Project Report
On

Design And Development of Low-Cost Universal Testing Machine using Piezoelectric Sensor and Arduino

submitted by

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MADAN MOHAN MALAVIYA UNIVERSITY OF TECHNOLOGY *to the*

National Institute of Technology Patna *in partial fulfilment of the requirements for the completion of*

Summer Internship

in

the **Department of Mechatronics and Automation Engineering**

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JUNE 2025

National Institute of Technology Patna

An Institute of National Importance under Ministry of Education

(Shiksha Mantralaya), Government of India

INTERNSHIP PROJECT REPORT

CERTIFICATE

This is to certify that the work embodies in this dissertation entitled **Design & Development of a Low-Cost Universal Testing Machine (UTM) using Piezoelectric sensor and Arduino"** being submitted by **"ANURAG KUMAR"** for partial fulfilment of the requirement for the award of **"Certificate"** during the long term **16 May to 30 June 2025** internship programme is a record of a bonafide piece of work, which was carried out by him under my supervision and guidance in the **Department of Mechatronics and Automation Engineering** of **National Institute of Technology, Patna** .

Supervisor
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Forwarded by
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CANDIDATE'S DECLARATION

.

I, ANURAG KUMAR hereby declare that the report entitled "Design & Development of a low-cost Universal Testing Machine (UTM) using Piezoelectric sensor and Arduino" which is being submitted to Department of Mechatronics and Automation Engineering in **National Institute of Technology Patna** is our authentic work carried out during internship.

I declare that my work has not been submitted in part or in full to any other university or institution for the award of any certificate.

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I would also like to acknowledge the **Training and Placement Cell, NIT Patna**, for their consistent efforts in coordinating internship opportunities and supporting students in their professional journey.

Their collective guidance and encouragement have been instrumental in the successful completion of my internship.

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INTERNSHIP PROJECT REPORT

Abstract

This report provides a comprehensive overview of the internship experience focused on the design and development of a Portable Universal Testing Machine (UTM). The main objective of the project was to create a compact, cost-effective, and efficient system capable of conducting material strength tests—such as tensile and compressive strength—outside of traditional laboratory environments.

During the internship, key activities included mechanical assembly, sensor calibration, and embedded programming using Arduino. A 12V DC linear actuator was used to apply force to specimens, while an extensometer and load cell were employed to measure deformation and force, respectively. These components were integrated into a single system using Arduino, enabling real-time data acquisition and display.

The project enhanced technical skills in mechatronics, instrumentation, and embedded systems, while also fostering professional and personal growth. The outcome demonstrated the feasibility of using low-cost components to build a functional, portable UTM that can support material testing in remote or field-based scenarios.

1. Introduction

1.1 Background

This project was completed as part of an internship at a company specializing in **mechanical testing equipment and embedded system design**. The organization operates in the **mechanical and instrumentation industry**, providing solutions for testing the physical and mechanical properties of materials. With a focus on innovation and portability, the company develops equipment for real-time, on-site testing applications, which is increasingly important for industries such as construction, manufacturing, and quality assurance.

During the internship, the focus was on contributing to the design and prototyping of a **Portable Universal Testing Machine (UTM)**—a compact system intended to replace traditional, bulky laboratory-based UTMs.

1.2 Objective of the Internship

The primary objective of the internship was to gain practical, hands-on experience in **mechatronics and embedded systems**, particularly in the context of material testing. The key goals included:

- Designing and assembling a **portable UTM** using a **12V DC linear actuator**.
- Interfacing an **extensometer** and other sensors with an **Arduino microcontroller**.
- Developing a system to measure and display **material extension and force** during testing.
- Enhancing understanding of mechanical properties such as tensile strength and deformation.
- Learning about calibration, data acquisition, and analysis in a real-world engineering setup.

Through this project, the internship aimed to bridge academic concepts with practical engineering applications and contribute to the ongoing innovation in mobile testing equipment

2. Internship Activities

2.1 Description of Tasks and Responsibilities

During the internship, I was primarily involved in the development of a **Portable Universal Testing Machine (UTM)**. My responsibilities included:

- Assisting in the mechanical design and assembly of the UTM frame.
- Wiring and configuring the **12V DC linear actuator** for motion control.
- Interfacing sensors like the **extensometer** and **load cell** with the **Arduino microcontroller**.
- Supporting testing and calibration of the system using various material specimens.
- Participating in team meetings to discuss progress, challenges, and improvements.

2.2 Projects/Modules Undertaken

The key project undertaken was the **design and implementation of a portable UTM machine**. The project was divided into the following modules:

- **Mechanical Design Module**: Focused on designing the test rig capable of applying tensile/compressive loads.
- **Actuation Module**: Implemented using a **12V DC linear actuator** to apply force to the test specimen.
- **Measurement Module**: Included integration of an **extensometer** for deformation measurement and a **load cell** for force detection.
- **Embedded System Module**: Based on **Arduino**, responsible for reading sensor data, controlling the actuator, and displaying real-time results on an LCD or serial monitor.

2.3 Tools and Technologies Used **Hardware**:

- 12V DC Linear Actuator
- Load Cell
- Extensometer
- Arduino Uno
- Power Supply Unit
- Breadboard, jumper wires, relays

Software/Programming:

- Arduino IDE (C/C++)
- Proteus (for basic circuit simulation)
- MS Excel (for result analysis and plotting)
- Serial Monitor/LCD Display for output

2.4 Skills Acquired

2.4.1 Professional Skills

- Time management and task prioritization during project execution.
- Effective team collaboration and communication in a technical environment.
- Documentation and reporting of project progress and technical findings.
- Adapting to a structured engineering workflow and problem-solving under supervision.

2.4.2 Technical Skills

- Embedded programming using **Arduino** and sensor interfacing.
- Understanding and implementation of **material testing principles**.

- Calibration and data acquisition from load cells and extensometers.
- Knowledge of **linear actuators**, load applications, and safety procedures.
- Basic circuit design and troubleshooting skills.

2.4.3 Personal Growth

The internship significantly contributed to my personal development by building confidence in applying theoretical knowledge to real-world projects. It improved my critical thinking, boosted my curiosity to learn new technologies, and strengthened my ability to work both independently and collaboratively. I also gained a deeper appreciation for the practical challenges involved in product development and engineering innovation.

3. Challenges and Solutions

3.1 Challenges Faced

During the course of the internship and while working on the Portable UTM Machine project, several challenges arose:

Sensor Calibration Issues: Initially, the load cell and extensometer provided inconsistent readings due to improper calibration and electrical noise.

Actuator Control Limitations: The 12V DC linear actuator lacked precise motion control, making it difficult to apply a gradual and stable load to the test specimen.

Power Supply Instability: The actuator drew more current than expected at peak load, leading to power drops and system resets.

Mechanical Misalignment: The setup sometimes caused uneven force distribution on the specimen due to misalignment of fixtures.

Coding and Data Handling Errors: Managing real-time data from multiple sensors and displaying accurate results required efficient coding and filtering techniques, which were initially challenging.

3.2 Solutions and Strategies

To overcome these challenges, the following strategies were implemented:

Proper Sensor Calibration: Used known weights and reference values to calibrate the load cell and extensometer, and implemented a software-based filtering algorithm to minimize noise.

Improved Actuator Control: Added a motor driver module with PWM control to regulate actuator speed more precisely, allowing smoother load application.

Stable Power Supply Design: Introduced a dedicated power supply with current limiting and protection circuits to support the actuator without affecting Arduino operation.

Redesigned Fixture Alignment: Adjusted the mechanical design and ensured proper alignment of grips and fixtures using precision clamps and guides.

Modular Code Development: Broke the Arduino code into modules for sensor reading, data filtering, and display. Used serial debugging tools to test and refine each part separately.

These solutions not only resolved technical issues but also enhanced my problem-solving ability and understanding of system integration in real-time applications.

4. Conclusion

The internship experience proved to be a highly valuable and rewarding phase of my academic and professional development. Working on the Portable Universal Testing Machine (UTM) project provided me with practical exposure to mechanical systems, sensor integration, embedded programming, and real-time data processing. It bridged the gap between theoretical knowledge and practical application, allowing me to engage in every stage of the project—from design and development to testing and troubleshooting.

Through this experience, I gained critical insights into material testing, the functionality of components like load cells, extensometers, and linear actuators, and the use of Arduino for real-time control and monitoring. I also developed essential soft skills such as teamwork, time management, and effective communication in a technical environment.

Most importantly, the internship has helped clarify my career interests. It strengthened my desire to pursue a career in embedded systems, mechatronics, or product development, where I can contribute to the design of innovative, real-world engineering solutions. This hands-on project has boosted my confidence and has laid a strong foundation for future professional and academic endeavours.

5. Appendices

Appendix A: Block Diagram of Portable UTM Machine

[DC Power Supply] → [Motor Driver] → [12V Linear Actuator]

↓

[Arduino Uno]

↙ ↘

[Load Cell] [Extensometer]

↓

[LCD Display / Serial Monitor

Appendix B: List of Components Used

S.no	Component	Specification/Model	Purpose
1	Arduino Uno	ATmega328P	Main controller for the system
2	Linear Actuator	12V DC, 100mm stroke	Applies load to the specimen
3	Load Cell	10 kg capacity	Measures applied force
4	HX711 Module	Load cell amplifier	Converts analog signal to digital
5	Extensometer	Custom-built / Commercial	Measures specimen elongation
6	Motor Driver	L298N or equivalent	Controls the actuator motion
7	LCD Display	16x2 or 20x4	Displays force and extension data
8	Power Supply	12V DC, 5A	Powers the actuator and electronics

Appendix C: Sample Arduino Code Snippet(FOR ANALOG READING)

```
const int analogPin = A0; // Define the analog input pin int static_ variable
= 500; void setup() {
```

```
  Serial.begin(9600); // Initialize serial communication
}

void loop () {
  // Read the analog value   int sensorValue
= analogRead(analogPin);

  // Get the current time in milliseconds   unsigned long
currentMillis = millis (); unsigned long second
= currentMillis/1000;

  // Print the time and sensor value to the serial monitor
   Serial.print("Variable_1:");
   Serial.print(sensorValue);
  Serial.print(",");
  Serial.print("Variable_2:");
  Serial.println(static_variable);
  Serial.print("Time: ");
  Serial.print(second);
  Serial.print(" s, Analog Value: ");
  Serial.println(sensorValue);

  // Add a small delay to control the reading rate     delay
(100);
// Adjust delay as needed
}
```

Test No.	Material	Max Load (kg)	Elongation (mm)	Remarks
1	**RUBBER TUBE**	**20MM**		

Appendix D: Photos / Diagrams of the Project Setup

Figure 1. Linear Actuator with Piezoelectric Sensor

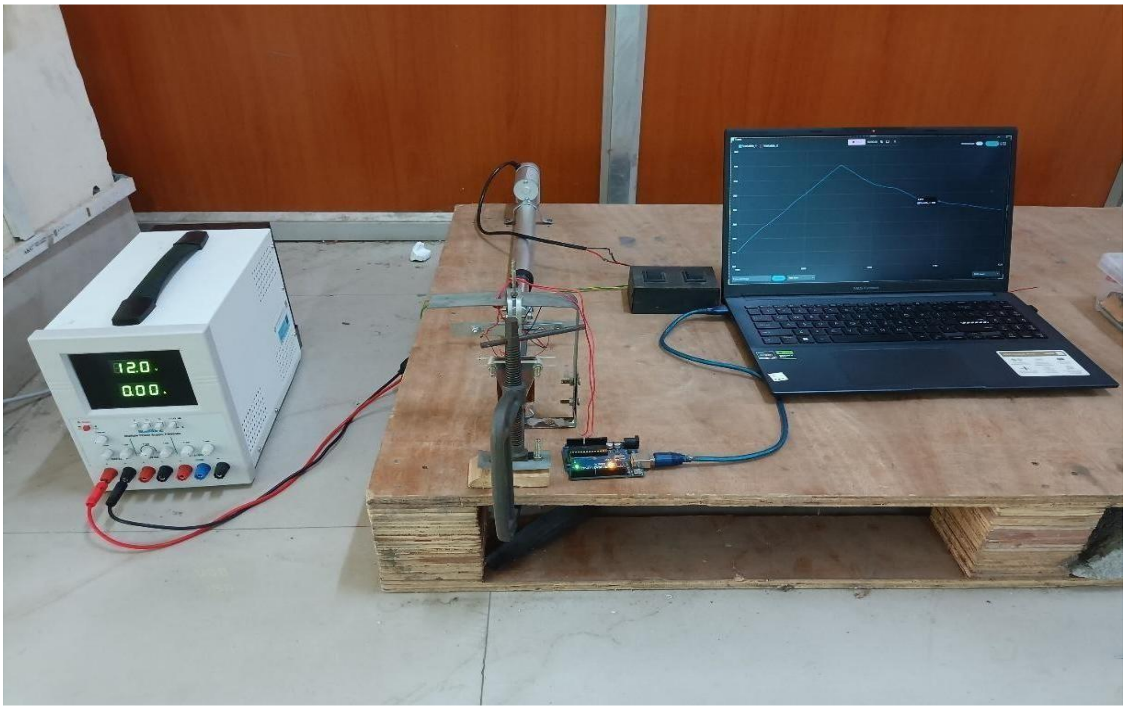

Figure 2. Setup Of Utm

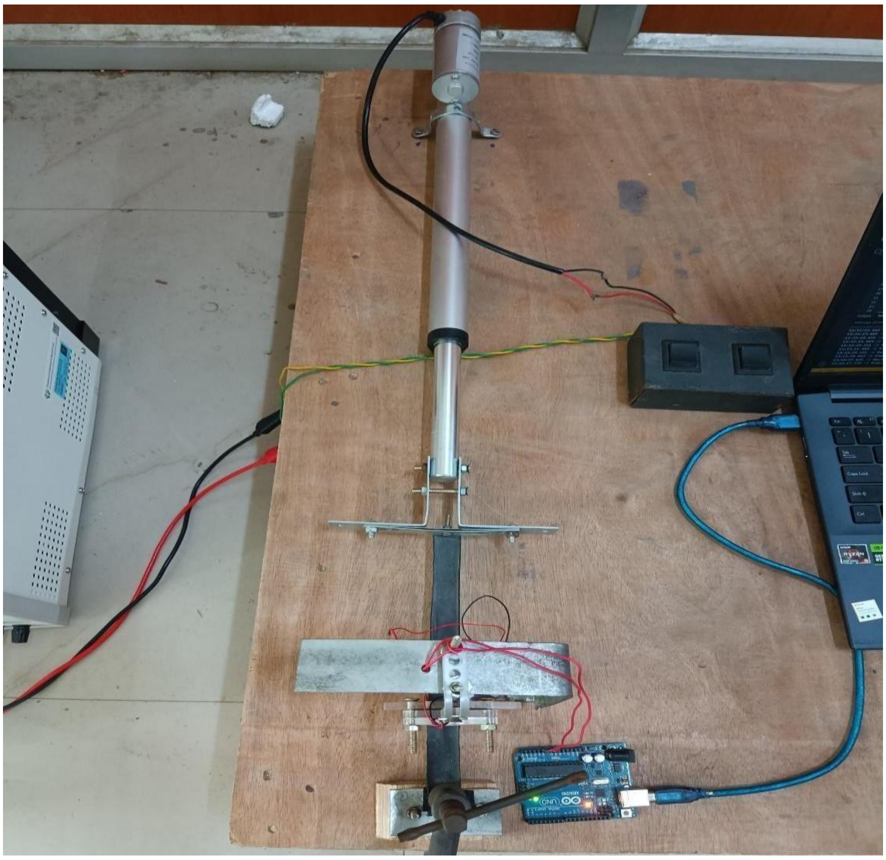

Figure 3. Linear Actuator Connected With Dpdt Switch

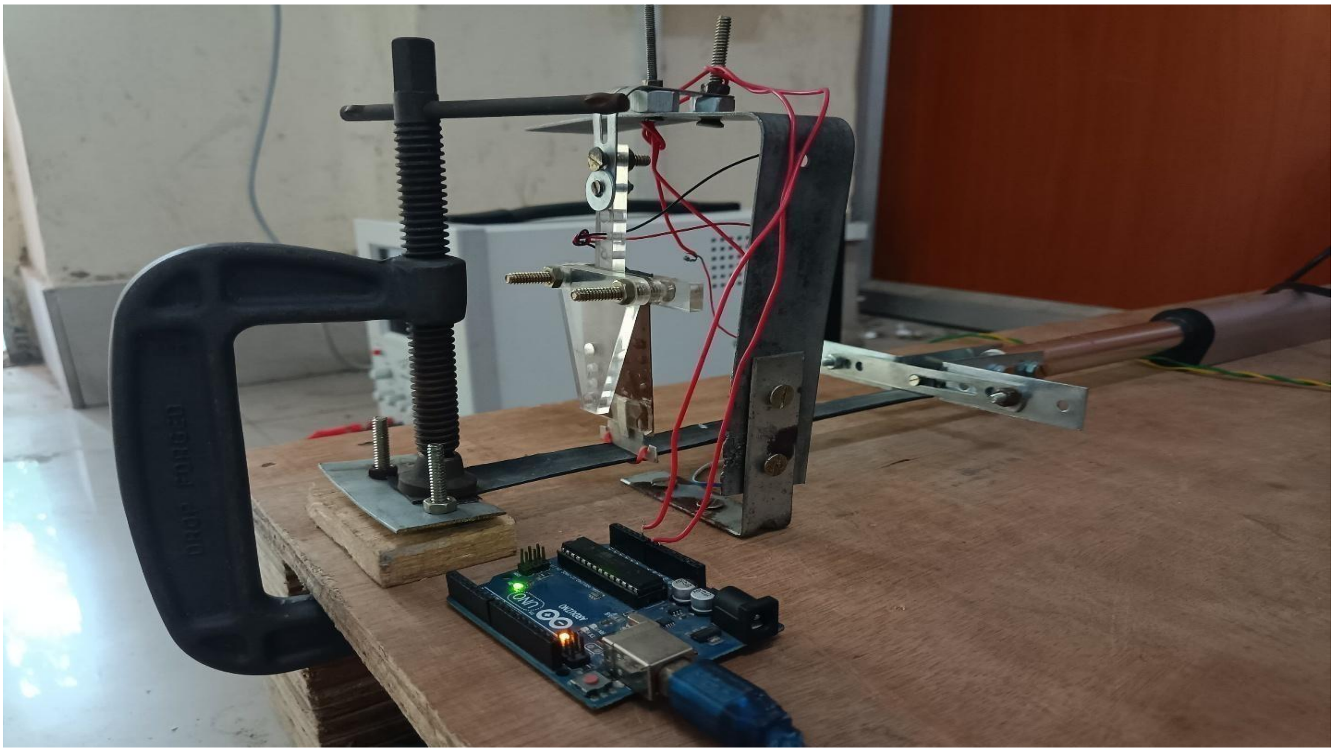

Figure 4.Piezoelectric Sensor With Arduino

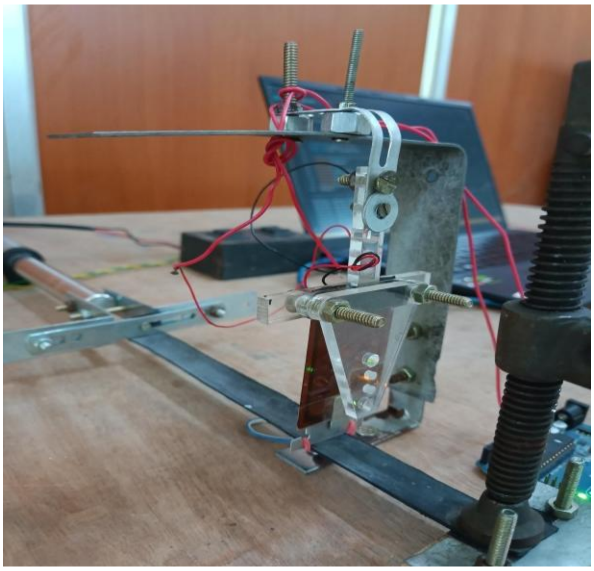

Figure 5.Piezoelectric Sensor For Measuring Stress And Strain Of Specimen

Appendix E: READING OF EXPERIMENT AND THEIR GRAPHS

TABLE 1: ELONGATION OF SPECIMEN

S.NO	CURRENT(AMPERE)	LENGTH(MM)
1	0.47	215
2	0.5	245
3	0.55	253
4	0.68	295

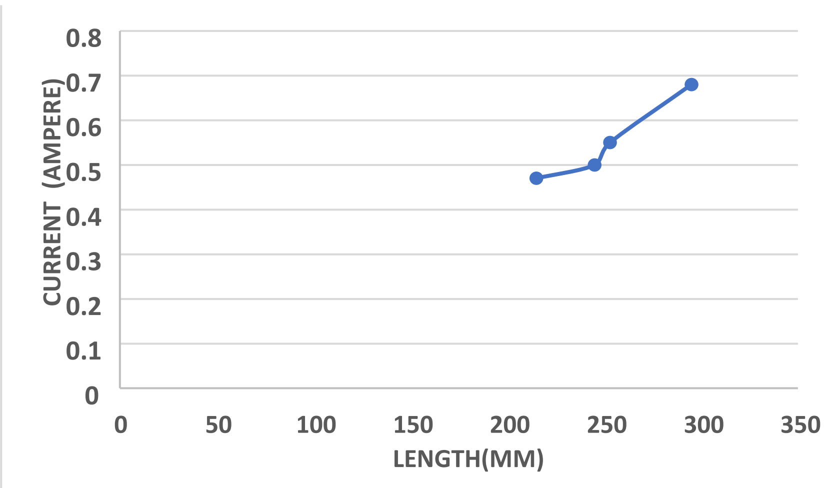

Figure 6.Plot Current V/S Length

TABLE 2: STRAIN OF ELONGATION

S.no	STRAIN (%)	TIME(S)
1	0.0013	860
2	0.00166	865
3	0.00032	870
4	0.285	875

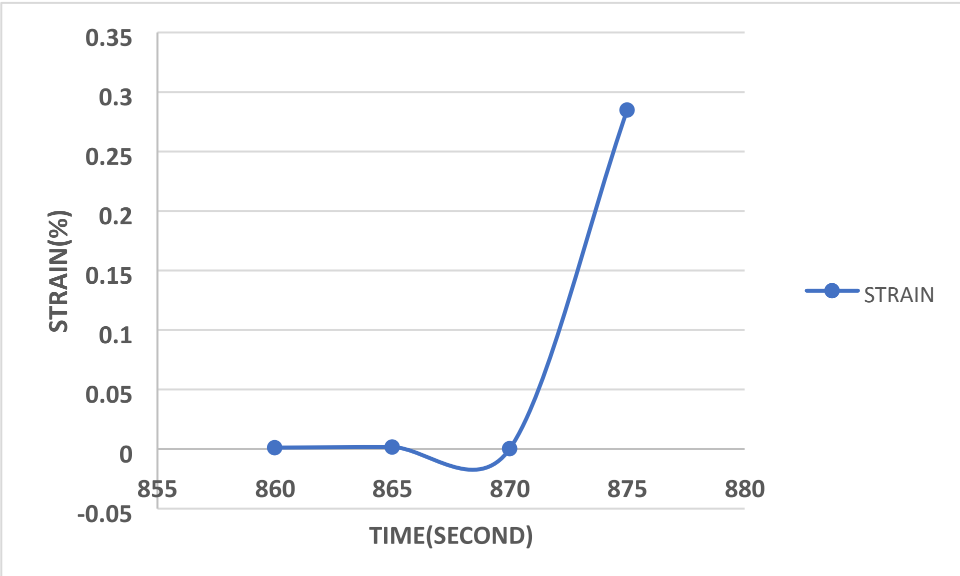

Figure 7.Plot Strain V/S Time

TABLE 3: ANALOG VERSUS FORCE

S.no	ANALOG	FORCE
1	61	0.47
2	63	0.50
3	166	0.55
4	303	0.68

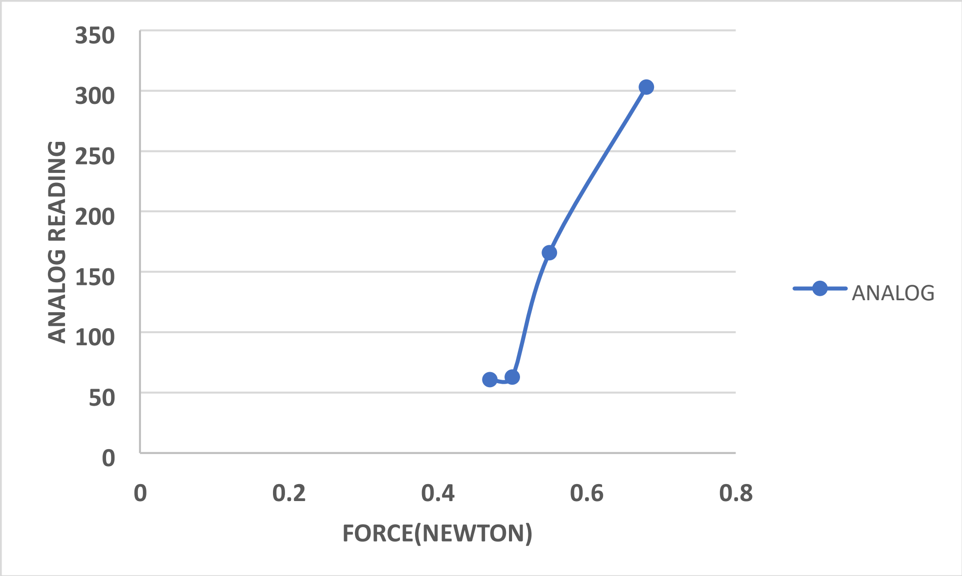

Figure8.Plot Analog Reading V/S Force

TABLE 4: RETRACT

S.no	CURRENT	LENGTH(MM)
1	0.35	24.2
2	0.4	22.1
3	0.42	20
4	0.47	17.5

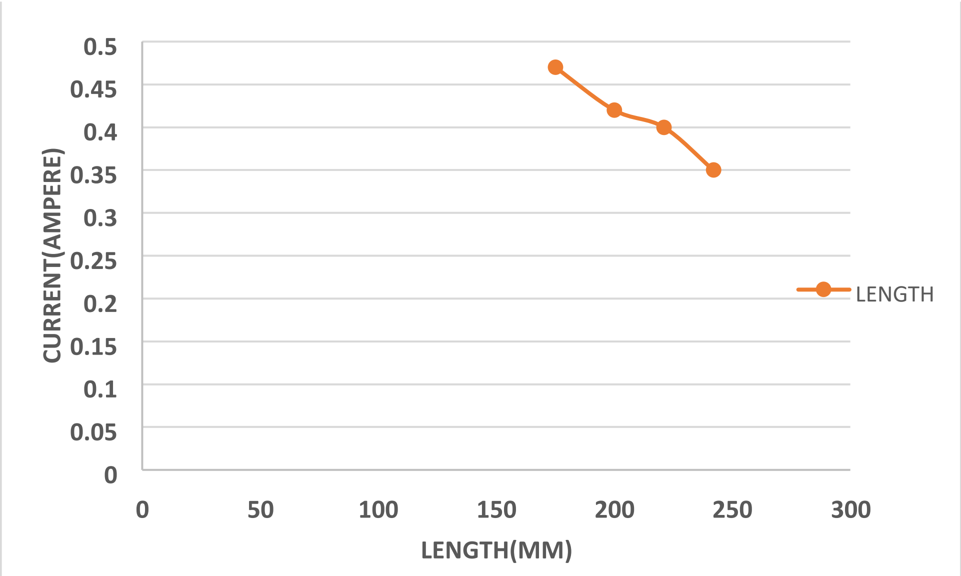

Figure 9.Plot Current V/S Length

TABLE 5: STRAIN OF RETRACT

S.no	STRAIN (%)	TIME(S)
1	0.0014	880
2	0.00105	885
3	0.00095	890

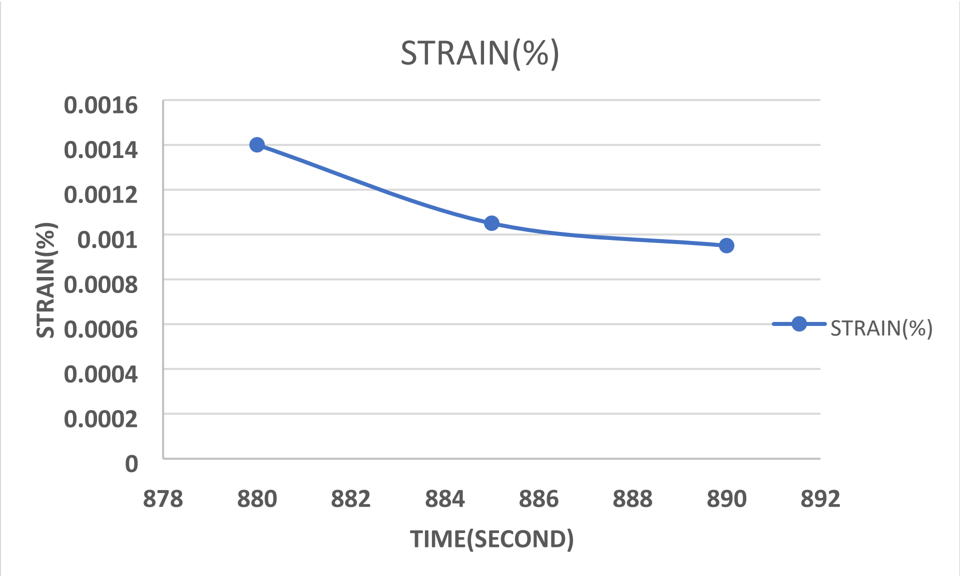

Figure 10.Plot Strain V/S Time

TABLE 6 ANALOG VERSUS FORCE

S.no	ANALOG	FORCE
1	61	0.47
2	63	0.42
3	166	0.40
4	303	0.35

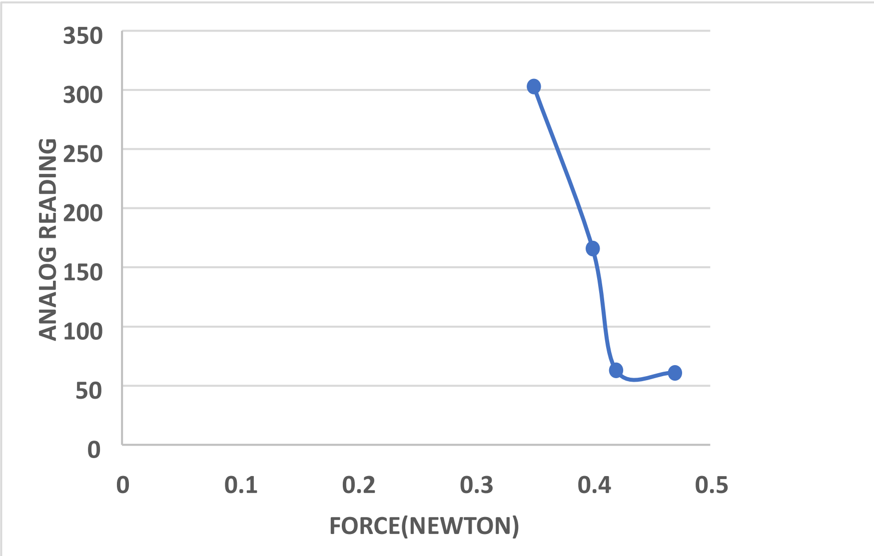

Figure 11.Plot Analog Reading V/S Force

TABLE:7 ANALOG READING OF PIEZOELECTRIC SENSOR

S.no	ANALOG READING	TIME
1	61	860
2	63	864
3	166	865
4	303	866
5	429	867

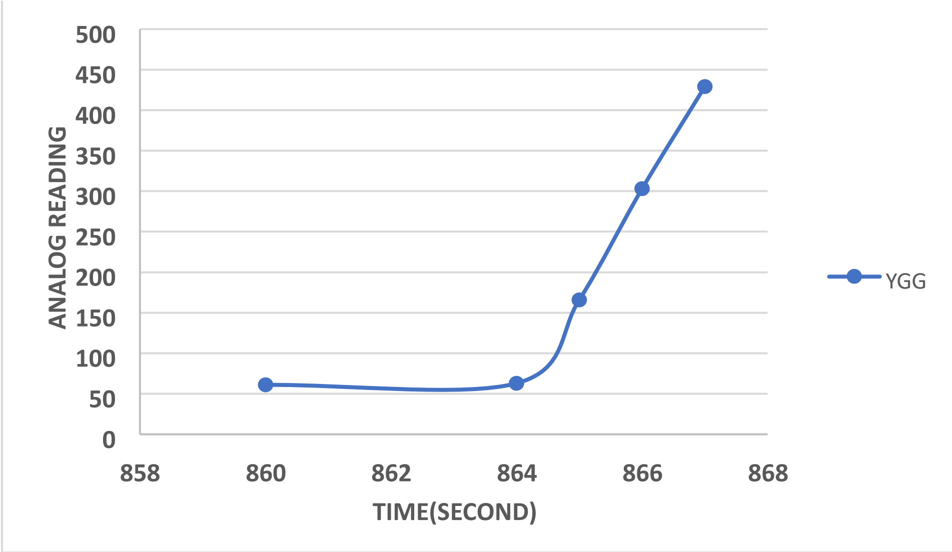

Figure 12.Plot Analog V/S Time

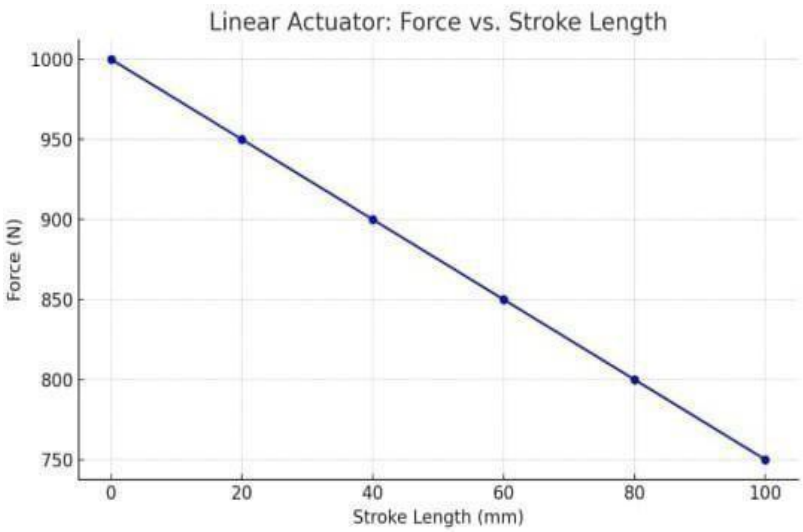

Figure 13: Variation Of Force V/S Stroke Length Of LinearActuator

6.References

Arduino Official Documentation https://www.arduino.cc/reference/en/

Used for understanding Arduino functions, pin configurations, and sensor interfacing.

Linear Actuator Control Using Arduino https://howtomechatronics.com/tutorials/arduino/linearactuat or control-witharduino / *Helped in understanding actuator control using motor drivers and relays*.