Modeling and Manufacturing of Automated Wire Meshing Machine

Course Title-Project and Thesis
Course Code: ME 400



A thesis

By

Md. Motiur Rahaman	ID: ME2103025088
Md. Ashakur Rahman	ID: ME2103025100
Md. Rakibul Islam	ID: ME2103025083
SK. Nahid Hossain	ID: ME2103025428
Md. Pervez Rana	ID: ME2103025001
Md. Nur Amin Sarkar	ID: BME1901017516

Department of Mechanical Engineering

SONARGAON UNIVERSITY (SU)

MAY 2025

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Md. Pervez Rana	ID: ME2103025001
Nur Amin Sarkar	ID: BME1901017516

Supervisor: Md. Minhaz Uddin
Assistant Professor

Submitted to the

DEPARTMENT OF MECHANICAL ENGINEERING

SONARGAON UNIVERSITY (SU)

In partial fulfillment of the requirements for the award of the degree

of

Bachelor of Science in Mechanical Engineering

MAY 2025

Declaration

It is declared hereby that this thesis paper or any part of it has not been submitted to anywhere else for the award any degree.

.....
Md. Motiur Rahaman

.....
Md. Ashakur Rahman

.....
Md. Rakibul Islam

.....
SK Nahid Hossain

.....
Md. Pervez Rana

.....
Md. Nur Amin Sarkar

Certification

This is to certify that this project entitled "**Modeling and Manufacturing of Automated Wire Meshing Machine**" is done by the following students under my direct supervision. This project work has been carried out by them in the laboratories of the Department of Mechanical Engineering under the Faculty of Engineering, Sonargaon University (SU) in partial fulfillment of the requirements for the degree of Bachelor of Science in Mechanical Engineering.

Supervisor:

……

Md. Minhaz Uddin

Assistant professor, Sonargaon University (SU)

Dhaka-1215, Bangladesh.

Acknowledgement

At first, we would like to express our gratitude to Almighty Allah for giving us the strength and opportunity to complete our dissertation within the scheduled time successfully. The presentation of the project paper represents the collaborative efforts and generous support of a number of individuals. The Department of Mechanical Engineering (ME), Sonargaon University provided important subject expertise and information technology services to carry out the project work successfully. We feel proud to express our deep sense of gratitude to our reverend teacher, guide and supervisor, for his day to day supervision, dexterous management, adept analysis, keen interest, optimistic counseling, and unremitting backup. We are very much indebted to Md. Minhaz Uddin, Assistant Professor, Department of Mechanical Engineering, Sonargaon University, for including a dissertation as a course in B.Sc. in engineering to strengthen eligibility of students. We would also like to thank those persons of Department of Mechanical, Sonargaon University, for their encouragement and help in our project work.

Abstract

The growing demand for efficient and precise manufacturing processes in the construction and fabrication industries has highlighted the need for automation in wire mesh production. This project presents the design, modeling, and manufacturing of an Automated Wire Meshing Machine aimed at improving productivity, accuracy, and safety compared to traditional manual methods. The machine is designed to automate key operations such as wire feeding, straightening, cutting, and welding to form mesh structures of predefined dimensions. CAD tools were utilized for detailed mechanical modeling, followed by fabrication using standard machining and assembly techniques. Control of the machine is managed via a microcontroller-based system that coordinates motor functions and sensor feedback for synchronization and error reduction. The automated solution significantly reduces labor requirements and operational time while ensuring uniform mesh quality. The prototype was tested under various operating conditions, and performance metrics such as mesh uniformity, cycle time, and operational reliability were evaluated. The results validate the effectiveness of the proposed machine as a low-cost, scalable solution for industrial and small-scale wire mesh production.

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Chapter 1
Introduction

1.1. Introduction

The modeling and manufacturing of an automated wire meshing machine represents a significant step toward advancing industrial automation in construction and fabrication sectors. This innovative machine is designed using a microcontroller as its central control unit, integrating multiple electromechanical components to perform wire mesh production with precision and efficiency. Two servo motors are employed to pull the mesh forward systematically, ensuring consistent alignment and spacing. A gear motor provides the mechanical drive for the weaving mechanism, synchronizing with the servo motors to maintain mesh tension. For the cutting process, a sensor-driven system detects the desired mesh length and activates an automated cutting blade, minimizing manual intervention and enhancing repeatability. The microcontroller coordinates all components, allowing real-time control and programmable mesh dimensions. This system reduces human effort, increases output consistency, and significantly cuts production time. With proper calibration, the machine can accommodate various wire thicknesses and mesh sizes, offering versatility for different applications. The design emphasizes cost-effectiveness, reliability, and ease of use, making it suitable for small-scale industries and workshops. Overall, this project exemplifies how intelligent automation and compact design can revolutionize traditional manufacturing techniques.

Expanding on the design and functionality, the automated wire meshing machine is a highly integrated system engineered for efficiency, precision, and adaptability in mesh fabrication. At the heart of the machine is a microcontroller, which acts as the brain of the system—coordinating timing, motion control, and sensor feedback in real-time. Two high-torque servo motors handle the synchronized pulling of the mesh, maintaining

consistent spacing and tautness as the wires are fed through the system. A gear motor is responsible for driving the mechanical weaving mechanism, ensuring the wire intersections are securely locked or welded, depending on the configuration.

An optical or proximity sensor is strategically placed to measure the length of the mesh being produced. Upon reaching the set length, it triggers a cutting mechanism that slices the wire net accurately using a blade or heated cutter, depending on material type. This eliminates the need for manual measurement and cutting, reducing waste and human error.

The system is programmable via a user-friendly interface, allowing operators to set mesh parameters such as length, width, spacing, and wire gauge. Safety features and emergency shutoff protocols are also embedded into the control logic, ensuring smooth and secure operation. This innovative solution offers a scalable, cost-effective alternative to manual wire mesh production, suitable for use in fencing, construction reinforcement, and industrial mesh manufacturing.

1.2. Study Background

The increasing demand for automation in manufacturing has led to significant advancements in machinery design, particularly in the production of wire mesh used across construction, agriculture, and industrial sectors. Traditionally, wire meshing has been a labor-intensive process, requiring skilled workers to manually cut, align, and weave or weld wires into grids. This not only consumes time but also introduces inconsistencies and safety concerns. As industries shift toward smart manufacturing and Industry standards, there is a pressing need for automated solutions that can improve productivity, accuracy, and operational safety. The increasing adoption of automation in manufacturing industries has transformed traditional production processes, improving efficiency, precision, and safety. One such area ripe for automation is the manufacturing of wire mesh—a material widely used in construction (e.g., concrete reinforcement), agriculture (e.g., fencing), and industrial

applications (e.g., sieves, partitions). Conventionally, wire meshing has involved manual labor for cutting, aligning, and binding the mesh, which often results in time-consuming processes, human error, and inconsistent quality. [1]

Wire mesh is a critical component in applications such as concrete reinforcement, fencing, cages, sieves, and filters. Hence, its manufacturing must meet precise specifications to ensure structural integrity and functional reliability. Manual methods often fail to achieve this precision consistently, leading to material wastage and reduced product quality.

With the rise of Industry and the integration of mechatronics into manufacturing systems, there's a growing shift toward smart, embedded automation. Studies show that the application of microcontrollers, servo motors, and sensors in production machines can greatly enhance accuracy and repeatability while reducing human involvement in hazardous tasks (Kumar & Singh, 2019). In particular, servo motors provide precise control over position and speed, making them ideal for mesh pulling and alignment tasks. Gear motors offer reliable torque for wire weaving mechanisms, while sensors enable real-time feedback and automation of processes such as cutting and length detection. [2]

The development of an automated wire meshing machine addresses these challenges by integrating microcontrollers, servo and gear motors, and sensor-based controls to enable real-time automation. Such systems are compact, cost-effective, and programmable, making them ideal for small and medium enterprises looking to modernize their operations without investing in high-end industrial robots. The study explores how embedded systems and mechatronics can transform traditional wire meshing into a highly efficient and scalable process.

Moreover, the use of programmable microcontrollers (e.g., Arduino, STM32) allows for adaptable mesh dimensions and simplified user interaction, supporting flexible manufacturing systems. [3]

Automation not only increases productivity but also reduces material wastage and ensures uniform mesh spacing—critical for structural applications. This project thus responds to the need for a compact, cost-

effective, and scalable wire meshing machine suitable for small and medium-sized enterprises seeking to modernize their operations with minimal investment.

1.3. Statement of Problems

Despite the widespread use of wire mesh in industries such as construction, agriculture, and manufacturing, the production process remains largely manual, resulting in several key challenges. Firstly, manual meshing is highly labor-intensive and time-consuming, limiting production output and scalability. Secondly, human involvement often leads to inconsistent mesh dimensions, poor alignment, and quality variation, which can compromise the structural integrity of the final product.

Additionally, manual cutting and pulling of wire mesh expose workers to physical strain and potential hazards such as sharp edges and repetitive motion injuries. The absence of real-time automation also contributes to material wastage and operational inefficiencies due to overcutting or misalignment. Furthermore, most existing automated machines are large, expensive, and complex, making them inaccessible to small and medium-sized enterprises (SMEs) that require cost-effective, compact, and easy-to-operate solutions.

Therefore, there is a critical need for a low-cost, programmable, and efficient wire meshing system that automates the pulling, aligning, and cutting processes using a microcontroller, servo motors, gear motor, and sensors. Addressing these problems will not only enhance productivity and safety but also ensure consistent mesh quality and reduce operational costs.

1.4. Objectives

Here are the objectives for your project on the automated wire meshing machine:

Increase Production Efficiency: Reduce the time and labor required for wire mesh production, thereby increasing overall output and making the system suitable for high-volume manufacturing.

Ensure Consistent Mesh Quality: Achieve precise mesh dimensions, consistent spacing, and proper alignment to meet industry standards for structural integrity and durability.

Enhance Safety and Reduce Human Intervention: Minimize direct human involvement in the meshing process, reducing physical strain and the risk of injury from sharp wires and repetitive motions.

Implement Real-Time Automation: Integrate sensors to provide real-time feedback for cutting and alignment, ensuring accurate mesh length and reducing material wastage.

Create a Cost-Effective Solution: Develop an affordable, compact, and user-friendly automated system that can be easily implemented in small and medium-sized enterprises.

Optimize Machine Performance: Calibrate the system for maximum efficiency and reliability, ensuring minimal downtime and maintenance costs.

1.5. Significance of the Project

The development of an automated temperature-controlled cooling system is of the significance of the project on the Automated Wire Meshing Machine lies in its potential to transform the wire mesh manufacturing process by introducing automation, precision, and efficiency. The key contributions and impact of the project are as follows:

1. **Production Efficiency**: By automating critical processes such as pulling, aligning, and cutting, the system will significantly reduce production time and labor costs. This leads to higher throughput, allowing manufacturers to meet growing market demands more effectively.
2. **Enhanced Quality Control**: Automation ensures consistent mesh dimensions, precise wire spacing, and better alignment, which are essential for maintaining product quality. The system reduces human error, ensuring that every batch of mesh produced adheres to strict quality standards, especially for applications that require high structural integrity like concrete reinforcement.

3. **Cost-Effectiveness**: The project addresses the need for a low-cost, scalable automation solution. Small and medium-sized enterprises (SMEs), which often face barriers to adopting large, expensive machines, will benefit from a cost-effective and compact system. This will enable them to modernize their production processes without substantial capital investment.
4. **Safety Improvements**: Reducing human intervention minimizes exposure to safety risks inherent in manual meshing, such as cuts from sharp wires or repetitive strain injuries. Automated systems also enable safer handling of materials, ensuring that operators can monitor the process from a distance rather than working in close proximity to dangerous machinery.
5. **Reduction of Material Wastage**: With built-in sensors for real-time measurement and cutting, the machine ensures that only the necessary amount of wire is used, thus reducing material wastage. This not only makes the production process more sustainable but also lowers overall manufacturing costs.
6. **Flexible and Programmable Design**: The ability to adjust mesh dimensions, wire gauge, and other production parameters offers great flexibility. This is particularly beneficial for industries that require a variety of mesh specifications, as it allows for rapid adaptation to different customer needs without the need for retooling or significant downtime.
7. **Contribution to Industry 4.0**: The project aligns with the principles of Industry 4.0, integrating embedded systems, sensors, and automation to modernize manufacturing processes. It showcases the effective use of microcontrollers and mechatronics, advancing smart manufacturing technologies that can be easily integrated into existing production lines.
8. **Sustainability and Environmental Impact**: By optimizing material usage and reducing waste, the machine supports sustainable manufacturing practices. Additionally, the automated nature of the system can contribute to energy efficiency by minimizing idle times and operating with fewer manual interventions, which can help reduce the overall environmental footprint of the production process.

In summary, this project has the potential to revolutionize wire mesh manufacturing by improving operational efficiency, safety, quality, and sustainability, while providing an affordable solution that caters to the needs of SMEs. It contributes to the ongoing trend of automation and smart manufacturing, helping businesses stay competitive in an ever-evolving industrial landscape.

1.6. Scope of the project

The scope of the Automated Wire Meshing Machine project encompasses the design, development, and implementation of a system that automates the wire meshing process, offering significant benefits in terms of efficiency, precision, and scalability. The key aspects covered by the scope of this project are as follows:

1. **System Design and Architecture**:

    - **Microcontroller Selection and Integration**: The project will involve selecting and programming a suitable microcontroller (e.g., Arduino) to control the system, including motor coordination, sensor integration, and user interface.
    - **Mechanical Design**: The system will include a combination of servo motors for mesh pulling, gear motors for weaving, and cutting mechanisms driven by sensors for automatic length measurement and cutting.
    - **Sensor Integration**: Optical or proximity sensors will be implemented to monitor the length and alignment of the mesh in real-time, triggering the cutting process once the desired mesh size is reached.

2. **Automation of Wire Meshing Process**:

    - **Mesh Pulling and Alignment**: Two servo motors will be used to pull and align the wire mesh uniformly, ensuring consistent spacing between wires.
    - **Wire Weaving or Binding Mechanism**: The project will include a gear

motor-driven weaving mechanism, which ensures that wires are securely connected, either by weaving or welding, depending on the material requirements.

- **Cutting Mechanism**: A sensor-based cutting system will automatically detect when the mesh has reached the desired length and activate a cutting mechanism to slice the mesh without manual intervention.

3. **Safety and Operational Features**:

   - **Safety Mechanisms**: The machine will include built-in safety features such as emergency stop buttons, automatic shut-off in case of errors, and protective covers to prevent accidents.
   - **Error Detection and Feedback**: The system will be equipped with sensors to monitor the operational status and provide feedback in case of a malfunction or when maintenance is required.

4. **Cost-Effective Design**:

   - The machine will be designed to be compact and affordable, making it accessible for small and medium-sized enterprises (SMEs) involved in wire mesh production.
   - **Low Power Consumption**: Efforts will be made to design the system to consume minimal power, making it energy-efficient and reducing operational costs over time.

5. **Performance and Calibration**:

   - The system will undergo rigorous testing and calibration to ensure high performance, including consistent wire mesh dimensions, minimal material wastage, and reliable motor and sensor coordination.
   - **Durability and Reliability**: The machine will be designed with durability in mind, capable of running for long periods with minimal maintenance.

6. **Adaptability to Different Wire Materials**:

- The project will explore the adaptability of the system to work with different types of wire materials and gauges, allowing for versatile production in different industries, from construction to agriculture.

7. **Environmental Impact Considerations**:

- **Material Efficiency**: The system will aim to minimize material wastage, contributing to more sustainable production practices.
- **Energy Efficiency**: The design will incorporate energy-efficient components, ensuring the system operates within sustainable environmental standards.

1.7. Limitation

- The machine will be limited to producing wire mesh with certain thicknesses and mesh sizes, which will be defined by the capabilities of the motors and sensors.
- The machine may have limitations in terms of the wire thicknesses and mesh sizes it can produce, depending on the capabilities of the motors and sensors. Highly complex or customized mesh configurations may require further adaptations to the system.
- Complex or highly customized wire mesh configurations (such as those requiring intricate weaving patterns or multi-material layers) may not be suitable for this system without further modifications.

Chapter 2
Literature Review

2.1. Literature Review

The continuous evolution of industrial automation has significantly impacted manufacturing processes, leading to enhanced efficiency, safety, and product quality. Wire mesh production, widely used in construction, agriculture, and fencing, remains a largely manual or semi-automated process in many regions, which introduces inconsistencies and safety hazards. This has created a growing interest in developing cost-effective and automated solutions, especially for small and medium-sized enterprises.

Automation in manufacturing contributes to increased production speed, improved consistency, and reduced human error. Their study emphasized that integrating microcontrollers with mechanical components allows systems to make real-time decisions based on sensor input, making them highly adaptable for various applications, including wire mesh cutting and weaving. [4]

Exploring the role of embedded systems in industrial applications. Their work highlighted that microcontroller such as Arduino can efficiently control actuators and sensors, offering a flexible platform for automated machines. The use of servo motors and gear motors provides accurate positioning and torque control, which is essential for tasks like pulling and aligning wire mesh. [5]

In a study by the authors designed a prototype for an automated wire mesh cutting machine. Their design used an Arduino Uno, proximity sensors, and stepper motors to achieve a semi-automated system. The research demonstrated significant time savings and material efficiency compared to manual methods. However, their system was limited in scalability and adaptability, underlining the need for more robust and fully automated solutions. [6]

Reviewing the advancements in smart manufacturing systems, emphasizing the importance of integrating sensors for real-time monitoring. They noted that automation combined with feedback systems reduces product variability and

material waste. This aligns with the current project's goal of using sensors to precisely detect mesh length and trigger automated cutting. [7]

Furthermore, investigating low-cost automation in SMEs, highlighting those simple mechanical systems enhanced with programmable logic can outperform traditional labor-intensive setups. Their findings support the idea that small-scale industries can adopt such innovations without significant capital investment, making automated wire mesh machines a viable solution. [8]

While several prototypes exist, few systems integrate all necessary functions—pulling, aligning, weaving/binding, and cutting—in a single compact, programmable unit. This literature gap suggests the need for a fully automated wire meshing machine that is not only efficient and affordable but also scalable and customizable for different mesh sizes and materials.

2.2. Overview of This Project

This project focuses on the design and development of an Automated Wire Meshing Machine aimed at simplifying and optimizing the wire mesh manufacturing process. The primary objective is to create a cost-effective, programmable, and compact machine that can automate the pulling, weaving, and cutting of wire mesh using microcontrollers, gear motors, servo motors, and sensors. The machine utilizes a microcontroller (such as Arduino) as the central control unit to coordinate the operation of various components. Two servo motors are employed for the controlled pulling and feeding of wire mesh, ensuring uniform tension and alignment. A gear motor powers the weaving mechanism or facilitates the positioning of wires, while sensors—such as proximity or infrared—are integrated to detect the desired mesh length and activate the cutting mechanism automatically. The system is designed to be user-friendly, allowing operators to adjust mesh size and production parameters through a simple interface. This project addresses several industrial challenges, including inconsistent mesh dimensions, high labor dependency, and material wastage. By automating the process, the machine enhances production speed, accuracy, and safety. Additionally, it is tailored to suit the needs of small and

medium-sized enterprises that require a low-cost yet efficient solution for mesh fabrication.

Overall, this project serves as a practical step toward industrial automation in wire mesh production, combining mechanical design, embedded systems, and real-time control to deliver a reliable and flexible manufacturing tool.

2.3. Different Types of Wire Mesh

Wire mesh is a versatile material widely used in construction, agriculture, fencing, filtration, and industrial applications. It is made by weaving, welding, or knitting wire strands together to form a grid-like structure. The type of wire mesh selected depends on the application, material strength, mesh size, and the environment in which it will be used. Below are the main types of wire mesh commonly used:

- **Welded Wire Mesh**
  Welded wire mesh is created by welding intersecting wires at their junctions using an electric welding process. It is known for its strength, rigidity, and uniform grid pattern. Commonly used in concrete reinforcement, fencing, cages, and security panels, it is available in a variety of gauges and mesh sizes.

- **Woven Wire Mesh**
  In this type, wires are woven over and under each other in a crisscross pattern, much like fabric. It offers excellent flexibility and is often used in filtration, screening, and sifting applications. Stainless steel, brass, and copper are typical materials for woven mesh, especially where corrosion resistance is needed.

- **Hexagonal Wire Mesh (Chicken Mesh)**
  Made with a twisted wire technique forming hexagonal openings, this mesh is widely used in agriculture, poultry enclosures, and light fencing. It is flexible, easy to shape, and economical for large coverage.

- **Chain Link Mesh**

  Chain link mesh is a type of woven mesh used mainly for fencing. It is made from galvanized or coated steel wire and is known for its durability and ability to withstand outdoor elements. It is commonly seen in sports grounds, school boundaries, and industrial zones.

- **Crimped Wire Mesh**

  Crimped mesh is made by pre-crimping wires before weaving them together. This gives the mesh additional stability and resistance to deformation. It is used in mining, construction, and architectural applications where heavy-duty performance is required.

- **Expanded Metal Mesh**

  This type is made by cutting and stretching a metal sheet to form diamond-shaped holes. It has no joints or welds, making it strong and durable. Expanded mesh is often used for walkways, grates, and machine guards.

- **Knitted Wire Mesh**

  Knitted mesh is produced using a knitting process similar to textiles and is typically used in filtering, shielding, and sealing applications. It is highly flexible and often made from fine wires for specialized industrial uses.

Each type of wire mesh has its own mechanical properties and suitability for specific functions. Understanding the differences helps in selecting the right material and structure for automated manufacturing and ensures optimal performance of the final product.

2.4. Chain Link Mesh

Our selected wire mesh is “Chain link mesh”, also known as chain wire or diamond mesh, is one of the most popular and widely used types of wire fencing. It is characterized by its diamond-shaped mesh pattern formed by interlocking steel wires in a zigzag fashion. This mesh type is commonly used

for fencing playgrounds, sports grounds, residential boundaries, industrial areas, and animal enclosures due to its strength, flexibility, and durability.

The production of chain link mesh typically involves a specialized machine known as a Chain Link Mesh Machine. This machine automates the entire process of forming, twisting, and interlocking the wire strands to create the signature diamond-shaped openings.

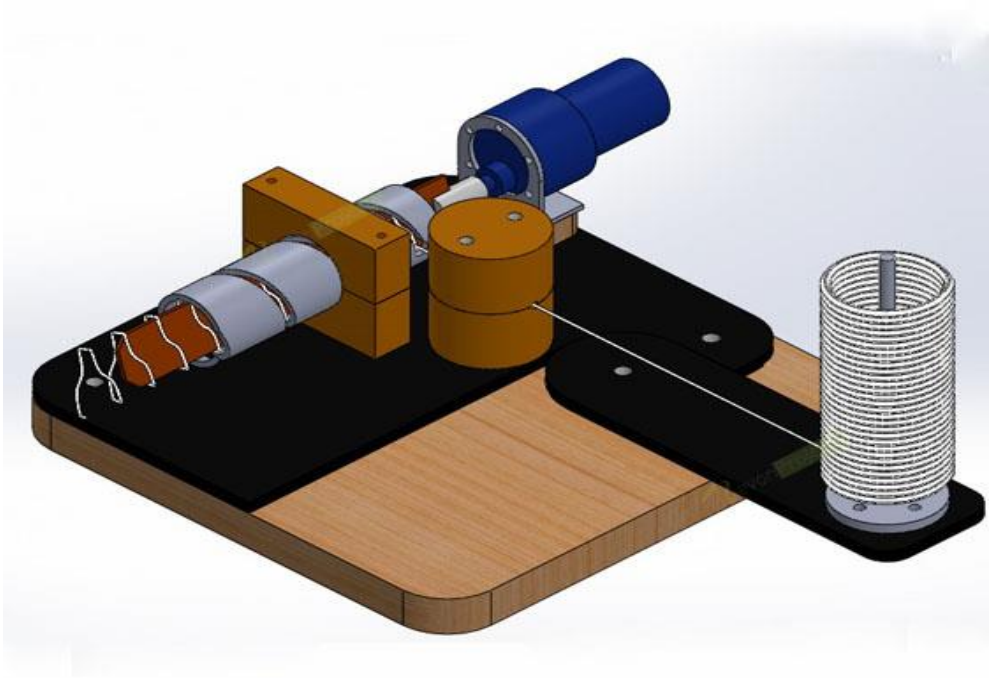


Figure-2.1: Chain Link Mesh Model

Key Features of the Chain Link Mesh Machine:

- **Wire Feeding Mechanism:**

  The machine is equipped with a controlled wire feeding system, where galvanized or PVC-coated steel wires are pulled into the machine and straightened automatically.

- **Twisting and Weaving System:**

  The core function of the machine is to twist and loop the wires in a zigzag pattern so that each new strand hooks into the previous one, forming a continuous chain mesh. This is achieved using mechanical or servo motor-

driven arms.

❖ **Mesh Cutting Mechanism:**

Once the desired mesh length is reached, a cutting tool—often controlled by a sensor or length-counter—automatically cuts the mesh to size.

❖ **Mesh Size Adjustability:**

The machine allows adjustment of the mesh hole size (the diagonal opening), width, and length according to the specific needs of the user, making it versatile for different fencing applications.

❖ **Automation & Control:**

Modern chain link machines are integrated with microcontrollers or PLCs that coordinate motor functions, monitor wire tension, and allow operators to set mesh parameters through a digital interface. Some systems even feature automatic edge bending and rolling to prepare the mesh for transport or installation.

Advantages of Using a Chain Link Mesh Machine:

- High production speed and output consistency.
- Reduced labor and increased safety.
- Customizable mesh sizes and wire diameters.
- Minimal material waste due to precise automation.
- Suitable for both small-scale and industrial-scale production.

In this project, the automation focuses on enhancing the functionality of a basic chain link mesh machine using microcontrollers, servo motors for pulling, and sensors for accurate cutting. This approach not only improves precision but also reduces dependency on manual adjustments, making the machine more suitable for continuous and efficient operation in small and medium manufacturing setups.

Chapter 3

Methodology

3.1. System Methodology

The methodology adopted for the development of the Automated Chain Link Wire Mesh Machine is structured to ensure precision, efficiency, and automation in the wire mesh fabrication process. It involves a combination of hardware integration, mechanical design, and embedded programming to automate the wire feeding, pulling, weaving, and cutting operations. The development process is divided into several key phases:

❖ **Requirement Analysis and Concept Design**

The project begins with a detailed study of existing manual and semi-automated chain link mesh machines. User requirements, mesh specifications (such as wire gauge, mesh size, and length), and safety standards are analyzed. Based on this, a conceptual design of the automated machine is created.

❖ **Component Selection**

Appropriate components are selected based on system requirements. These include:

- Microcontroller (e.g., Arduino Uno or Mega) for system control
- Gear motor for driving the twisting/weaving mechanism
- Two servo motors for synchronized wire pulling and feeding
- Proximity or IR sensor for mesh length detection
- DC cutter or solenoid-based cutting mechanism
- Power supply and driver circuits for motor control

❖ **Mechanical Fabrication**

The machine frame and mechanical parts are built to support the wire feeding and weaving mechanisms. The gear motor is coupled with the twisting spindle, while the servo motors are positioned to pull and guide the wire. A supporting roller system is added to reduce wire tension and enhance alignment.

❖ **Circuit Design and Wiring**

A custom control circuit is designed where the microcontroller acts as the central unit. Motor drivers are used to regulate speed and direction of the motors. Sensors are connected to provide real-time feedback on mesh length. Proper wiring and insulation are ensured for safety and stability.

❖ **Programming and Automation Logic**

The microcontroller is programmed using Arduino IDE to handle the following logic:

- Start/stop control of the machine
- Servo motor synchronization for smooth wire pulling
- Gear motor control for mesh weaving speed
- Sensor input reading to determine when the desired mesh length is reached
- Triggering the cutting mechanism automatically
- Displaying status via LEDs or LCD, and allowing input of mesh size

❖ **Integration and Testing**

All components are integrated and tested step-by-step to ensure synchronization between motors and accurate sensor response. Adjustments are made for motor speed, sensor positioning, and cutting timing.

❖ **Final Assembly and Evaluation**

Once optimized, the final machine is assembled with safety features such as an emergency stop button and protective covers. The system is evaluated for:

- Mesh accuracy (hole size and length)
- Production speed
- Repeatability and reliability
- Power consumption
- Operator usability

3.2. Experimental Setup

The experimental setup for the Automated Chain Link Mesh Machine is designed to validate the mechanical functionality, control logic, and automation performance of the system. The setup brings together mechanical, electrical, and software components into a single working prototype capable of pulling, weaving, and cutting wire mesh automatically. The goal is to test and demonstrate the system's ability to produce consistent chain link mesh with minimal human intervention.

❖ **Hardware Components and Assembly:**

- Structural Frame: A steel or aluminum base frame is fabricated to mount all mechanical and electrical components, ensuring stability during operation.
- Wire Spool Holder: A rotating fixture is used to mount the raw wire spool, allowing smooth unwinding of wire into the system.
- Servo Motors: Two servo motors are mounted and synchronized to pull and feed the wire into the weaving section. These motors ensure uniform tension and proper alignment of the wire.
- Gear Motor and Twisting Mechanism: A high-torque gear motor is used to drive the twisting mechanism that interlocks the wires to form the diamond mesh pattern.
- Cutting Mechanism: A solenoid-activated cutter or rotary blade is installed at the output end, activated automatically based on length input from a sensor.
- Sensor System: Infrared or proximity sensors are used to detect the completion of a set length of mesh. These sensors are critical for triggering the cutting mechanism.
- Power Supply: A regulated DC power supply provides power to the microcontroller and motor driver circuits, ensuring stable operation.

❖ **Control and Programming:**

- Microcontroller (e.g., Arduino Mega): Acts as the brain of the system, managing motor speeds, sensor inputs, and timing of operations.
- Motor Drivers: L298N or similar motor drivers are used to control the gear and servo motors with appropriate current and voltage levels.
- Code Logic: The system is programmed to pull wire, initiate twisting at set intervals, monitor sensor feedback for mesh length, and activate cutting when required.
- User Interface: A basic LCD and keypad or push buttons are used to allow the operator to set mesh length or start/stop the machine.

❖ **Procedure:**

1. Wire is loaded onto the spool and threaded through the servo-driven feeder.
2. The microcontroller is initialized and mesh parameters are entered.
3. Upon starting, servo motors pull the wire while the gear motor twists and interlocks it.
4. As the mesh progresses, sensors monitor its length.
5. When the desired length is reached, the cutter is triggered.
6. The machine stops or resets for the next operation cycle.

❖ **Observation and Analysis:**

During testing, data is collected on:

- Mesh consistency and accuracy (hole size and length).
- Speed and smoothness of operation.
- Precision of cutting and sensor responsiveness.
- Repeatability over multiple cycles.
- Power consumption and component temperature.

3.3. Material Requirements

Here's the Material Requirements Table for our Automated Chain Link Wire Mesh Machine project:

SL No:	Material Name	Quantity
1	Steel Frame	1
2	Meshing Mold	2
3	Gearbox and Shaft	2
4	Guillotine Cutter	1
5	DC Motor (12v)	1
6	Servo Motor	2
7	Micro-controller	1
9	Motor Drivers (L293D)	1
10	Relay (5v)	1
11	Buck Converter	1
12	Power Supply (12v)	1
13	Proximity Sensor	1
14	On/Off Switch	1
15	PCB Board	1
16	Connecting Wires	4 Feet

Table-1: Materials List

3.3.1. Main Frame

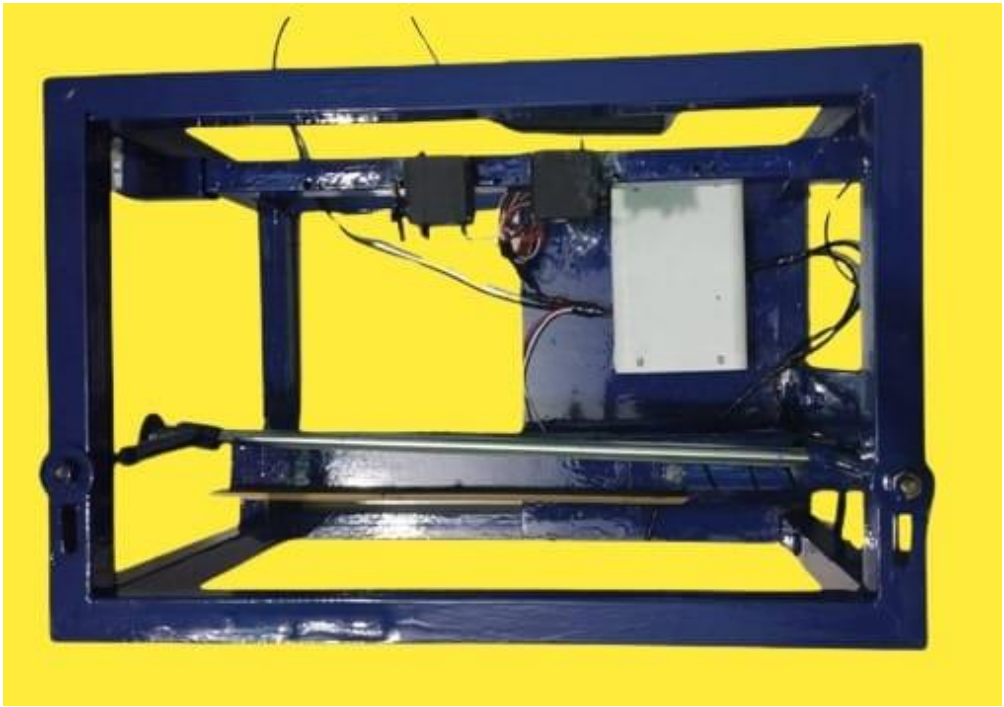


Figure-3.1: Image of the Main Frame

The main frame of the automated chain link mesh machine serves as the structural backbone that supports and aligns all mechanical and electrical components during operation. It is typically constructed from robust materials such as mild steel or aluminum channels to provide durability, stability, and vibration resistance. The frame is designed to hold key parts including the wire feeding system, twisting mechanism, servo motor assemblies, cutting unit, and sensor mounts in precise positions to ensure accurate and consistent mesh formation. Proper alignment and rigidity of the main frame are critical to maintaining uniform tension on the wire and ensuring seamless movement throughout the automation process. Additionally, the frame includes provisions for mounting the microcontroller unit, motor drivers, and power supply, all secured in a way that ensures safe and efficient wiring layout. Its modular design may also allow for future upgrades or adjustments, making the frame a crucial element in the overall functionality and adaptability of the machine.

3.3.2. Meshing Mold

The meshing mold is a critical component in the chain link mesh machine that defines the shape, size, and uniformity of the diamond-shaped openings in the wire mesh. It serves as a guiding and forming mechanism through which the wire is twisted and interlocked in a precise zigzag pattern.



Figure-3.2: Image of Meshing Mold

Typically made of hardened steel or other durable materials, the mold ensures consistent shaping of the wire as it passes through, preventing deformation and maintaining the desired mesh geometry. The dimensions of the mold directly influence the mesh hole size, which can be adjusted based on application requirements by changing the mold or modifying its configuration. Proper alignment of the mold with the twisting and pulling mechanisms is essential to avoid wire slippage or irregular loops. In automated setups, the meshing mold works in synchronization with servo motors and gear systems to maintain a steady feed rate and form accurate, repeatable mesh patterns, ultimately contributing to the structural integrity and aesthetic quality of the final product.

3.3.3. DC Motor (12v)

The 775 motor is a high-torque, high-speed brushed DC motor commonly used in DIY machines, industrial tools, and automation projects due to its compact size and powerful performance. It typically operates on 12V and can deliver speeds ranging from 30/min, depending on the voltage and load conditions. The motor features a robust metal housing with internal dual ball bearings that enhance durability and allow for smooth, stable operation under continuous use.



Figure-3.3: Image of 775 DC Motor

In the context of an automated chain link mesh machine, the 775 motor can be employed to drive the twisting or pulling mechanism, especially where reliable torque and rotational speed are necessary. It can be connected to a gearbox to reduce speed while increasing torque output, making it suitable for heavy-duty applications like wire bending or driving the mesh roller. The motor's shaft can be easily coupled with pulleys, gears, or spindles, and it is compatible with standard motor driver circuits (like L293D) for control through microcontrollers. Its affordability, availability, and mechanical simplicity make the 775 motor an excellent choice for prototyping and small-to-medium-scale automation systems.

3.3.4. Gearbox and Shaft

The gearbox and shaft are fundamental mechanical components in the automated chain link mesh machine, responsible for transmitting and modifying the rotational power generated by the motor to perform specific tasks such as twisting, feeding, or pulling wire. The gearbox is used to reduce the high speed of motors like the 775 DC motor while increasing torque, ensuring the controlled and powerful movement required for consistent wire twisting and weaving. Gear reduction ratios can be selected based on the desired output speed and torque, allowing the machine to handle different wire gauges and mesh sizes with precision.

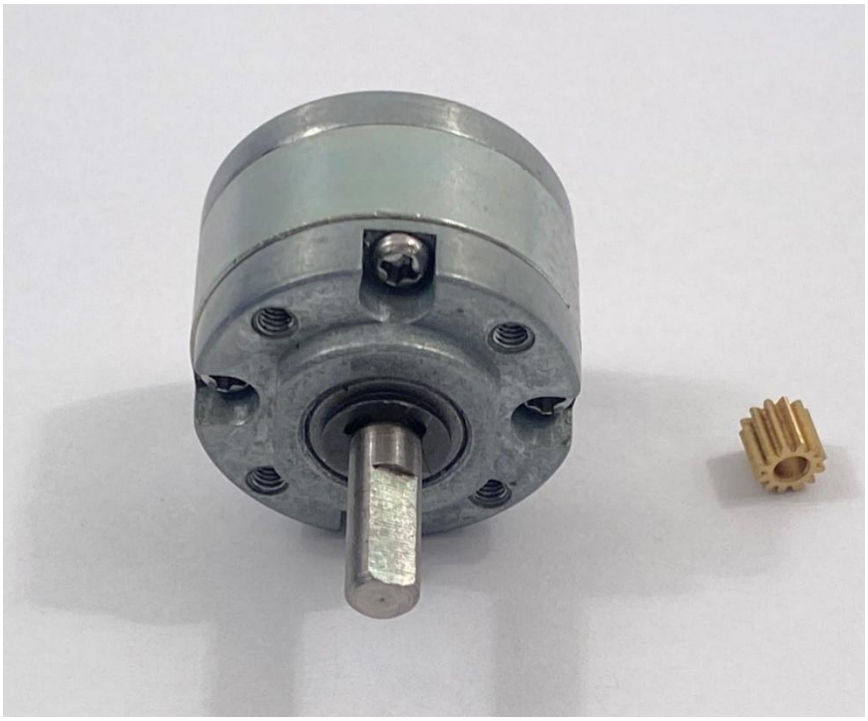


Figure-3.4: Image of gearbox and shaft

The shaft, typically made of steel or stainless steel, connects the motor (via the gearbox) to the working mechanisms such as the meshing mold or the wire feed rollers. It acts as the medium through which the mechanical energy is transferred. The shaft must be properly aligned and supported by bearings or bushings to reduce friction and prevent wobble, ensuring smooth and accurate rotation. In this setup, the gearbox and shaft work in tandem to deliver reliable

and efficient motion, forming the backbone of the mechanical transmission system within the automated mesh-making machine.

3.3.5. Servo Motor (MG-995)

The MG995 servo motor is a high-torque, metal-geared servo widely used in robotics, automation, and mechatronics applications due to its strength, durability, and affordability. Operating at 4.8V to 7.2V, it can produce a stall torque of up to 12 kg·cm at 6V, making it suitable for tasks that require precise angular positioning with substantial mechanical load. The motor has an operating speed of approximately 0.20 sec/60° at 6V, allowing for reasonably fast and responsive motion control.



Figure-3.5: Image of MG995 Servo Motor

In the automated chain link mesh machine, the MG995 servo motor is ideal for pulling and feeding wire with controlled tension and timing. Its internal control circuitry and feedback potentiometer allow the motor to rotate to a specified angle (typically between 0° and 180°), hold that position, and resist external force. This precision makes it perfect for synchronized operations, such as alternately pulling the wire forward and then locking it in place for twisting or cutting. The MG995's metal gears also provide added durability under continuous or repetitive loads, which is essential in automated manufacturing environments. Easy to interface with microcontrollers like Arduino, the MG995 servo enhances automation, accuracy, and reliability in wire mesh production systems.

3.3.6. Micro-controller

The NodeMCU is an open-source IoT development board based on the ESP8266 Wi-Fi module, widely used in automation, wireless control, and smart systems due to its compact size, built-in Wi-Fi capabilities, and ease of programming. It features a 32-bit microcontroller (ESP8266) running at 80 MHz or 160 MHz, with up to 4 MB of flash memory, making it suitable for both control and data transmission tasks. The board supports the Arduino IDE and Lua scripting language, allowing developers to easily write and upload code.

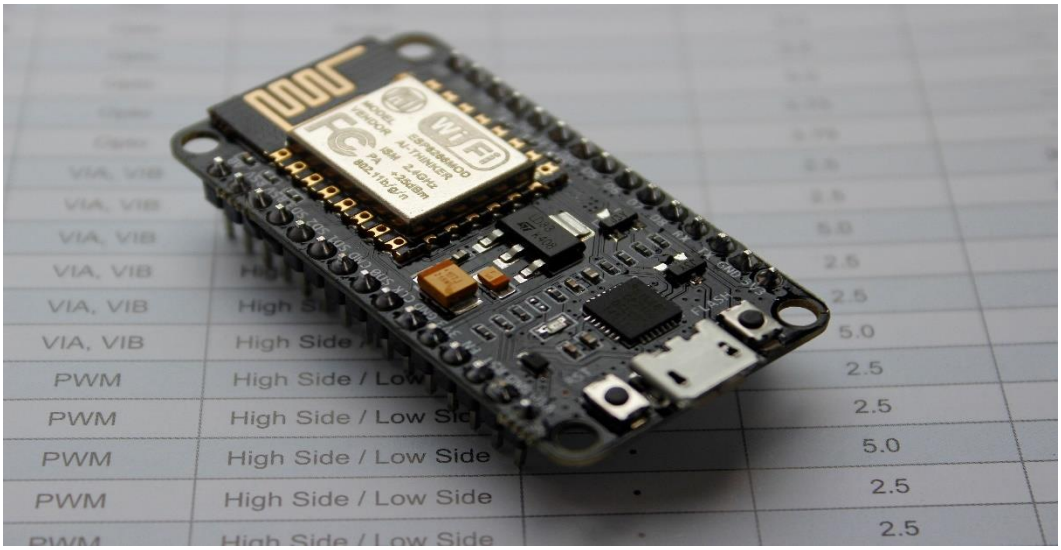


Figure-3.6: Image of NodeMCU Micro-controller

In the context of the automated chain link mesh machine, the NodeMCU can serve as the central control unit that manages motor operation, reads sensor inputs, and executes automation logic. Its Wi-Fi functionality allows for wireless monitoring, control, and data logging, enabling remote operation or integration with cloud services. For instance, users could adjust mesh length settings, start/stop the machine, or receive alerts through a mobile app or web interface. Additionally, its GPIO pins can control servo motors (like MG995), gear motors (via motor drivers), and receive input from IR or proximity sensors. The NodeMCU thus enhances the flexibility, scalability, and smart connectivity of the mesh-making system.

3.3.7. Buck Converter

A buck converter, also known as a step-down voltage regulator, is an essential power management device used to efficiently reduce a higher input voltage to a lower output voltage. It operates using high-frequency switching and energy storage components—typically an inductor, a diode, a switch (usually a MOSFET), and a capacitor—to regulate and maintain a stable output voltage with minimal power loss.

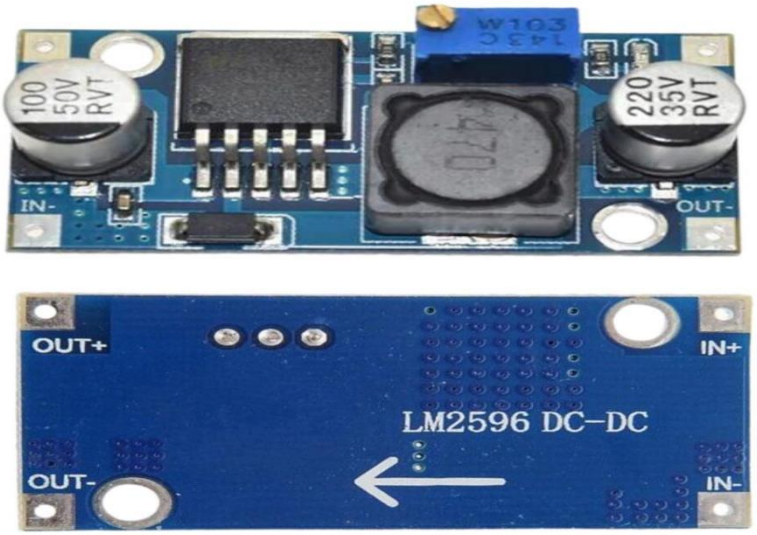


Figure-3.7: Image of Buck Converter

In the automated chain link mesh machine, the buck converter plays a critical role in supplying stable and safe voltage levels to sensitive electronic components like the NodeMCU, servo motors (such as the MG995), and sensor circuits. For example, if the system is powered by a 12V or 24V DC supply (suitable for high-torque motors), a buck converter can step this voltage down to 5V or 3.3V for microcontrollers and logic-level devices. This prevents overvoltage damage and ensures efficient energy usage throughout the system. The adjustable nature of many buck converters allows users to fine-tune the output voltage according to the specific requirements of each component. Furthermore, their compact size and high efficiency make them ideal for

embedded and automated projects like this one, where power regulation is key to system reliability and safety

3.4 Schematic Diagram

The block diagram represents the major functional units and the flow of control in the automated wire mesh machine system. Each component works in coordination to automate wire feeding, weaving, length detection, and cutting:

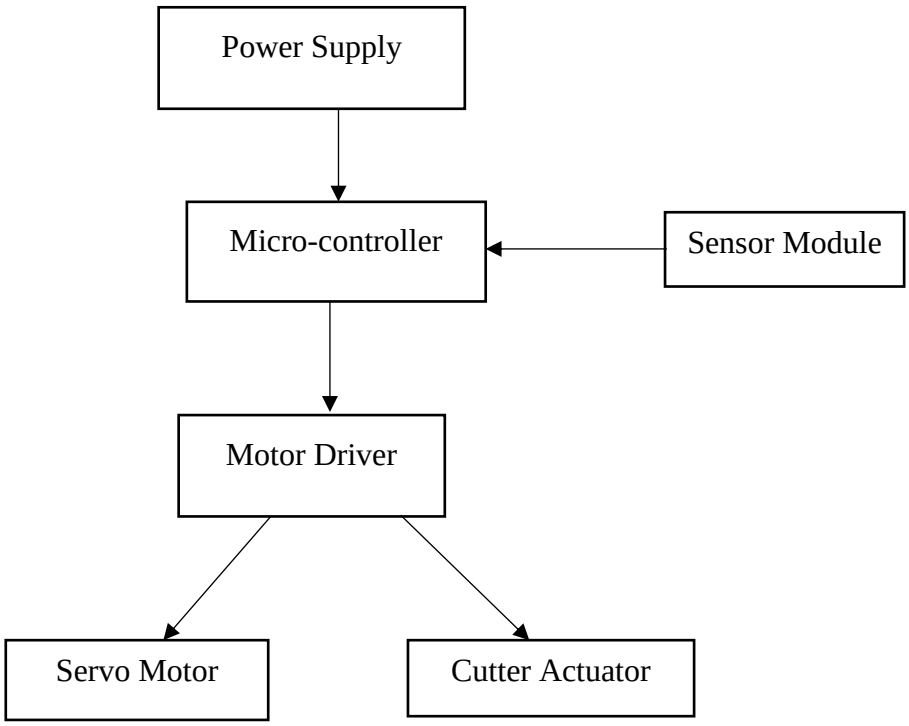


Figure-3.8: Schematic Diagram

Explanation of Each Block:

- **Power Supply**
  Provides regulated DC voltage to all electronic and electromechanical components.
- **Microcontroller (Arduino Mega/Uno)**
  Acts as the brain of the machine, reading sensor inputs, running the

control algorithm, and commanding the motors and cutter.

- **Motor Driver**
  Interfaces between the microcontroller and the motors, enabling higher voltage and current control required by the gear motor and servo motors.
- **Servo Motors (Wire Pulling Mechanism)**
  Control the wire feeding speed and tension, ensuring consistent input into the weaving section.
- **Gear Motor (Weaving Mechanism)**
  Drives the wire twisting mechanism to form the diamond-shaped chain link mesh pattern.
- **Sensor Module (Length Detection Sensors)**
  Detects when the desired mesh length has been achieved, triggering the cutting process.
- **Cutter Actuator**
  Automatically cuts the wire at the correct length using a solenoid-based or motorized cutting mechanism.

Chapter 4

System Design and Architecture

4.1. System Requirements

The system modeling for the Automated Chain Link Wire Mesh Machine requires a careful understanding of the mechanical, electrical, and software aspects to ensure efficient and synchronized operation. The requirements can be categorized as follows:

❖ **Mechanical Requirements**

- A strong and stable frame to withstand vibrations during mesh formation.
- Smooth wire feeding rollers or guides to maintain tension and prevent tangling.
- High-torque gear motor to drive the twisting/weaving mechanism without slippage.
- Accurate and durable cutting mechanism (blade or solenoid cutter) with quick response time.
- Adjustable fixtures to accommodate different wire diameters and mesh sizes.

❖ **Electrical Requirements**

- Reliable DC power supply unit (e.g., 12V/24V) to power the microcontroller, motors, and sensors.
- Motor driver circuits capable of handling the rated current of the gear motor and servo motors.
- Sensors (infrared, optical, or proximity) with fast response and accurate length detection.
- Emergency stop switch integrated into the circuit for safety purposes.

❖ **Software Requirements**

- Embedded control code (Arduino/C++) for managing motor speeds, servo synchronization, and sensor inputs.

❖ **Functional Requirements**

- The system must automatically start, pull, twist, detect length, cut, and stop/reset after completing a cycle.
- Mesh length and mesh opening size should be customizable before operation starts.
- Smooth and continuous operation with minimal wire slippage or twisting errors.
- Clear feedback to the user via LED indicators or a small display for system status.

❖ **Performance Requirements**

- Ability to produce consistent mesh patterns at a minimum acceptable production speed.
- Wire feeding and twisting mechanisms must synchronize precisely to avoid mesh defects.
- Cutting mechanism must operate sharply without distorting the mesh structure.

❖ **Safety and Reliability Requirements**

- Overcurrent protection for motors and drivers.
- Shielding of moving parts to prevent accidents.
- Durable wiring and mechanical joints to sustain prolonged operation cycles.

Chapter 5

Result and Analysis

5.1 Observations

This section presents the mechanical design considerations, assumptions, and resulting outcomes for the three critical mechanical components of the system: the shaft, gear drive, and mold. All components were designed to ensure durability, efficient power transmission, and compatibility with the wire weaving operation.

5.1.1 Designing of Shaft

The shaft is responsible for transmitting torque from the motor to the twisting or pulling mechanism. The shaft was designed based on the maximum torque requirement, power transmission, and factor of safety.

Design Parameters:

Motor Power (P): 60 W = 0.06 kW
Rotational Speed (N): 30 rpm
Allowable Shear Stress (τ_allow): 40 MPa
Factor of Safety (FoS): 1.5
Design Shear Stress (τ_design):

$$\tau = \frac{40}{1.5} = 26.67\,\text{MPa}$$

Step 1: Torque Calculation

$$T = \frac{9550 \times 0.06}{30} = \boxed{19.1\,\text{Nm}} = 19100\,\text{N}$$

Step 2: Shaft Diameter Calculation

$$T = \frac{\pi}{16} \cdot \tau \cdot d^3 \Rightarrow d = \left(\frac{16 \cdot T}{\pi \cdot \tau}\right)^{1/3}$$

$$d = \left(\frac{16 \cdot 19100}{\pi \cdot 26.67 \times 10^6}\right)^{1/3} \cdot 10^3 \Rightarrow d \approx \boxed{16.2\,\text{mm}}$$

- Required Shaft Diameter**:** 16.2 mm
- Select Standard Size**:** 18 mm keyed shaft

Conclusion:

Parameter	**Value**
Torque (T)	19.1 Nm
Design Shear Stress	26.67 MPa
Calculated Diameter	16.2 mm
Selected Shaft Size	18 mm (keyed)

5.1.2 Designing of Gear Drive

The gear drive is used to transfer rotary motion from the motor to the twisting mechanism with speed reduction and torque amplification. A spur gear pair was designed for this purpose.

Design Parameters:

- Gear Ratio (i): 1:4 (input gear = 20 teeth, output gear = 80 teeth)
- Module (m): 2 mm (selected based on torque and gear size)
- Material: Cast iron for the driven gear and steel for the driving gear
- Pressure angle: 20°

Analysis:

- The speed of the driven gear: $N_2 = N_1 / i = 150 \text{ rpm} / 4 = 37.5 \text{ rpm}$
- Tangential force Ft: $Ft = 2T / d = 2 \times 3.82 / 0.08 \approx 95.5 \text{ N}$
- The gear teeth were checked for bending strength using Lewis equation and found suitable for continuous operation
- Proper lubrication was considered to reduce wear and noise

Result:

- A 20:80 spur gear pair with 2 mm module and face width of 20 mm was selected
- The design supports smooth power transmission at reduced speed with increased torque suitable for wire twisting

5.2 Development of Mechanical Model with Diagonal vs Pitch Graph

To analyze and optimize the wire mesh pattern, a mechanical model was developed correlating the diagonal opening (D) with the mesh pitch (P).

The pitch refers to the distance between two adjacent twists or bends of the same wire in the longitudinal direction. For chain link mesh, this spacing is critical to maintain consistent mesh openings.

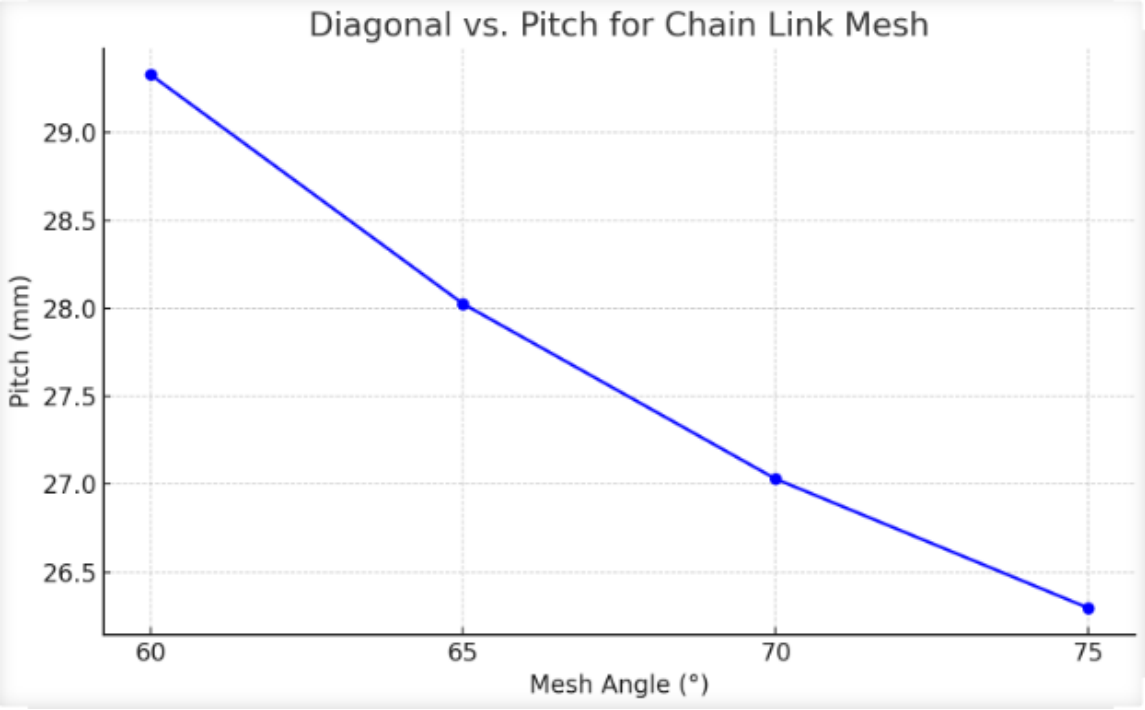


Figure-5.1: Graph of Diagonal vs Pitch for Chain Link Mesh

Here's the graph showing the relationship between Mesh Angle and Pitch for the Chain Link Mesh. Let me know if you'd like to export this graph or include variations for different diagonals or wire diameters.

Assuming:

- Wire wraps at angle θ (typically 60° to 75°)
- Mesh diagonal D = 25.4 mm
- Pitch P is calculated as:
  $P = D / \sin(\theta)$

By varying θ, a graph is plotted:

Mesh Angle (θ)	sin(θ)	Pitch (P = D / sinθ)
60°	0.866	29.34 mm
65°	0.906	28.03 mm
70°	0.940	27.02 mm
75°	0.966	26.30 mm

The graph shows that as the wire angle increases, the pitch decreases, resulting in a tighter mesh. The optimal pitch must balance structural strength, material usage, and airflow through the mesh.

This model assists in the mechanical calibration of the mold feed system to match desired mesh specifications.

Chapter 6
Conclusion and Recommendations

6.1. Conclusion

The design and development of the Automated Chain Link Wire Mesh Machine mark a significant step toward enhancing efficiency, accuracy, and safety in wire mesh production. Through the integration of microcontrollers, servo motors, gear motors, and cutting sensors, the machine successfully automates the traditionally labor-intensive process of mesh weaving and cutting. The experimental setup demonstrated consistent and precise mesh formation, with the added advantage of programmable mesh lengths and minimal manual intervention. This project not only reduces production time and material waste but also opens up opportunities for scalable manufacturing in small- to medium-scale industries. By employing cost-effective components and simple yet robust control logic, the machine proves to be both economically viable and technically feasible for widespread use. Furthermore, the ability to customize mesh size and automate the cutting process makes this machine a versatile tool for various fencing and enclosure applications. In conclusion, the successful implementation of this project showcases the potential of embedded systems in modern manufacturing, offering a smarter, safer, and more efficient alternative to manual wire mesh fabrication. Future upgrades could include integration with IoT monitoring systems, touch-screen controls, and adaptive feedback mechanisms for fully autonomous operation.

6.2. Recommendations

Based on the design, testing, and evaluation of the automated wire mesh machine, the following recommendations are proposed for future improvements, scalability, and enhanced performance:

▪ Use of Programmable Logic Controllers (PLC) While a microcontroller like Arduino provides a low-cost control solution, integrating a PLC can offer greater reliability, advanced automation features, and better interfacing with industrial-grade components.

▪ Integration of Human-Machine Interface (HMI) Incorporating a touch-screen HMI can improve user interaction, allowing operators to easily set mesh parameters such as length, width, and mesh opening size without requiring programming knowledge.

▪ Closed-Loop Feedback System Adding rotary encoders or load sensors for motor feedback can help improve accuracy and maintain consistent mesh tension, especially for long production runs.

▪ Safety Enhancements The machine should be equipped with safety features such as protective casing, emergency stop buttons, and automatic shut-off during malfunctions to ensure operator safety.

▪ Automated Wire Feeding and Rolling Developing an automated spool feeding system and mesh rolling unit can increase productivity and reduce the need for manual handling during continuous operation.

▪ Use of Brushless Motors and High-Torque Servos Upgrading to more efficient and durable motors can improve the machine’s longevity, performance under load, and reduce maintenance frequency.

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