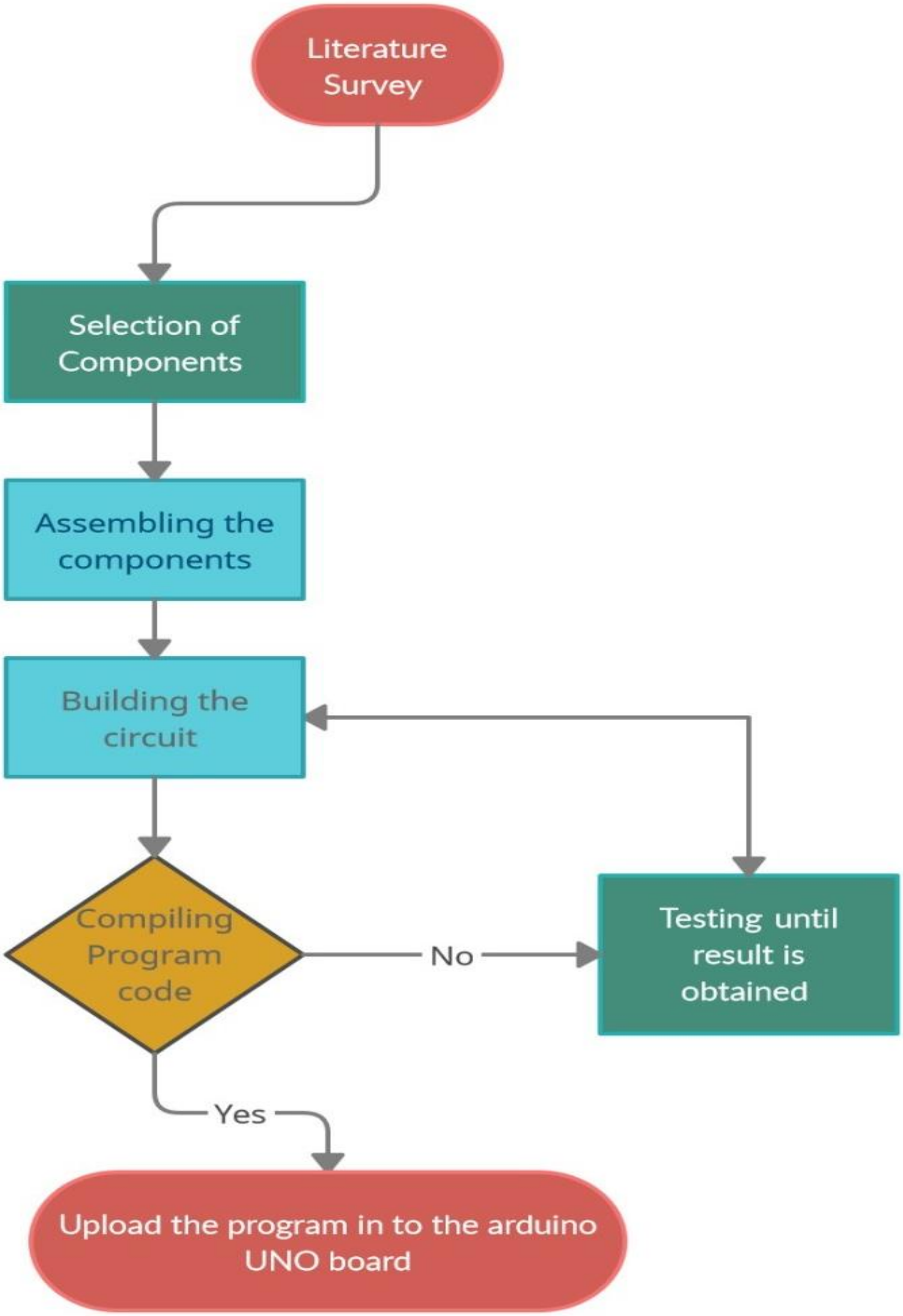

Fig 3.1 Flowchart of project methodology

Chapter 4: Experimental Setup

4.1. SPECIFICATION OF COMPONENTS

4.1.1 Specifications of NEMA-17 Stepper Motor

- Rated Voltage: 12V DC
- Current: 1.2A at 4V
- Step Angle: 1.8 deg.
- No. of Phases: 4
- Motor Length: 1.54 inches
- 4-wire, 8 inch lead
- 200 steps per revolution, 1.8 degrees
- Operating Temperature: -10 to 40 °C
- Unipolar Holding Torque: 22.2 oz-in

4.1.2 Specifications of Node MCU

- Microcontroller: Tensilica 32-bit RISC CPU Xtensa LX106
- Operating Voltage: 3.3V
- Input Voltage: 7-12V
- Digital I/O Pins (DIO): 16
- Analog Input Pins (ADC): 1

- UARTs: 1
- SPIs: 1
- I2Cs: 1
- Flash Memory: 4 MB
- SRAM: 64 KB
- Clock Speed: 80 MHz
- USB-TTL based on CP2102 is included onboard, Enabling Plug n Play
- PCB Antenna

4.1.3 Specifications of Bluetooth Module (hc05)

- Serial Bluetooth module for Arduino and other microcontrollers
- Operating Voltage: 4V to 6V (Typically +5V)
- Operating Current: 30mA
- Range: <100m
- Works with Serial communication (USART) and TTL compatible
- Follows IEEE 802.15.1 standardized protocol
- Uses Frequency-Hopping Spread spectrum (FHSS)
- Can operate in Master, Slave or Master/Slave mode

4.1.4 Specifications of Arduino Uno

- Rated Voltage: 3~6V
- Continuous No-Load Current: 150mA +/- 10%
- Min. Operating Speed (3V): 90+/- 10% RPM
- Min. Operating Speed (6V): 200+/- 10% RPM
- Torque: 0.15Nm ~0.60Nm
- Body Dimensions: 70 x 22 x 18mm
- Weight: 30.6g

4.2 CIRCUIT DIAGRAMS AND SCHEMATICS

The circuit diagram for the ECDM setup is as shown in Fig 4.1. The working table is mounted on the X stage motor. The working table is thus capable of moving horizontally with the workpiece. The main motor is responsible for the vertical movement (Y-stage). The stepper motor mounted is responsible for the fine control of the feed rate which is essential for the micro-machining of the glass workpiece. A high-speed motor is responsible for the rotation of the spindle. The support base supports the entire setup and also absorbs the residual vibrations of the moving components.

4.2.1 Schematic of ECDM setup

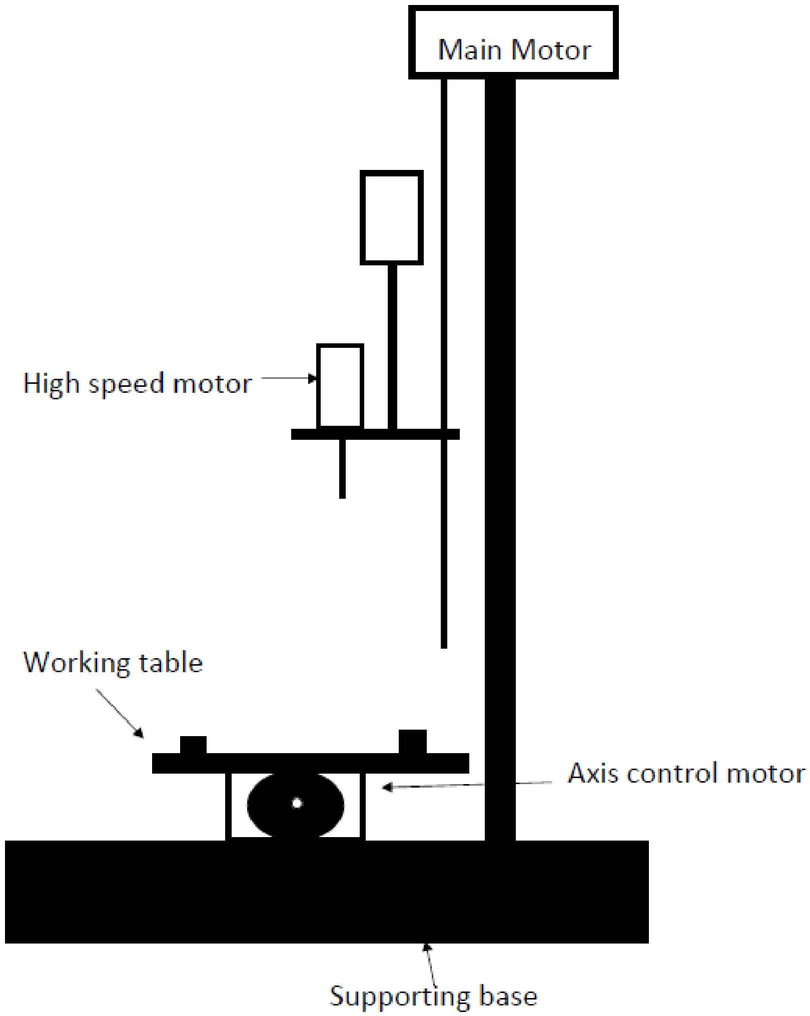

Fig 4. 1 Schematic of ECDM setup

The schematic for the ECDM power module is as shown in Fig 4.2. The tool electrode is the cathode and the Auxiliary electrode acts as the anode. A 5V DC power source is used. The transistor and MOSFET is used to generate pulse frequency for the spark during the machining of the component. The waveform can be visualized using an oscilloscope.

4.2.2 Schematic of ECDM Power Module

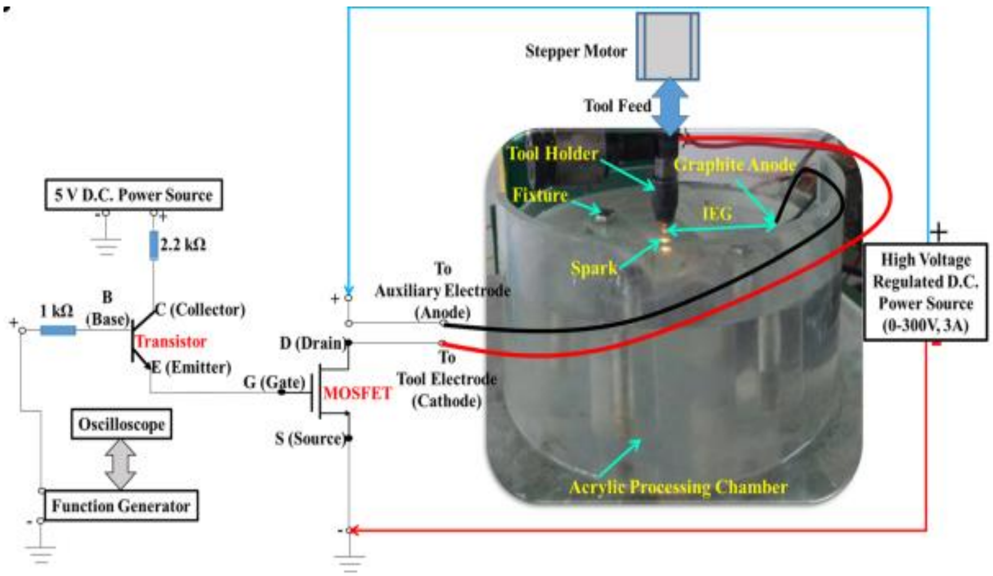

Fig 4. 2 ECDM power module schematic

The layout of the ECDM test rig is as shown in Fig 4.3. The movement of the stages and the speed of the spindle can be controlled indirectly by a mobile phone. The temperature, spark frequency and the spindle speed can be viewed in the LCD display. The data is also available on the cloud and can be viewed on phone/laptop.

4.2.3 Layout of ECDM Test rig

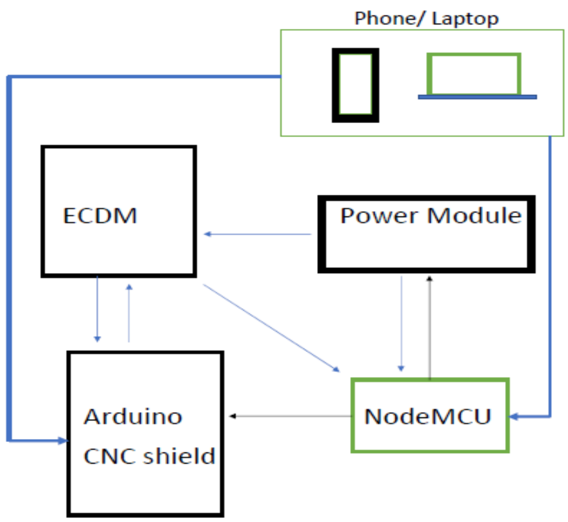

Fig 4. 3 Layout of ECDM test rig

4.2.4 Power module for ECDM

The MOSFET IRF540 acts as a switch for turning on and off the high voltage and high current power at desired frequency.

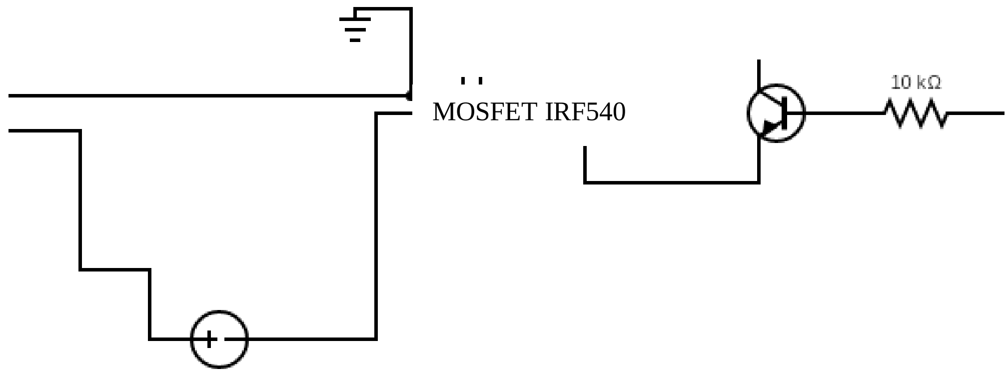

Fig 4. 4 Power Module for ECDM

4.2.5 GRBL Controller Circuit

The circuit to control the stepper motors and to facilitate the uploading and running of G-Codes using GRBL controller is as shown in Fig 4.5

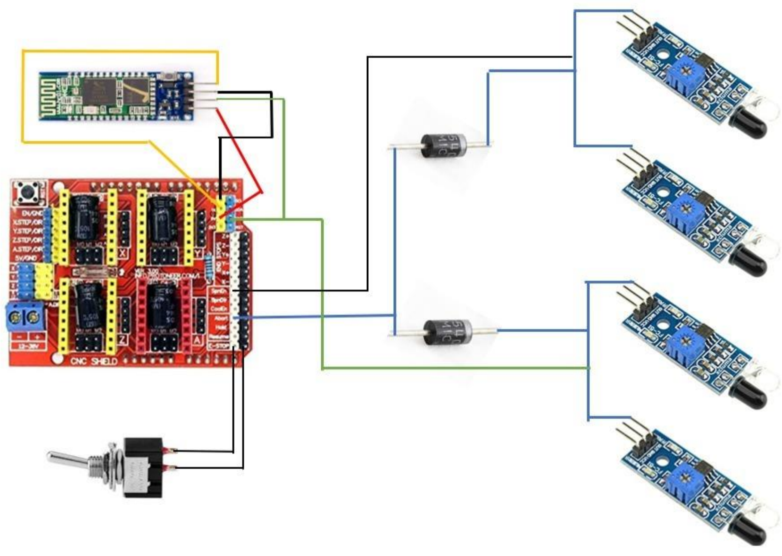

Fig 4. 5 GRBL controller circuit(CNC Shield)

4.2.6 Main Z-Axis controller circuit

The circuit to control the main Z-Axis is as shown in Fig 4.6.

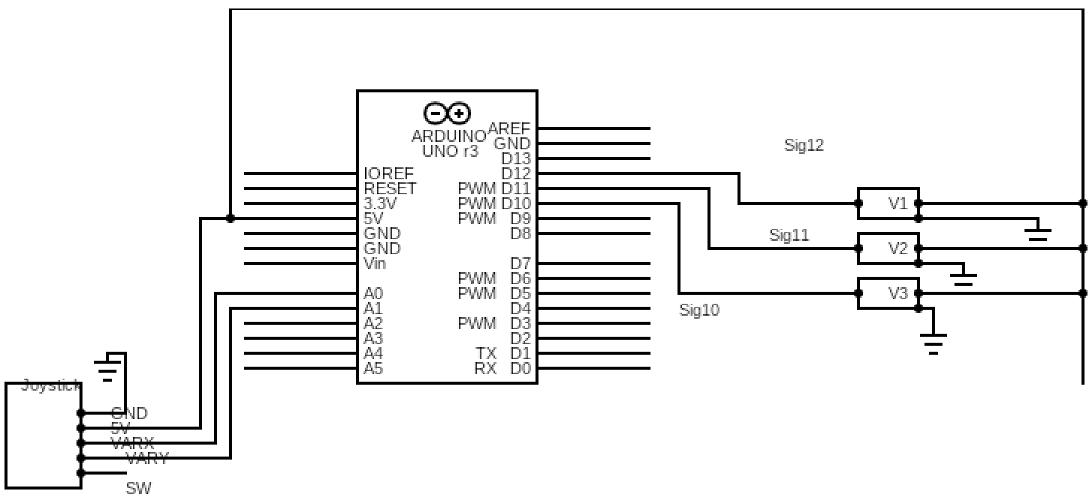

Fig 4. 6 MAIN Z AXIS CONTROLLER CIRCUIT

4.2.7 Frequency generation circuit

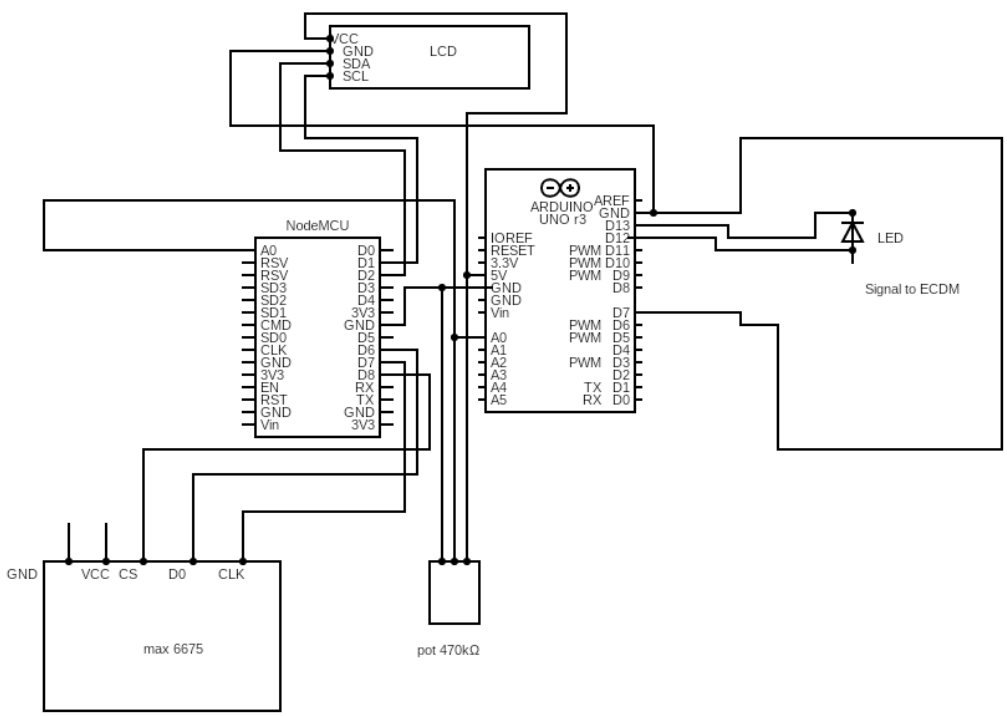

Fig 4. 7 Frequency generation circuit

4.3 SOFTWARES AND LIBRARIES USED:

4.3.1 Arduino IDE

For coding and for uploading the code in Arduino-uno.

4.3.2 New Ping library

A library that makes working with ultrasonic sensors easy.

4.3.3 HCSR04 library

Allows Arduino board to use HCSR04 model for getting current distance in cm.

4.3.4 AF Motor library

Provides speed and direction control for up to four DC motors when used with a motor shield.

4.4 PROGRAM CODE

4.4.1 Slave -β

```
int yValue = 0 ;

void setup()

{

  Serial.begin(9600) ;

  pinMode(8,INPUT);

  pinMode(7,INPUT);

  pinMode(12, OUTPUT);

  pinMode(11, OUTPUT);

  pinMode(10, OUTPUT);

}
```

```
void loop()
{
  yValue = analogRead(A0);
   if(yValue <400 )
   {
     digitalWrite(12,LOW);
     Serial.println(yValue);
    }
   else
   {
    digitalWrite(12,HIGH);
      }
   if(yValue>700 )
     {
       digitalWrite(12,LOW);
       digitalWrite(11,LOW);
      digitalWrite(10,LOW);
     }
    else
```

```
    {
      digitalWrite(12,HIGH);
       digitalWrite(11,HIGH);
      digitalWrite(10,HIGH);
    }
}
```

4.4.2 Slave -∝

```
#include <SoftwareSerial.h>
#include <Wire.h>

SoftwareSerial nodemcu(2,3);

float value=0;
float rev=0;
int rpm;
int oldtime=0;
int time;
int sen = A0;
```

```
int sensor2 = A1;

int sensor3 = A2;

int freq;

int sdata1 = 0; // sen data

int sdata2 = 0; // sensor2 data

int sdata3 = 0; // sensor3 data

const int buz=7;

int led=12;

long int data;

float n;

int sig=11;

String cdata; // complete data, consisting of sensors values



void isr() //interrupt service routine

{

rev++;

}
```

```
void setup()

{

Serial.begin(9600);

nodemcu.begin(9600);

attachInterrupt(0,isr,RISING);

pinMode(sen, INPUT);

pinMode(sensor2, INPUT);

pinMode(sensor3, INPUT);

pinMode(4, OUTPUT); // TO ON/OFF VARIABLE RESISTOR

digitalWrite(4, HIGH);

pinMode(8, OUTPUT);

pinMode(sig, INPUT);

digitalWrite(8,HIGH);

pinMode(led,OUTPUT);

pinMode(buz,OUTPUT);


}


void loop()
```

```
{

    sdata1 = freq;
    sdata2 = analogRead(sensor2);
    sdata3 = rpm/3;
  cdata = cdata + sdata1+","+sdata2+","+sdata3;  //comma will be used a delimiter//
   Serial.println(cdata);
    nodemcu.println(cdata);
    cdata = "";

    int data = analogRead(sen)+1;
    freq=data/10;
    float n= 1000/freq;

    int i;
    for(i=0;i<100;i++){
       int data = analogRead(sen)+1;
       freq=(data/10)+1;
```

```
  float n= 1000/freq;

  digitalWrite(led,HIGH);

  delay(n);

  digitalWrite(led,LOW);

  delay(n);


  detachInterrupt(0);          //detaches the interrupt

  time=millis()-oldtime;        //finds the time

  rpm=(rev/time)*60000;         //calculates rpm

  oldtime=millis();             //saves the current time

  rev=0;




  Serial.println(rpm);


  attachInterrupt(0,isr,RISING);

 }


if((freq>50) || (rpm >8000)){
```

```
  for(int i=0;i<30;i++){
    tone(buz,1000);
    delay(100);
    noTone(buz);
    delay(100);

  }
 }

}
```

4.4.3 Slave-γ

```
#define BLYNK_PRINT Serial
#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>
#include <SoftwareSerial.h>
#include <LiquidCrystal_I2C.h>
#include "max6675.h"
String l;
String m;
```

```
String n ;

int sdata;

int sdata1;

int firstVal;

int secondVal;

int thirdVal ;

// Your WiFi credentials.

// Set password to "" for open networks.

char auth[] = "2yUed--y-n7iA5nj42vsEFMxQQCF7ljD";

char ssid[] = "MallinathNavade";

char pass[] = "meem1234";


int thermoDO = 12;

int thermoCS = 15;

int thermoCLK = 14;

int pinValue;

int sensor1 = A0;

float sen;

float vref = 3.3;
```

```
float resolution = vref / 1023.0;

float temp1;

float temp2;

MAX6675 thermocouple(thermoCLK, thermoCS, thermoDO);

LiquidCrystal_I2C lcd(0x27, 20, 4);


SimpleTimer timer;


String myString;

char rdata;




void myTimerEvent()

{

  Blynk.virtualWrite(V1, millis() / 1000);

}


void setup()

{
```

```
  Serial.begin(9600);
  lcd.init();
  lcd.backlight();
  Blynk.begin(auth, ssid, pass);
  timer.setInterval(1000L,sensorvalue1);
  timer.setInterval(1000L,sensorvalue2);
}

void loop()
{
  if (Serial.available() == 0 )
  {
    Blynk.run();
    timer.run(); // Initiates BlynkTimer
  }

 if (Serial.available() > 0 )
 {  lcd.clear();
   rdata = Serial.read();
```

```
  myString = myString+ rdata;

  if( rdata == '\n')

  {

String l = getValue(myString, ',', 0);

String m = getValue(myString, ',', 1);

String n = getValue(myString, ',', 2);

firstVal = l.toInt();

secondVal = m.toInt();

thirdVal = n.toInt();


 myString = "";


 float temp=thermocouple.readCelsius();

  lcd.setCursor(0,0);

  lcd.print("Frequency :     Hz");

  lcd.setCursor(0,1);

  lcd.print("Drv. Temp :");

  lcd.setCursor(12,1);

  lcd.print(temp);
```

```
lcd.setCursor(12,0);
lcd.print(firstVal);
lcd.setCursor(18,1);
lcd.print("'C");
lcd.setCursor(0,2);
lcd.print("RPM       :");
lcd.setCursor(12,2);
lcd.print(thirdVal);
lcd.setCursor(0,3);

if(firstVal>50){
lcd.clear();
lcd.setCursor(0,0);
lcd.print("Warning !!!..");
lcd.setCursor(0,1);
lcd.print(" Max freq reached");
lcd.setCursor(0,2);
lcd.print("Reduce freq below 50");
delay(10000);
```

```
 lcd.clear();
 }
if(thirdVal>8000){
 lcd.clear();
 lcd.setCursor(0,0);
 lcd.print("Warning !!!..");
 lcd.setCursor(0,1);
 lcd.print(" Max rpm reached");
 lcd.setCursor(0,2);
 lcd.print("RPM < 8000 !!..");
 delay(10000);
 lcd.clear();
 }
  Blynk.virtualWrite(V2,firstVal);
  Blynk.virtualWrite(V5,temp);
  Blynk.virtualWrite(V4,thirdVal);
  delay(5000);
 }
}
```

```
}

void sensorvalue1()
{
int sdata = firstVal;
  // You can send any value at any time.
  // Please don't send more that 10 values per second.


}
void sensorvalue2()
{
int sdata1 = secondVal;
  // You can send any value at any time.
  // Please don't send more than 10 values per second.
}

String getValue(String data, char separator, int index)
{
```

```
    int found = 0;

    int strIndex[] = { 0, -1 };

    int maxIndex = data.length() - 1;


    for (int i = 0; i <= maxIndex && found <= index; i++) {

        if (data.charAt(i) == separator || i == maxIndex) {

            found++;

            strIndex[0] = strIndex[1] + 1;

            strIndex[1] = (i == maxIndex) ? i+1 : i;

        }

    }

    return found > index ? data.substring(strIndex[0], strIndex[1]) : "";

}
```

4.4.4 Slave -δ

```
#include <grbl.h>
```

4.5 ASSEMBLING AND TESTING OF PARTS AND COMPONENTS

The parts and components of the circuit as well as the machine have been assembled in several stages as mentioned below. After the completion of the assembly process several tests have been carried out with different feeds and speeds. The tests were carried out on glass workpieces.

4.5.1 Building Circuit for Motion Control

The circuit for motion control is as shown in Fig 4.8. This circuit is responsible for the movement of the X and Y stages as well as the spindle rotation. The code has been uploaded to the Arduino boards.

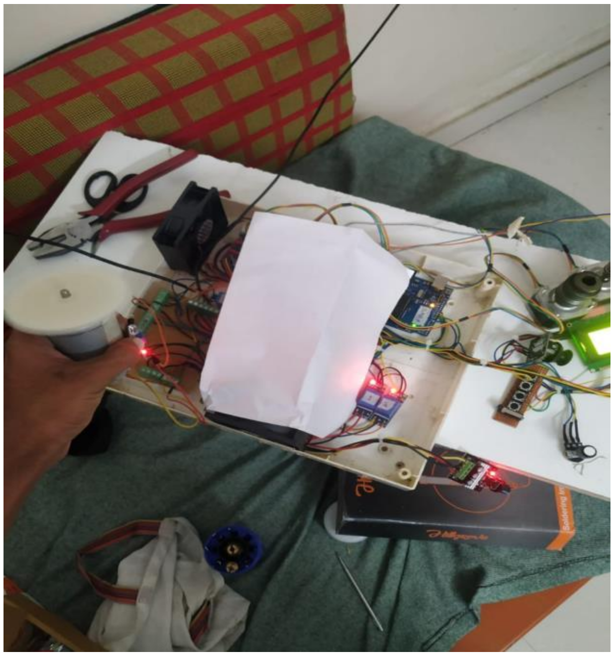

Figure 4.8 Building circuit for motion control

4.5.2 Fabrication Of Motion Control and ECDM Circuits

The fabrication of circuits for motion control and the ECDM process is as shown in Fig 4.9 and Fig 4.10. The cooling fan is necessary to remove the heat developed in the circuit environment during machining operation. The parameters that can be displayed are pulse frequency, spindle speed and the circuit housing temperature.

The control of motion of the different stages and the spindle speed can be controlled indirectly from a mobile phone.

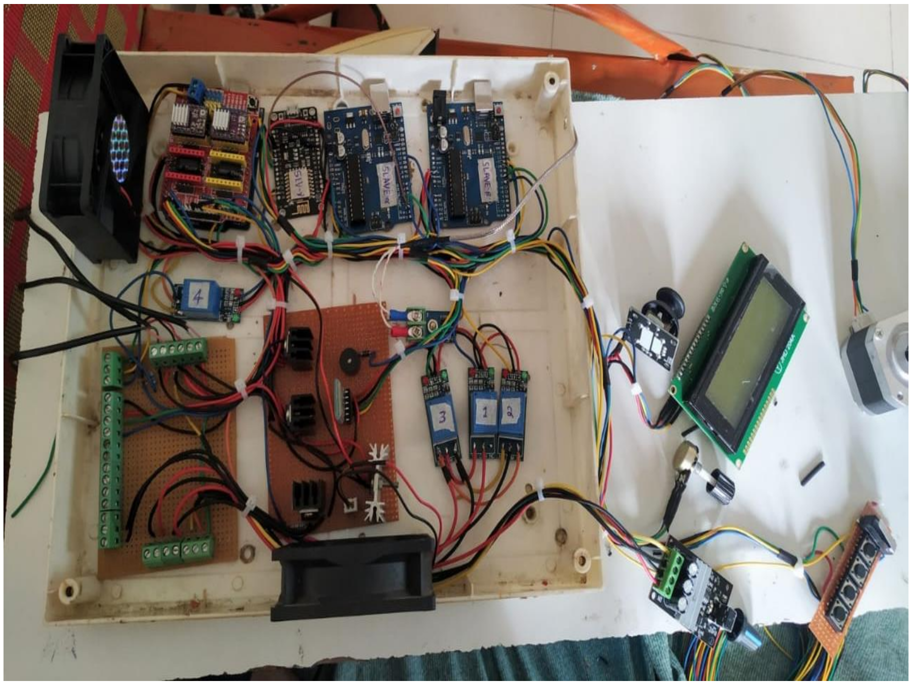

Fig 4.9 Fabricating motion control circuit

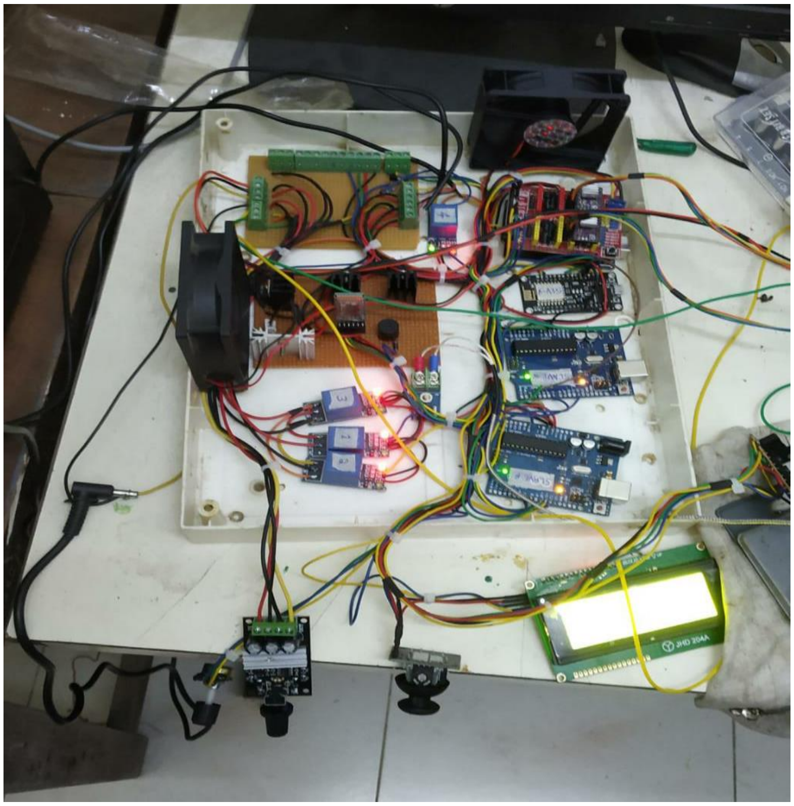

Fig 4.10 fabricated circuit for both motion control and ECDM process

4.5.3 Testing of ECDM Process

The testing of the ECDM process is as shown in Fig 4.11 and Fig 4.12. The workpiece used is a glass workpiece. The objective of the testing phase is to validate the development of the circuitry for the power module and IOT control. Several holes have been machined on the glass surface for different values of speed and feed.

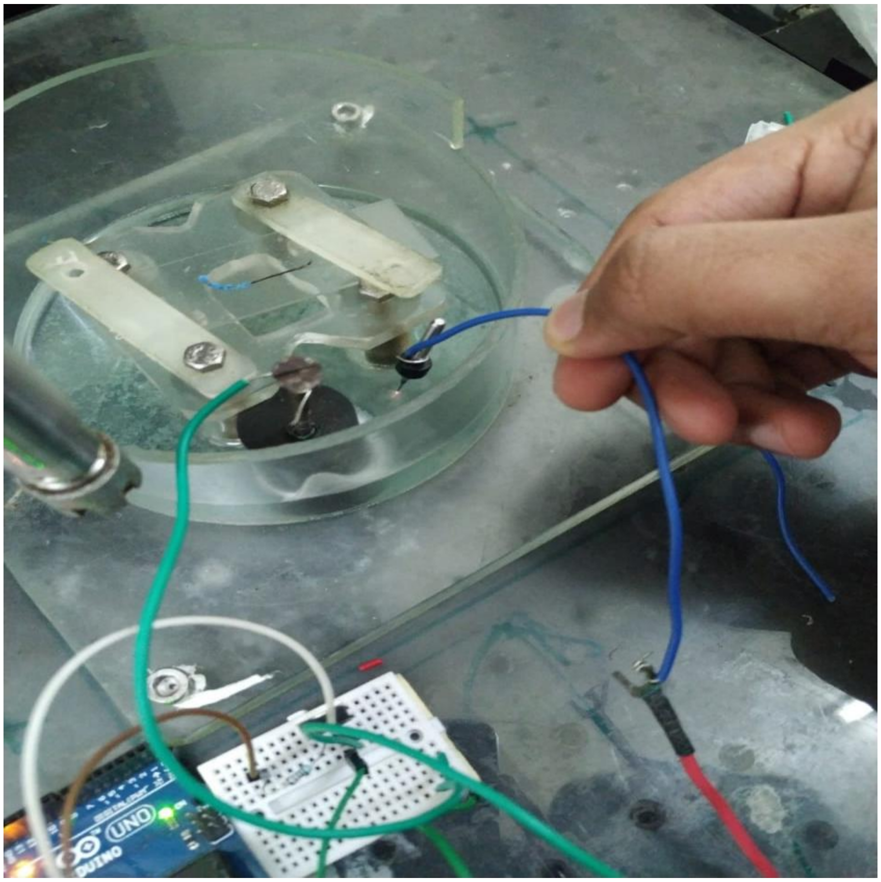

Fig 4.11 Testing of ECDM process

The LCD display displaying the process parameters of pulse frequency, circuit housing temperature and the spindle speed are as shown in Fig 4.12.

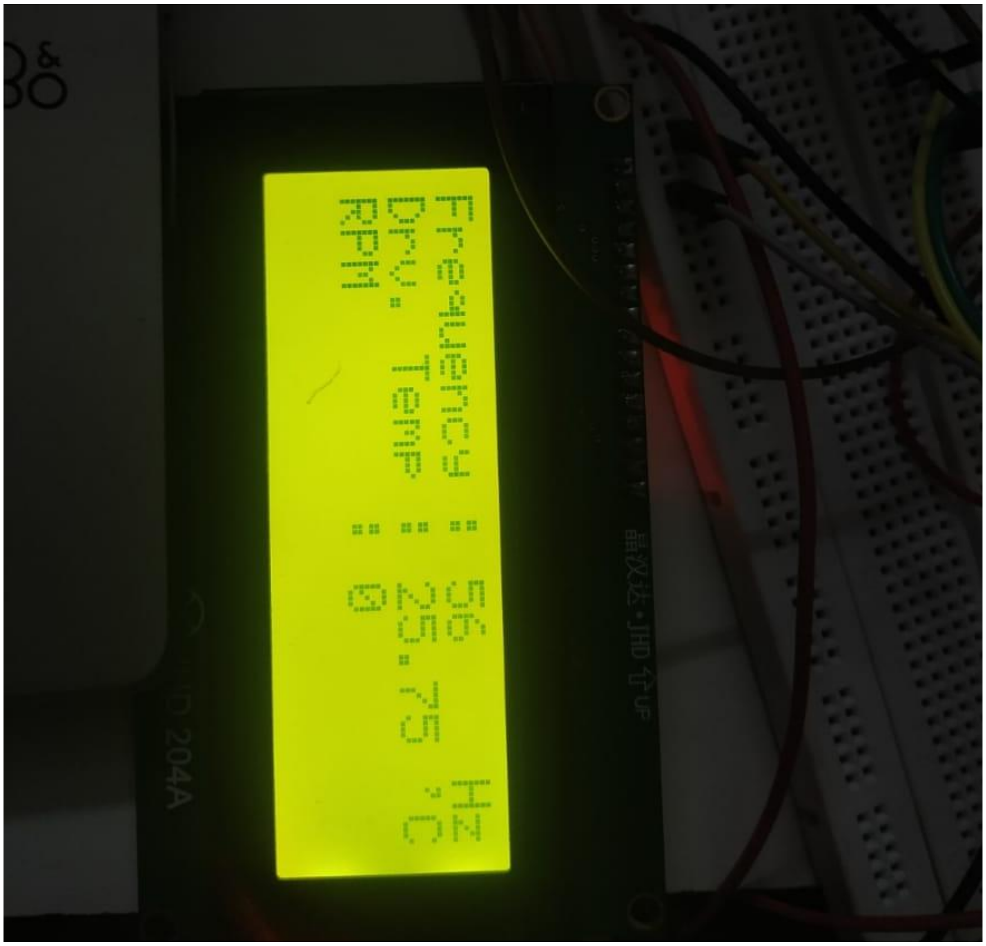

Fig 4.12 LCD display showing Frequency, speed and temperature

4.5.4 Refurbished ECDM Setup

The existing ECDM has been refurbished and retrofitted with new stepper motors. Additionally IOT control and power module have also been incorporated in the final refurbished setup as shown in Fig 4.13.

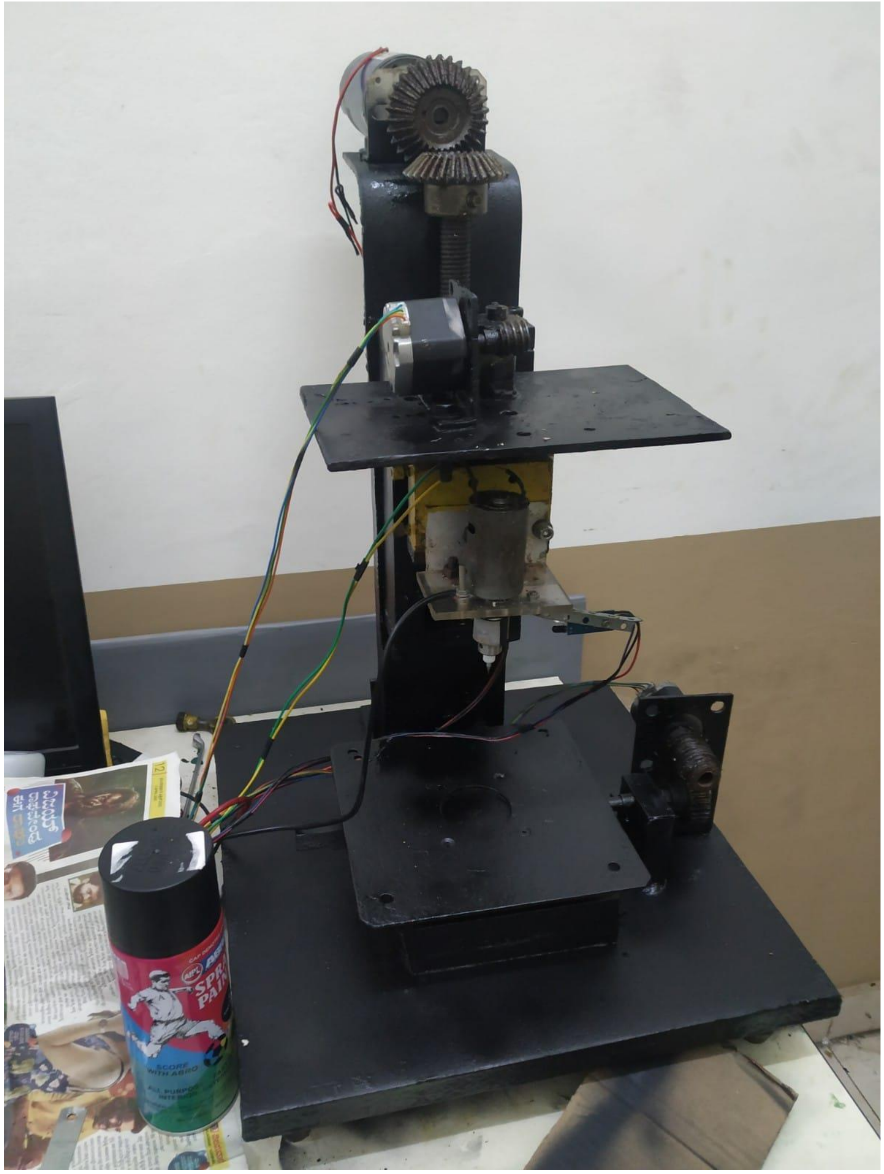

Fig 4.13 Refurbished ECDM Setup

4.5.5 Video Link of Testing

Video Demonstration of the working of our IOT CONTROLLED ECDM SETUP

https://drive.google.com/drive/folders/1Tu3e0XoFAIoIlNFfe7ZQQhMpzmgSqIgG

4.5.6 Bill of Materials

SL.NO	COMPONENT	NO. OF COMPONENTS
1	Arduino Uno	3
2	Node MCU	1
3	Cooling Fan	2
4	Relays	4
5	Temperature sensor (MAX 6675)	1
6	Bluetooth module	1
7	Buzzer	1
8	Arduino CNC Shield	1
9	Stepper Motor	2
10	DC MOTOR	1
11	Spindle	1
12	IR Sensor	1
13	IC 7805, 7812, IRE 540	3

Chapter 5: Results and Discussion

The Electrochemical Discharge Machining setup has been successfully repurposed and retrofitted. The power module for the ECDM setup has been successfully designed and tested and IOT control has also been incorporated.

The Electrochemical Discharge Machining Setup is capable of machining non-conducting materials such as glass. Fine holes have been machined successfully with the desired accuracy and the desired feed and speed as shown in Fig 5.1 and Fig 5.2. The process parameters of pulse frequency, spindle rpm and power module environment temperature are displayed in the LCD dashboard. The system can also be remotely controlled by a mobile phone through IOT control and the process parameter data is also available via the cloud and can be viewed on a phone.

Fig 5.1 Holes machined on glass workpiece of 2 mm thickness at a federate of 3 mm/min

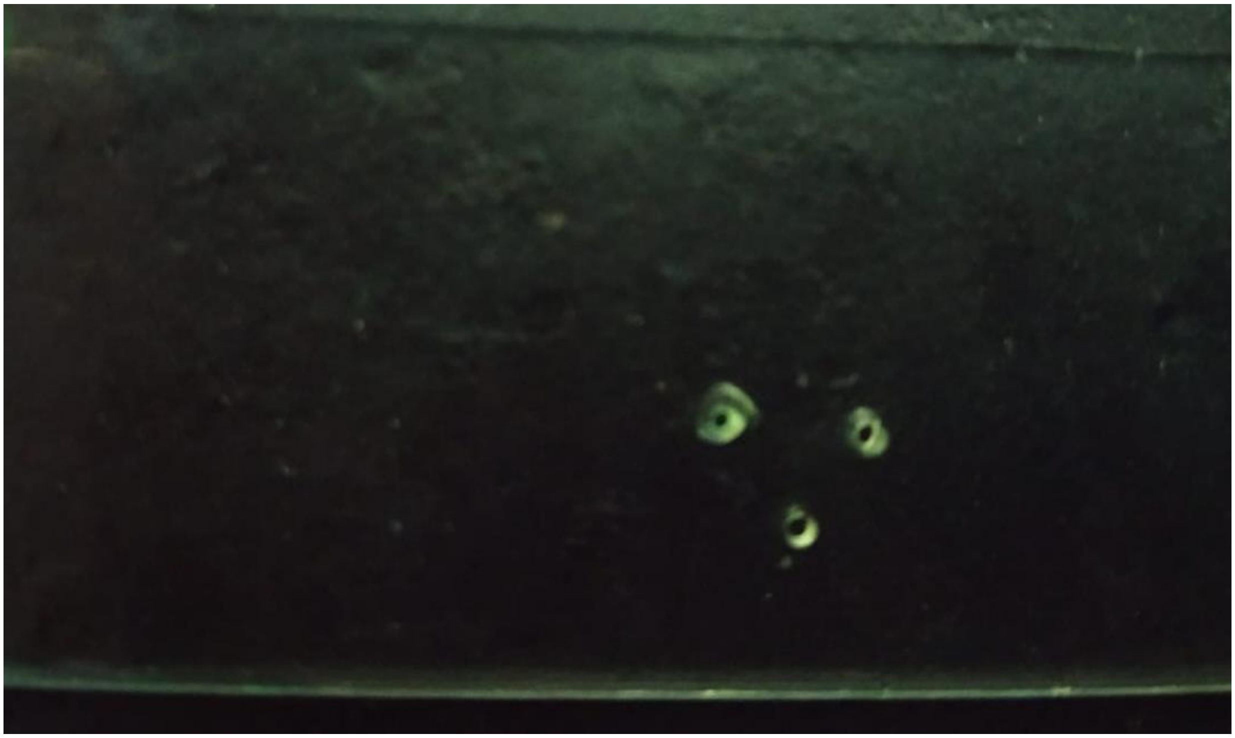

Fig 5.2 Holes machined on a glass workpiece of 2 mm thickness at a feed rate of 0.4 mm/min

The results of the test can be viewed via the cloud using the Blynk app as shown in Fig 5.3. The dashboard shows the operating values of pulse frequency, electronics housing temperature and the spindle rotation speed.

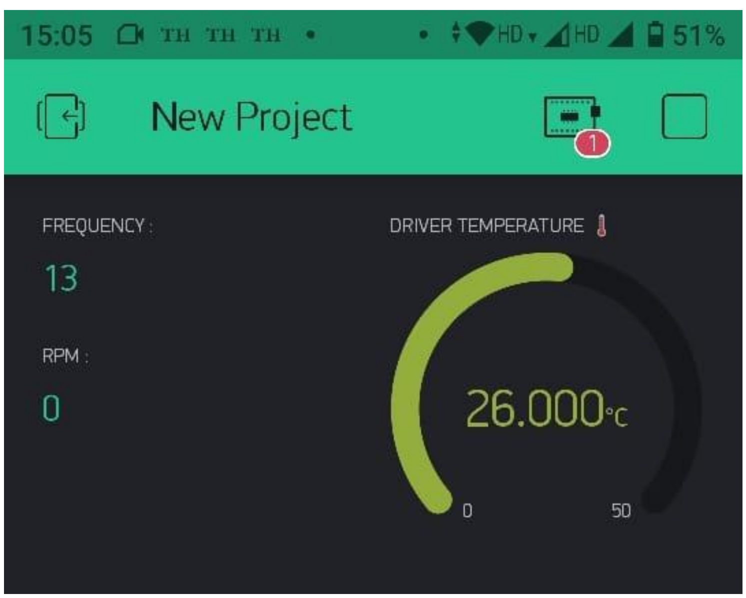

Fig 5.3 Display of parameters in Blynk App

The movement of the stages and the spindle speed can be controlled via G-Codes by using the GRBL+ Controller Application as shown in Fig 5.4

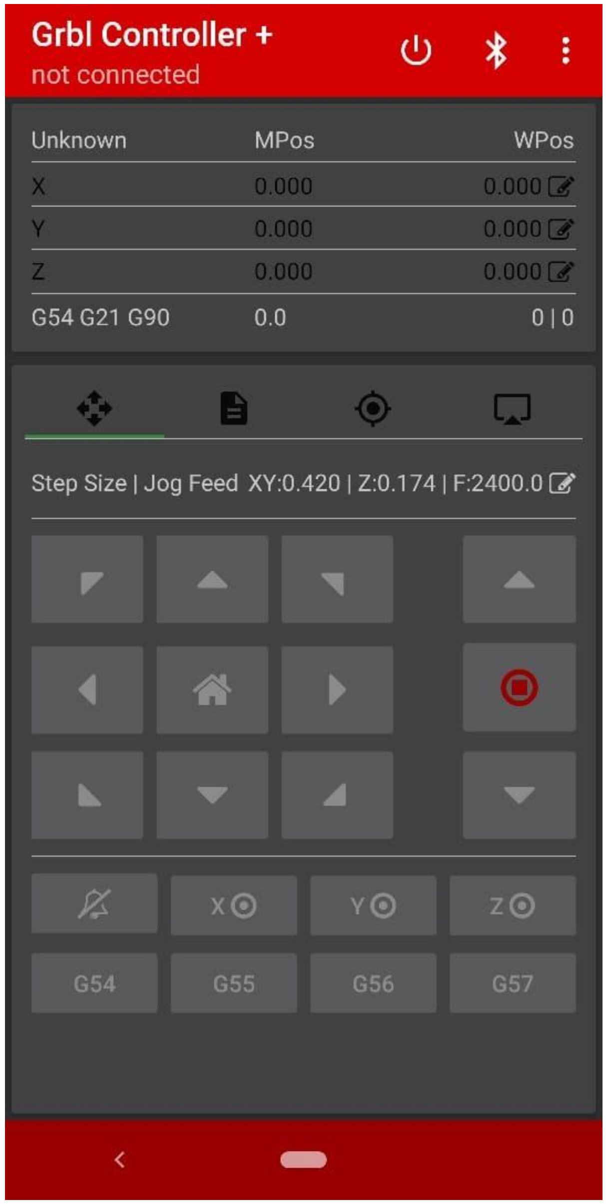

Fig 5.4 GRBL+ Controller

Chapter 6: Conclusions and Future Scope

Conclusion

The Electrochemical Discharge Machining setup has been successfully repurposed and retrofitted. The power module for the ECDM setup has been successfully designed and tested and IOT control has also been incorporated. The project result is worth the team effort. By doing this project we came across many challenges, fixed them and now we are confident enough to work in any component in the embedded field.

In this phase we have successfully built and assembled the ECDM setup and the power module. Several tests have been carried out for different conditions of voltage, pulse frequency and speeds. Fine holes have been machined on the glass workpiece successfully using custom CNC codes generated in the AUTODESK FUSION 360 software.

Future Development & Scope

The power module can be integrated with the newer version of the existing ECDM setup. The spindle speed monitoring system can be improved so that the instantaneous response to changes in speed can be measured more accurately after accurate calibration. Additional Degrees of Freedom can be added to the existing system to provide more freedom in fabrication and machining of complex contours. The ECDM set up can be further extended to support fabrication of microchannels for microfluidic devices and MEMS.

References

1. Harry Krotz, Konrad Wegener "Sparc assisted electrochemical machining: a novel possibility for micro drilling into electrical conductive materials using the electrochemical discharge phenomenon" International Journal of Advanced Manufacturing Technology DOI 10.1007/s00170-015-6913-9
2. Lijo Paul, Somashekhar S. Hiremath, Experimental and Theoretical Investigations in ECDM Process – An Overview, Procedia Technology, Volume 25, 2016, ISSN 2212-0173
3. Hajian M, Razfar MR, Movahed Saeid, An experimental study on the effect of magnetic field orientations and electrolyte concentrations on ECDM milling performance of glass, Precision Engineering (2016),
4. D. M. N. Vijayakumar, M. S. Archana and W. Kamalakant, "Exploratory Study On The Application Of IoT In CNC," 2018 3rd International Conference on Computational Systems and Information Technology for Sustainable Solutions (CSITSS), 2018, pp. 329-332, doi: 10.1109/CSITSS.2018.8768502.
5. M. K. K and P. Kannadaguli, "IoT Based CNC Machine Condition Monitoring System Using Machine Learning Techniques," 2020 IEEE 9th International Conference on Communication Systems and Network Technologies (CSNT), 2020, pp. 61-65, doi: 10.1109/CSNT48778.2020.9115762.
6. Yahya Mohammed Al-Naggar, Norlida Jamil, Mohd Firdaus Hassan, Ahmad Razlan Yusoff, Condition monitoring based on IoT for predictive maintenance of CNC machines, Procedia CIRP, Volume 102, 2021, Pages 314-318, ISSN 2212-8271.
7. B. Siddhartha, A. P. Chavan, G. K. HD and K. N. Subramanya, "IoT Enabled Real-Time Availability and Condition Monitoring of CNC Machines," 2020 IEEE International Conference on Internet of Things and Intelligence System (IoTaIS), 2021, pp. 78-84, doi: 10.1109/IoTaIS50849.2021.9359698.
8. I. R. K. Al-Saedi, F. M. Mohammed and S. S. Obayes, "CNC machine based on embedded wireless and Internet of Things for workshop development," 2017 International Conference on Control, Automation and Diagnosis (ICCAD), 2017, pp. 439-444, doi: 10.1109/CADIAG.2017.8075699.
9. Wansheng Zhao, Mo Chen, Weiwen Xia, Xuecheng Xi, Fuchun Zhao, Yaou Zhang, Reconstructing CNC platform for EDM machines towards smart manufacturing,Procedia CIRP, Volume 95, 2020, Pages 161-177, ISSN 2212-8271.
10. Katsushi Furutani, Shunsuke Kojima, Prototyping of Acceleration Sensor by Using Lathe-type Electro-chemical Discharge Machine, Procedia CIRP, Volume 42, 2016, Pages 772-777, ISSN 2212-8271,