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Design and Development of a Low-Cost Arduino-Based Automatic Wire Cutting Machine for Small-Scale Industrial Applications

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Abstract: *Automation has become an essential part of modern manufacturing by improving production efficiency, reducing manual effort, and ensuring consistent product quality. Wire cutting is a repetitive operation performed in electrical, electronic, automotive, and cable manufacturing industries, where manual cutting often results in inconsistent wire lengths, lower productivity, and increased labour costs. This paper presents the design and development of a low-cost Arduino-based automatic wire cutting machine intended for small-scale industries and educational laboratories. The proposed system integrates an Arduino Uno microcontroller, BO motor, servo motor, relay module, and mechanical cutting mechanism to automate the wire feeding and cutting processes. The microcontroller controls the sequence of operations by driving the feeding motor and actuating the cutting mechanism after the required wire length is achieved. The developed prototype provides a simple, economical, and reliable alternative to expensive industrial wire cutting machines while maintaining satisfactory cutting accuracy and operational efficiency. The system is compact, easy to operate, and requires minimal maintenance, making it suitable for applications where moderate production capacity and affordability are important. The proposed design demonstrates how low-cost embedded systems can be effectively utilized to improve productivity in small manufacturing environments.*

Keywords: Arduino Uno, Automation, Embedded System, Low-Cost Manufacturing,Wire Cutting Machine.

I. INTRODUCTION

Industrial automation has significantly transformed manufacturing processes by replacing repetitive manual operations with intelligent electromechanical systems. Automation not only increases production efficiency but also improves product quality, reduces manufacturing costs, and enhances operator safety. Among various manufacturing operations, wire cutting is one of the most frequently performed processes in electrical and electronic industries. The demand for accurately cut wires has increased considerably with the growth of industries such as automotive manufacturing, consumer electronics, telecommunications, renewable energy systems, and industrial control panels.

In many small-scale industries and workshops, wire cutting is still performed manually using hand-operated tools. Although manual cutting requires minimal investment, it suffers from several disadvantages, including inconsistent wire lengths, lower production rates, operator fatigue, and higher material wastage. Repetitive manual operations also increase the possibility of human error, affecting the quality of the final product and reducing manufacturing efficiency.

Large manufacturing industries generally employ Computer Numerical Control (CNC) wire cutting machines or fully automated cable processing systems. These machines provide excellent precision and high production rates but involve substantial capital investment, making them economically unsuitable for educational institutions, laboratories, and

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small manufacturing units. Consequently, there is a need for an affordable automation solution that offers acceptable accuracy without significantly increasing production costs.

Microcontroller-based automation systems provide an effective solution to this problem. The availability of low-cost embedded platforms such as the Arduino Uno enables the development of economical automation systems with sufficient processing capability for industrial applications. Arduino-based controllers are easy to program, highly reliable, and capable of interfacing with various actuators and sensors, making them suitable for prototype development and small-scale automation projects.

The automatic wire cutting machine presented in this research utilizes an Arduino Uno as the central control unit. The system consists of a wire feeding mechanism driven by a BO motor, a relay-controlled cutting mechanism, and a servo motor for precise cutting operation. The controller automates the entire sequence of wire feeding and cutting, thereby reducing manual intervention and improving repeatability.

Unlike costly industrial equipment, the proposed system focuses on affordability, simplicity, and ease of operation. The machine is intended for educational institutions, maintenance workshops, small-scale cable manufacturing industries, and prototype development laboratories where production volumes are moderate but consistent cutting accuracy is required.

The major contribution of this work is the development of a compact and economical automatic wire cutting machine that demonstrates the practical application of embedded control systems in manufacturing automation. The proposed design provides a foundation for future enhancements while maintaining a low manufacturing cost suitable for resource-constrained environments.

II. LITERATURE REVIEW

Automation of wire processing systems has attracted considerable attention because of the increasing need for higher productivity, precision, and reduced operational costs. Researchers have proposed several automatic wire cutting machines employing different control techniques, mechanical configurations, and embedded platforms.

Patil *et al.* developed a microcontroller-based automatic wire cutting machine aimed at improving productivity in small-scale industries. Their system utilized motor-driven rollers for wire feeding and a mechanical blade controlled through an embedded controller. Experimental results indicated that the developed machine significantly reduced manual effort while achieving acceptable cutting accuracy. However, the proposed system primarily focused on automation and did not emphasize user-friendly operation or flexibility for different wire dimensions.

Mohamad proposed an automatic wire cutting mechanism capable of reducing human intervention during repetitive wire processing tasks. The study highlighted the importance of selecting appropriate motors and mechanical components to achieve stable wire feeding. Although the prototype demonstrated satisfactory performance, improvements in system compactness and operational efficiency were suggested for future development.

Ahmad and Ishak presented an Arduino-based automatic cable cutter integrating a roller feeding mechanism with programmable control. The Arduino controller was responsible for measuring the required cable length and initiating the cutting sequence. Their work demonstrated that low-cost embedded controllers can effectively replace expensive industrial automation systems for educational and small-scale manufacturing applications.

Mansingh *et al.* developed an economical automatic wire cutting machine emphasizing affordability and simplicity. Their design successfully reduced operator fatigue while maintaining consistent wire lengths. The authors concluded that embedded automation provides a practical solution for workshops and small manufacturing industries where production volumes are moderate.

Recent developments in industrial automation have increasingly focused on integrating programmable controllers, precise motion control, and intelligent monitoring techniques into wire processing systems. Although advanced industrial machines provide exceptional accuracy and productivity, their high installation and maintenance costs limit their adoption by educational institutions and small manufacturing enterprises. Consequently, there remains significant

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interest in developing economical embedded automation systems that balance cost, simplicity, and acceptable performance.

Table 1. Summary of Previous Research

Author	Year	Contribution	Limitation
Patil et al.	2017	Automatic wire cutting using embedded control	Limited flexibility for different wire types
Mohamad	2018	Automated wire feeding and cutting mechanism	Limited experimental evaluation
Ahmad & Ishak	2022	Arduino-based cable cutter	Suitable mainly for educational applications
Mansingh et al.	2022	Low-cost automatic wire cutter	No detailed performance comparison

III. RESEARCH GAP

The literature indicates that most existing low-cost automatic wire cutting systems concentrate primarily on automating the cutting operation while providing limited emphasis on affordability, ease of fabrication, compact design, and suitability for educational institutions and small manufacturing units. Furthermore, commercially available automatic wire cutting machines are often expensive and require sophisticated maintenance, making them inaccessible to many small-scale users.

There is therefore a need for a simple, low-cost, Arduino-based automatic wire cutting machine that can provide reliable wire feeding, consistent cutting performance, and straightforward operation using readily available components. The proposed work addresses this requirement by developing a compact embedded automation system that balances performance, cost, and ease of implementation.

IV. OBJECTIVES

The primary objectives of the proposed research are:

1. To design and fabricate a low-cost automatic wire cutting machine using an Arduino Uno microcontroller.
2. To automate the wire feeding and cutting operations, thereby reducing manual intervention.
3. To improve cutting consistency and minimize errors associated with manual wire cutting.
4. To develop an economical solution suitable for small-scale industries and educational laboratories.
5. To demonstrate the application of embedded control systems in industrial automation.
6. To provide a reliable prototype that can serve as a foundation for future enhancements such as automatic wire stripping and advanced control features.

V. PROPOSED SYSTEM DESIGN

A. System Overview

The proposed Automatic Wire Cutting Machine is a compact electromechanical system developed to automate the repetitive process of wire feeding and cutting. The system integrates mechanical components with an Arduino Uno microcontroller to achieve consistent wire lengths while minimizing human intervention. The machine is designed primarily for small-scale manufacturing industries, educational laboratories, and maintenance workshops where affordability, simplicity, and reliability are major requirements.

The operating principle consists of three major stages: wire feeding, length control, and cutting. Initially, the wire is supplied from a spool and guided through a pair of feeding rollers. A BO motor rotates the rollers, feeding the wire forward at a controlled speed. The Arduino Uno controls the feeding duration according to the programmed wire length. Once the desired length is reached, the controller stops the feeding motor and activates the servo motor to

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operate the cutting blade. After the wire is cut, the servo returns to its initial position, and the system becomes ready for the next cutting cycle.

Unlike industrial CNC wire processing machines, the proposed system focuses on simplicity and low manufacturing cost while maintaining acceptable cutting accuracy for educational and small industrial applications.

B. System Architecture

The developed machine consists of three major subsystems:

A. Mechanical Subsystem

The mechanical subsystem performs the physical movement of the wire and cutting mechanism. It includes:

- Machine frame
- Wire guide
- Feeding rollers
- Cutting blade
- Wire holding arrangement

The frame provides structural rigidity while ensuring proper alignment of the wire throughout the cutting process.

B. Electrical Subsystem

The electrical subsystem supplies power and controls the actuators.

Main components include:

- Arduino Uno
- Relay Module
- Servo Motor
- BO Motor
- Power Supply
- Connecting Wires

C. Control Subsystem

The control subsystem coordinates all machine operations. The Arduino Uno executes the programmed sequence by controlling the relay and servo motor according to the predefined timing.

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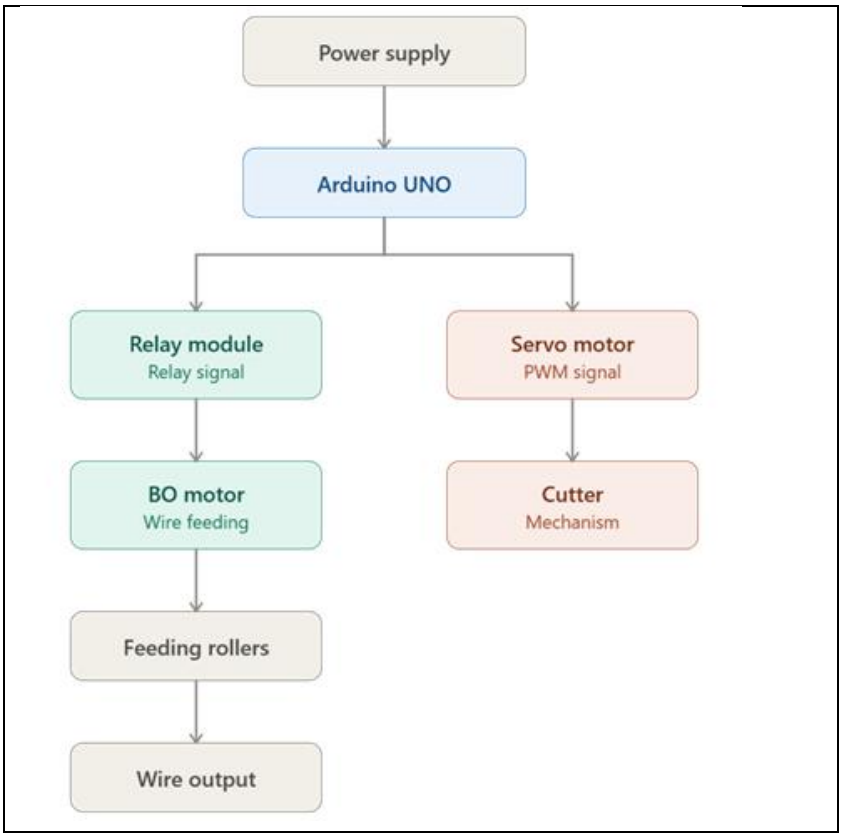

Figure 1. Functional block diagram of the Arduino based Automatic Wire Cutting Machine.

Materials and Components

The machine utilizes commercially available components to minimize fabrication cost while maintaining satisfactory performance.

Table 2. Hardware Components

Sr. No.	Component	Specification	Function
1	Arduino Uno	ATmega328P	Main controller
2	BO Motor	12 V DC	Wire Feeding
3	Servo Motor	SG90	Blade Movement
4	Relay Module	5V	Motor witching
5	Cutting Blade	Steel	Wire Cutting
6	Power Supply	12 V DC	System Power
7	Connecting Wires	Copper	Electrical Connections
8	Machine Frame	Acrylic/MS	Mechanical Support

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A. Arduino Uno

The Arduino Uno serves as the central processing unit of the developed system. It executes the embedded program responsible for controlling the feeding motor, relay module, and servo motor. The Arduino receives user-defined timing parameters and performs the cutting sequence automatically.

Its advantages include:

- Low cost
- Open-source platform
- Easy programming
- High reliability
- Availability of development libraries

B. BO Motor

The BO motor drives the feeding rollers responsible for pulling the wire through the machine. The rotational speed determines the wire feed rate and ultimately influences cutting accuracy.

Advantages include:

- Low power consumption
- Compact size
- Economical
- Easy speed control

C. Servo Motor

The servo motor performs the cutting operation by rotating the cutting blade through a predetermined angle. Its built-in feedback mechanism ensures repeatable blade movement during every cutting cycle.

Advantages include:

- Accurate positioning
- High repeatability
- Low maintenance
- Smooth operation

D. Relay Module

The relay module electrically isolates the Arduino controller from the higher current required by the BO motor. It functions as an electronically controlled switch, allowing the microcontroller to safely operate the feeding mechanism.

E. Cutting Blade

The cutting blade is fabricated using hardened steel capable of producing clean cuts on electrical wires. The blade is connected to the servo motor through a mechanical linkage to generate sufficient cutting force.

Working Principle

The operation of the developed machine follows a sequential control process.

Step 1: Wire Loading

The wire is mounted on a spool and inserted into the feeding guide.

Step 2: Wire Feeding

The Arduino energizes the relay, allowing the BO motor to rotate. The rollers pull the wire forward.

Step 3: Length Measurement

Instead of using a sensor, the required wire length is achieved by controlling the feeding duration through the programmed motor operating time. This timing-based approach matches the implemented prototype.

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Step 4: Motor Stop

Once the preset feeding time elapses, the Arduino deactivates the relay, stopping the BO motor.

Step 5: Cutting Operation

The Arduino generates a PWM signal to rotate the servo motor, moving the cutting blade downward and severing the wire.

Step 6: Servo Reset

After the cut is completed, the servo motor returns to its initial position.

Step 7: Repeat Cycle

The controller repeats the sequence until the required number of wire pieces is produced.

Flowchart of Machine Operation

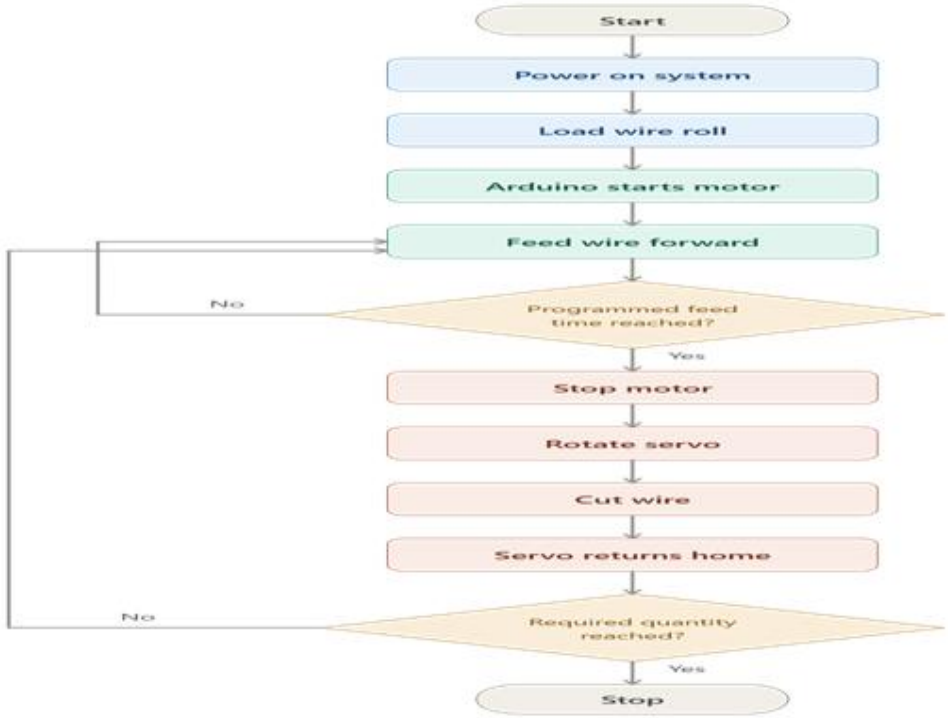

Figure 2. Operational flowchart of the proposed automatic wire cutting machine.

Control Algorithm

The control algorithm implemented in the Arduino Uno can be summarized as follows:

1. Initialize the Arduino and output pins.
2. Power on the system.
3. Activate the relay to start the BO motor.
4. Feed the wire for the programmed duration.
5. Stop the BO motor.
6. Rotate the servo motor to perform the cutting operation.
7. Return the servo to its initial position.
8. Check whether the required quantity has been completed.
9. If additional wire pieces are required, repeat the cycle; otherwise, stop the system.

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Experimental Setup

The developed prototype was assembled using readily available mechanical and electronic components to demonstrate the automatic wire cutting process. The experimental setup consisted of an Arduino Uno microcontroller, BO motor, servo motor, relay module, power supply, cutting blade, and mechanical frame. The wire spool was mounted on the frame and guided through the feeding rollers towards the cutting mechanism.

The Arduino Uno was programmed using the Arduino IDE to control the sequence of wire feeding and cutting. The BO motor rotated the feeding rollers to move the wire forward for a predetermined time, while the servo motor actuated the cutting blade after the feeding cycle was completed. A regulated DC power supply provided electrical power to the controller and actuators.

The prototype was tested by repeatedly performing the automatic feeding and cutting sequence to verify the synchronization between the electrical and mechanical subsystems. The overall setup is shown conceptually in Figure 3.

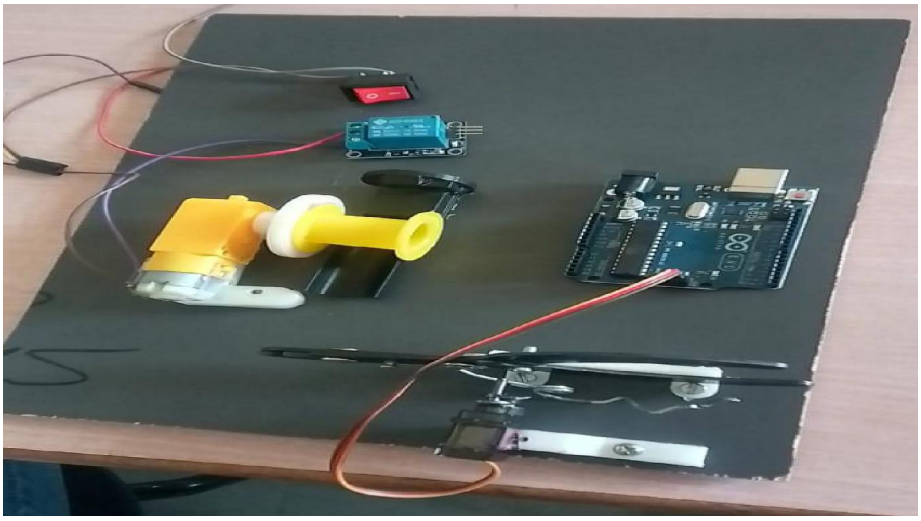

Figure 3. Experimental Setup

Table 3.Component Estimation for experimental Setup

Component	Specification	Purpose
Arduino Uno	ATmega328P	System Controller
BO Motor	12 V DC	Wire Feeding
Servo Motor	SG90	Cutting Blade Movement
Relay Module	5 V	Motor Switching
Power Supply	12 V DC	Power Source
Wire Guide	Acrylic	Wire Alignment
Cutting Blade	Hardened Steel	Wire Cutting
Frame	Acrylic / Mild Steel	Structural Support

Performance Evaluation

The developed prototype was evaluated based on its operational performance during repeated demonstrations. The evaluation focused on the following parameters:

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- Successful wire feeding
- Proper synchronization between feeding and cutting
- Reliable servo operation
- Consistent completion of the cutting cycle
- Ease of operation
- Compactness of the overall design

The prototype successfully completed the programmed sequence without requiring continuous operator intervention. The Arduino controller coordinated the motor and servo operations effectively, demonstrating the feasibility of using a low-cost embedded controller for automatic wire cutting.

Although the prototype achieved its intended objective, the wire length was controlled using motor operating time rather than a dedicated length sensor or encoder. Therefore, cutting accuracy may vary slightly depending on factors such as motor speed fluctuations, supply voltage, and roller slippage. Nevertheless, the timing-based control strategy proved suitable for demonstrating the concept of automatic wire cutting using low-cost components.

VI. RESULTS AND DISCUSSION

The developed automatic wire cutting machine successfully demonstrated the complete sequence of wire feeding and cutting under the programmed control of the Arduino Uno. During operation, the feeding motor transported the wire through the guide mechanism, after which the controller stopped the feeding process and actuated the servo motor to perform the cutting operation. The sequence was repeated automatically, confirming the reliability of the programmed control logic.

The experimental observations indicate that the proposed system effectively reduces manual effort associated with conventional wire cutting. Automation of the repetitive cutting process minimizes operator involvement and improves consistency in comparison with manual operation. Furthermore, the compact mechanical structure and use of commercially available components make the prototype suitable for educational laboratories and small-scale manufacturing environments.

The prototype also demonstrated the capability of integrating electrical and mechanical subsystems through embedded control. The Arduino Uno successfully synchronized the operation of the feeding motor and cutting mechanism without requiring complex industrial controllers. This confirms that low-cost embedded systems can provide an economical alternative for automation of simple manufacturing processes.

The developed system offers several practical advantages, including ease of assembly, low fabrication cost, simple programming, and straightforward maintenance. These characteristics make the prototype particularly attractive for institutions and workshops where sophisticated industrial automation equipment is not economically feasible.

Table 4. Functional Performance of the Prototype

Test Parameter	Observation
System Initialization	Successful
Wire Feeding	Successful
Motor Control	Stable
Relay Switching	Successful
Servo Operation	Successful
Automatic Cutting	Successful
Repeat Cycle	Successful

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Overall Operation	Satisfactory

Cost Analysis

One of the major objectives of this project was to develop an economical automatic wire cutting machine using readily available components. Compared with commercial automatic wire cutting machines, which involve considerably higher procurement costs, the developed prototype can be fabricated at a significantly lower cost.

Table 5. Estimated Cost of the Prototype

Component	Quantity	Approximate Cost (₹)
Arduino Uno	1	550
BO Motor	1	180
Servo Motor	1	180
Relay Module	1	120
Power Supply	1	250
Cutting Blade	1	100
Acrylic/Metal Frame	1	350
Connecting Wires & Miscellaneous	—	270
Total Estimated Cost		₹2,000 (Approx.)

Note: Costs are approximate and may vary depending on supplier and market conditions.

Advantages of the Proposed System

The developed automatic wire cutting machine offers several advantages over conventional manual wire cutting methods.

- Low fabrication cost using commercially available components.
- Compact and lightweight design.
- Easy installation and operation.
- Reduced manual effort.
- Improved productivity through automation.
- Repeatable cutting sequence.
- Simple programming using the Arduino platform Low maintenance requirements.
- Suitable for educational laboratories and small-scale industries.
- Modular design that allows future upgrades.

Limitations

Despite its successful operation, the prototype has certain limitations that should be considered.

- Wire length is controlled using motor timing rather than direct measurement.
- The system is suitable only for light-duty wire cutting.
- Cutting accuracy depends on consistent motor speed.
- No automatic wire stripping mechanism is provided.

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- The prototype is intended primarily for laboratory and educational applications rather than high-volume industrial production.

Comparison with Existing Systems

Table 6. Comparison of the Proposed Machine with Existing Systems

Parameter	Manual Wire Cutting	Commercial Automatic Machine	Proposed Prototype
Initial Cost	Low	High	Low
Automation	No	Yes	Yes
Operator Effort	High	Low	Low
Ease of Maintenance	High	Moderate	High
Suitable for Educational Use	Limited	No	Yes
Programming Flexibility	No	Limited	High
Portability	High	Low	High
Fabrication Complexity	Low	High	Low

Discussion

The proposed automatic wire cutting machine successfully demonstrates that embedded systems can be effectively applied to automate repetitive manufacturing tasks at minimal cost. The Arduino-based control architecture provides sufficient flexibility for controlling sequential operations while maintaining a simple hardware configuration.

Compared with industrial wire cutting equipment, the developed prototype emphasizes affordability rather than high-speed production. Nevertheless, it effectively illustrates the principles of industrial automation and embedded control, making it highly suitable for engineering education, laboratory experimentation, and small manufacturing applications.

The successful integration of mechanical design, embedded programming, and electromechanical actuation confirms the feasibility of developing practical automation systems using open-source hardware platforms.

Future Scope

Although the developed automatic wire cutting machine successfully automates the wire feeding and cutting operations, several enhancements can be incorporated in future versions to improve its functionality, accuracy, and industrial applicability.

One of the primary improvements would be the integration of a wire length measurement sensor or rotary encoder to achieve higher cutting accuracy and reduce dependence on motor timing. Such a feedback mechanism would enable precise wire length control regardless of motor speed variations or supply voltage fluctuations.

Another possible enhancement is the addition of a wire stripping mechanism that can automatically remove insulation from both ends of the wire after cutting. This would make the machine more suitable for cable harness manufacturing and electrical assembly applications.

The user interface can also be improved by incorporating an LCD display with a keypad, allowing the operator to enter the required wire length and quantity directly without modifying the Arduino program. This would increase operational flexibility and ease of use.

The mechanical design can be strengthened to process different wire gauges and insulation materials. A more rigid frame and industrial-grade feeding rollers would improve durability and enable the system to handle larger production volumes.

Additional safety features, such as emergency stop switches, overload protection, and protective covers around the cutting mechanism, can further enhance operator safety during machine operation.

Finally, the proposed prototype can serve as a foundation for future research in embedded automation, where advanced control techniques and intelligent sensing may be incorporated to improve productivity and operational efficiency.

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VII. CONCLUSION

This paper presented the design and development of a low-cost Arduino-based automatic wire cutting machine intended for small-scale industrial applications and engineering laboratories. The proposed system successfully automates the wire feeding and cutting process using an Arduino Uno microcontroller, BO motor, relay module, servo motor, and a simple mechanical cutting mechanism.

The developed prototype demonstrated reliable coordination between the electrical and mechanical subsystems, resulting in successful execution of the programmed cutting sequence. By automating repetitive wire cutting operations, the system reduces manual effort, improves operational consistency, and provides an economical alternative to conventional manual wire cutting methods.

One of the major advantages of the developed machine is its affordability. The use of readily available electronic components and open-source programming tools significantly reduces the fabrication cost while maintaining satisfactory performance for educational and small-scale industrial applications. The modular design also allows future upgrades without major modifications to the existing hardware.

Although the current prototype controls wire length using motor timing, the system effectively demonstrates the practical implementation of embedded automation in manufacturing applications. The developed prototype can therefore serve as an educational platform for students studying mechatronics, embedded systems, and industrial automation while also providing a useful solution for workshops and small production units.

Overall, the proposed automatic wire cutting machine successfully achieves the project objectives by combining simplicity, affordability, and automation into a compact electromechanical system. The work demonstrates the potential of low-cost embedded controllers for automating repetitive industrial processes and provides a strong foundation for future development.

VIII. ACKNOWLEDGEMENT

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