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INSTITUTE OF ENGINEERING

PULCHOWK CAMPUS

DESIGN AND FABRICATION OF MANUFACTURING MACHINE FOR BAMBOO PANEL PRODUCTION PROCESS

SUBMITTED BY:

Sanjeev Lamichhane (076BME039)

Bibek Shrestha (076BME004)

Bipin K.C. (076BME006)

Ganesh Sapkota (076BME011)

SUPERVISED BY:

Associate Professor Dr. Shree Raj Shakya

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Sanjeev Lamichhane (076BME039)
Bipin K.C. (076BME006)
Ganesh Sapkota (076BME011)
Bibek Shrestha (076BME004)

ABSTRACT

This study consists of the design and fabrication of bamboo panel production machine, along with compressive test of produced bamboo panel using it. It is aims to address the growing demand for sustainable construction materials by harnessing the mechanical properties of bamboo. The panel production processes mostly consisted of adhesive application, mat formation and hot pressing process. The design process involves conceptual development of project and 3D CAD model development. Structural analysis were done to validate the design where average von misses stress 24.02Mpa, maximum deflection 0.31029 mm. Steady state thermal analysis was done to ensure the temperature of hydraulic fluid doesn't exceed 65°C. Based on the result of the simulation, machine design with high factor of safety was selected. Fabrication of the machine was done in various phases where necessary required changes in design was made, including changes in cam-follower mechanism, and heating system. Bamboo panel was produced using three different types of adhesives, namely, urea formaldehyde, poly synthetic resin and alicyclic and ketonic solvents. Compressive tests were done in three different adhesive applications, where maximum peak load of 78.15KN was measured for urea formaldehyde resin.

Keywords: Bamboo production machine, Adhesive application, Mat formation, Hot pressing, Structure analysis, Steady state thermal analysis, Urea formaldehyde resin.

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LIST OF ABBREVIATIONS AND ACRONYMS

CAD	:	Computer Aided Design
SF	:	Safety Factor
LPM	:	Liter per minute
GPM	:	Gallon per minute
N.W.	:	Net weight
CSA	:	Cross-sectional Area
UTM	:	Universal Testing Machine
DC	:	Direct Current
RPM	:	Revolutions Per Minute
Fm	:	Maximum force

CHAPTER 1 : INTRODUCTION

1.1 Background

Bamboo, a type of grass in the Poaceae family, grows rapidly and is known as one of the fastest-growing wood plants. Once cut, it continues to grow due to its resilient underground root system. Bamboo poles can grow approximately 24 inches or more per day. Bamboo has a remarkable strength-to-weight ratio, making it a sustainable alternative to traditional construction materials. Its tensile strength ranges from 250 to 400 mega Pascal’s (MPa), comparable to mild steel. Compressive strength varies but generally falls between 30 to 80 MPa. Bamboo is used in buildings, textiles, and as a food source. Its versatility and historical significance have led to its widespread use in modern times.

1.1.1 Common Structural Materials in Modern Construction:

Concrete, steel, wood, masonry, composites, aluminum, glass, and composite panels are typical structural materials used in modern buildings. The strength, adaptability, lightweight qualities, and particular application needs are taken into consideration when selecting these materials.

1.1.2 Bamboo's Role in Construction:

Bamboo is an essential component in construction because it offers durability, adaptability, sustainability, and aesthetic appeal. It acts as a structural component, supporting infrastructure and buildings. Bamboo is a sustainable material because of its quick development, eco-friendliness, and affordability. Architectural designs gain aesthetic appeal from its natural beauty. Overall, bamboo encourages the building of environmentally friendly, economically sensible, earthquake resistant and aesthetically pleasing structures.

1.1.3 Industrialization and the Bamboo Panel/Furniture Market:

The Industrial Revolution played a significant role in amplifying bamboo's recognition and contributing to the industrialization of the bamboo panel and furniture market. As global trade expanded, bamboo furniture gained popularity in Europe and North America due to its lightweight, exotic appeal, and distinctive aesthetic qualities. Bamboo rattan furniture, particularly during the Victorian era, showcased intricate designs that combined bamboo frames with flexible rattan, further fueling the demand for bamboo-based products. Historical records indicate that bamboo furniture and handicrafts were first introduced to Europe in the 18th century, coinciding with the rise of global exploration and trade. This marked the beginning of bamboo's commercialization and subsequent integration into Western markets, spurring the industrialization of the bamboo panel and furniture sector.

1.1.4 Bamboo Panel Manufacturing Process

1. Bamboo Selection and Preparation: Beginning with the careful selection of mature bamboo poles, typically with a diameter averaging 9 cm, the poles are harvested from sustainable plantations. They are then split into rough slats using specialized machinery, revealing the intricate fibers within. These slats are planned to achieve uniform dimensions of desired size and undergo treatment through boiling in hydrogen peroxide to fortify against pests and fungi. Optionally, some strips may undergo carbonization for added durability and a distinct caramel coloration.

2. Drying, Sanding, and Quality Control: Following treatment, the bamboo strips are dried in kilns to achieve optimal moisture content and then meticulously sanded to ensure a flawlessly smooth surface. Stringent quality checks are conducted to ensure color consistency and structural integrity before the strips proceed to the next stage.

3. Panel Formation and Sizing: The dried and quality-assured bamboo strips are then meticulously arranged and pressed together, either horizontally or vertically, to

create distinct panel types. This process, known as plain pressing or side pressing, determines the appearance and characteristics of the final product. Utilizing precision equipment such as band saws, the panels are cut to desired dimensions, facilitating versatility in applications ranging from flooring to siding.

4. Final Finishing and Quality Assurance: The panels undergo a final round of sanding to achieve a flawlessly smooth surface, desired quality craftsmanship. Before packaging, each bamboo panel undergoes rigorous quality assessment to ensure adherence to exacting standards, delivering excellence to consumers.

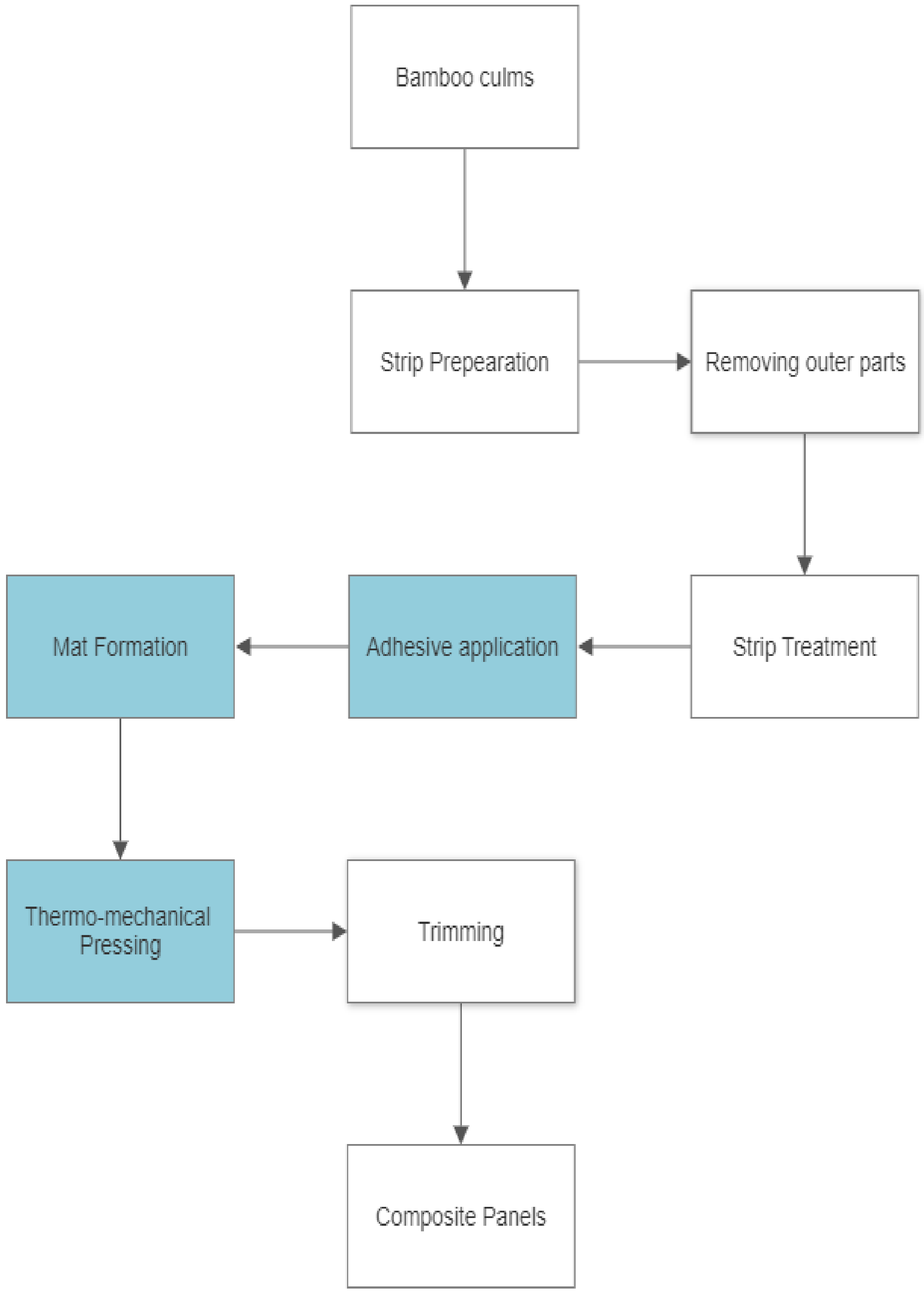


Figure 1-1: Block diagram of bamboo panel manufacturing process

1.2 Problem Statement

Steel, concrete and bricks being the major structural components of housing in the current scenario has lots of drawbacks. Manufacturing of steel and concrete causes various forms of pollution, cost inefficiency, extensive use of labor and poor aesthetics are some of them. There is a need of alternative solution, bamboo an easily available local resource with a high structural potential is being used conventionally with least efficiency. Manufacturing of bamboo panels causes very low amounts of pollution and can store CO_2 which otherwise would be emitted to the atmosphere when burnt.

Use of bamboo can be an alternative for housing. Bamboo is relatively cheaper environment friendly and can be manufactured from local resources. It has higher strength than slow growing and expensive timber. Its natural aesthetic is incomparable. These bamboo houses are not only cost-effective but also possess remarkable strength and aesthetic appeal, making them a superior option for sustainable housing solutions.

1.3 Objectives:

1.3.1 Main Objective:

- To design and develop a prototype of a manufacturing machine for bamboo panel production.

1.3.2 Specific Objective:

- To design and develop an automated adhesive application system.
- To design a mechanism that assembles the bamboo strips into a mat formation.
- To develop a robust and precise hydraulic pressing system along with heating elements attached.
- To test strength of produced bamboo panel.

1.4 System Requirements

1.4.1 Hardware requirements

1.4.1.1 I-Beams:

I-beams are structural steel members with a cross-section resembling the letter "I". They consist of a horizontal top and bottom flange connected by a vertical web. I-beams are known for their high strength-to-weight ratio and are commonly used in construction projects, bridges, and machinery frames due to their load-bearing capabilities and resistance to bending and shear forces. In bamboo panel production machine, I-beams can be used as the main structural components of the frame, providing rigidity and supporting the weight of the various components and the applied forces during the pressing process.

1.4.1.2 C-Channels:

C-channels, also known as C-sections or C-shaped structural members, have a cross-section resembling the letter "C". They consist of two parallel flanges connected by a web, forming a channel shape. C-channels are versatile structural components used for framing, bracing, and reinforcement purposes in various applications, including machinery and construction projects. In the bamboo panel production machine, C-channels can be used as secondary structural elements, reinforcing the frame, supporting the rollers or other components, or serving as guides for the bamboo strips or other moving parts.

1.4.1.3 Angle Rods:

Angle rods, also known as angle irons or angle bars, are structural steel members with an L-shaped cross-section. They are formed by bending a flat metal plate or sheet into a right angle (90 degrees) or other desired angles. Angle rods are commonly used for bracing, reinforcement, and framing applications in construction, machinery, and various other industries. In the bamboo panel production machine, angle rods can be used for reinforcing and connecting different components of the frame, providing additional support and stability to the structure.

1.4.1.4 Metal Sheets:

Metal sheets, also known as flat bars or plates, are flat pieces of metal with a uniform thickness. They can be made from various materials, such as steel, aluminum, or other metal alloys, depending on the required strength and properties. Metal sheets are widely used in construction, machinery, and fabrication industries for a variety of purposes, including structural components, cladding, and enclosures. In bamboo panel production machine, metal sheets can be used for constructing the frame, creating support structures, or forming protective enclosures for the various components.

1.4.1.5 Hydraulic Bottle Jack:

The hydraulic bottle jack is the primary component of the hydraulic system. It consists of a cylinder and a plunger or ram that moves in and out of the cylinder. In the bamboo panel production machine, a 20-ton capacity hydraulic bottle jack is used to generate the high force required for pressing the bamboo strips together

1.4.1.6 Motor:

Motors are typically permanent magnet DC motors or brush DC motors. These types of motors are well-suited for intermittent operation and provide the necessary torque and speed. Motors are designed to operate reliably in various environmental conditions, such as extreme temperatures, moisture, and vibrations. They are also built to withstand the mechanical stresses and loads involved in the cyclic operation

1.4.1.7 Belt Drives:

Belt drives represent a common and versatile solution in industrial settings, comprising two pulleys and a belt or rope to transfer power through friction. These systems find application across a wide range of speeds, making them ideal for diverse uses, including high-speed operations like air compressors. Within the realm of belt drives, various designs cater to specific requirements, offering flexibility and adaptability. Belts can span multiple parallel pulleys, adjusting speed as needed, and possess the ability to absorb shock loads, thus safeguarding other components of the drive system. Typically, both pulleys rotate in the same direction, unless configured otherwise, such as in a cross-belt drive. Among the primary types of belts used in belt drives are flat belts, V belts, and toothed belts. Flat belts are well-suited for general-purpose applications with moderate torque demands. They find use in a variety of equipment such as grinders, separators, roller conveyors, fans, and water turbines. Notably, flat belts offer reversibility and can transfer power from both sides, minimizing energy losses.

1.4.1.8 Chain Drives:

Chain drives serve as essential components in power transmission systems, particularly when bridging greater distances between two components. Comprising a roller chain and multiple sprockets, these drives play a pivotal role in transferring torque efficiently and reliably. The teeth of the driver sprocket mesh with the roller chain, facilitating the transmission of torque to the driven sprocket. While chain drives are commonly associated with applications in bicycles and motorcycles, their usage extends far beyond, finding 6 widespread adoption in various industrial machines. Chain Drive Their versatility is evident in their ability to navigate tight spaces through the incorporation of idler sprockets. One of the key advantages of chain drives lies in their suitability for applications where precise timing is imperative. In scenarios where even a slight delay or slippage could lead to significant issues, chain drives emerge as the preferred choice.

1.4.1.9 Gear Drive:

Gear drives are integral components in motion and power transmission systems, employing gears to relay power from one shaft to another. Consisting of a driving gear on the input shaft and a driven gear on the output shaft, these mechanisms facilitate power transmission through the precise meshing of gear teeth. Their versatility is evidenced by the myriad designs available, allowing them to adapt to various orientations and applications. Compared to chain drives, gear drives boast the capability to handle higher loads, making them particularly suitable for applications requiring robust power transmission. Gear Drive by utilizing multiple gears within a gear train, it becomes possible to manipulate various parameters such as gear ratio, rotational speed, torque, and direction. This versatility enables gear drives to accommodate diverse requirements across different industries and applications. Nonetheless, it's important to note that excessive gear usage within a single system can lead to diminished mechanical efficiency. One notable advantage of gear drives is their resistance to slipping, providing consistent and reliable power transmission.

1.4.1.10 Machine Required:

Welding:

Welding is a fabrication process that joins materials, usually metals or thermoplastics, by causing coalescence. This is typically achieved by melting the work pieces and adding a filler material to form a pool of molten material that cools to become a strong joint. There are several different welding processes, each with its own advantages and applications.

Lathe Machine:

A lathe is a machine tool that processes metal by rotating the material to be processed and applying a blade to cut it into a cylindrical shape. So Lathe is a machine that presses the cutting tool against the rotating material while moving it parallel to the main axis cutting it to form a cylindrical shape. A lathe spins a material and presses a tool (insert) against it to process it. It can be used for various types of machining depending on the type of cutting tool used and how it is moved. In general, it is possible to perform outer diameter machining, inner diameter machining, end face machining, thread machining, groove machining, hole machining (drilling), taper machining with an angle such as conical shape, and circular arc machining. A combination of these various machining methods is used to complete a single part.

Drill Machine:

A drilling machine works by rapidly rotating a tool bit and lowering it into the desired area at a predefined tool speed and feed rate to create cylindrical holes in a work piece. The work piece must be securely held in place on the drill table during drilling operations using vises and clamps. Most drilling machines are oriented with the drill in the vertical position, however, some specialized drills are designed to drill horizontally.

1.4.2 Software Requirements:

Arduino Ide:

Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board.

Solid works:

The SOLIDWORKS® CAD software is a mechanical design automation application that lets designers quickly sketch out ideas, experiment with features and dimensions, and produce models and detailed drawings.

ANSYS:

ANSYS is an analyzing software that provides its users an understanding of how their product will work or not work in real conditions. It is also called engineering simulation software and FEA or finite element analysis software. It analyzes a wide range of problems related to mechanical product design and civil structure design by using numerical techniques. These design models can be further tested for strength, elasticity, toughness, distribution, and temperature.

Proteus:

The Proteus Design Suite is a proprietary software tool suite used primarily for electronic design automation. It is a Windows application for schematic capture, Simulation, and Printed Circuit Board (PCB) layout design. It can be found in many configurations, depending on the size of designs being produced and the requirements for microcontroller simulation.

Tinkercad:

Tinkercad is a 3D modeling, circuitry-simulating, and block-coding software package that's accessible for free via a web browser. Its popularity is, no doubt, a result of its user-friendly simplicity. It consists of three sections, each of which can be considered its own endeavor and be used for different purposes.

CHAPTER 2 : LITERATURE REVIEW

Existing literature is reviewed for the optimal and efficient design bamboo panel production systems. Many research papers, articles and news were studied from different sources and the results are tabulated in the table below.

2.1 Feasibility study of Bamboo panels:

S.N.	Paper Name	Year	Journal	Summary
1.	On Structure, production, and market of bamboo-based panels in China	2002	Journal of Forestry Research, 13(2): 151-156 (2002)	This paper provides a comprehensive overview of the structure, production, and market of bamboo-based panels in China. It discusses the advantages of bamboo, the basic component units of bamboo-based panels, manufacturing techniques, and the market and selling prospects of these panels. The authors emphasize the importance of following principles such as symmetric structure, surface forming method, and structuring principle of equalizing stress in designing the structure of bamboo-based panels. Overall, the paper highlights the potential of bamboo-based panels as a sustainable and versatile alternative to other materials in various industries.
2.	Experimental study on bamboo hygrothermal properties and the impact of	2017	Construction and Building Materials 155 (2017) 1112–1125	This paper presents an experimental study on the hygrothermal properties of bamboo and the impact of the bamboo-based panel (BBP) process on these properties. The study includes nine test items on six typical bamboos, based on the building envelope heat and moisture process model. The results show that moisture and thermal

	bamboo-based panel process			transport properties show stronger correlation with open porosity than with bulk density and are affected by moisture content to varying degrees. The BBP process improves homogeneity and broadens the material properties spectrum, with transport properties being changed greater than storage properties in terms of both hygric and thermal aspects. The study's findings have practical implications for building construction and material science.
3.	Glued Laminated Bamboo Panels for Architectural Components	2022	International Conference on Non-conventional Materials and Technologies NOCMAT 2022	This paper reports on a research project that explores the use of glued laminated bamboo panels for architectural components, with a focus on eco-efficiency and sustainability. The study uses Dendrocalamus Asper bamboo culms from the Northeast Region of Brazil and a biodegradable adhesive based on mamona oil. The research includes a literature review, mechanical tests, and the design and realization of a prototype for a partition wall. The study concludes that glued laminated bamboo has significant potential as a renewable and expressive material for architectural components, but further research and investment in infrastructure and equipment are needed to support large-scale production.

Table 2-1: Feasibility study of bamboo panel

2.2 Performance Analysis of panel:

1.	Structural Performance Analysis of Cross-Laminated Timber-Bamboo (CLTB)	2019	BioResources 14(3), 5045-5058. 5045	This paper presents a study on the structural performance of cross-laminated timber-bamboo (CLTB) panels. The authors evaluated the bonding quality of three adhesives and produced eight cross-laminated panels with MUF adhesive in a three-layered configuration. The panels were tested for stiffness and rupture strength, and the results were compared to those of other lignocellulosic composites. The study found that CLTB panels had high mechanical properties and were structurally efficient, with stiffness and rupture strength values exceeding those prescribed by the ANSI/APA PRG 320 standard. The authors suggest that bamboo has great potential as a material for lignocellulosic panels and that revisions to existing standards could include bamboo as a viable option.
2.	Bamboo Reinforced Prefabricated Wall Panels for Low Cost Housing	2016	Journal of Building Engineering	This paper discusses the development of bamboo reinforced prefabricated wall panels as an alternative sustainable infrastructure component for low-cost housing. The authors conducted strength analysis, cost estimation, and environmental impact analysis to determine the potential of these panels in the construction industry. The study found that these walls are 56% lighter in weight, 40% cheaper, and have good strength compared to partition brick walls. The use of bamboo as a reinforcement material can

				significantly reduce greenhouse gas emissions and contribute to sustainable and affordable housing solutions in developing countries. The paper provides valuable insights into the use of bamboo as a reinforcement material for low-cost housing and its potential implications for sustainable development.

Table 2-2: Performance analysis of bamboo panel

2.3 Motorized Hydraulic bottle jack:

1.	Design and Fabrication of Motorized Hydraulic Jack System	2022	ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538 Volume 10 Issue IV Apr 2022	This paper "Design and Fabrication of Motorized Hydraulic Jack System" presents the development of a motorized hydraulic jack system for lifting heavy loads, particularly focusing on automotive vehicles. The system is designed to be operated from inside the vehicle or from a safe location off the road, providing stability and controllability through a switch. The design specifications include load capacity, operating pressure, lift range, and material properties. The calculations for the design of the ram are detailed, and the conclusion emphasizes the benefits of the motorized automated object lifting jack for heavy load lifting and lowering. The acknowledgments express gratitude to the college management and professors for their support, and the authors declare no conflict of interests. The references include relevant textbooks and previous research

				articles. Additionally, the paper cites other related works that have explored the modification of car jacks for easier load lifting and ergonomic solutions.
2.	Development of a Portable Motorized Car Jack	2019	Proceedings of the International Conference on Industrial Engineering and Operations Management Pilsen, Czech Republic, July 23-26, 2019	This paper presents a study on the development of a portable motorized car jack with a maximum lifting capacity of 2 tons. The design incorporates an electric motor powered by a 12-volt battery of a small vehicle and connected through a cigarette lighter adapter. The authors generated three possible solution concepts and used Binary Dominance Matrix analysis to determine the best solution for further development. Solid Works software was used to simulate the operation and loading of the resultant design. The study found that a motorized car jack reduces drudgery during maintenance operations, increases timeliness and efficiency, reduces the risk of injury, and can be accessed anywhere. The final design was found to be optimum and safe, with a total grand cost of USD 147. Overall, this study provides a useful contribution to the field of car jacks and their design.

Table 2-3: Motorized Hydraulic bottle jack

2.4 Adhesive:

1.	Physical-mechanical properties of	2019	Pesq. Agropec. Trop., Goiânia, v.	This paper discusses the physical-mechanical properties of laminated bamboo panels and their potential as a sustainable and eco-friendly

	laminated bamboo panels		49, e53714, 2019	construction material. The study evaluates the properties of bamboo panels produced with two species and two adhesive processes. The results show that bamboo can be used as an alternative for laminated panels production, provided the suitable species and methodological processes are determined. The paper also provides information on the structure and classification of bamboo and its potential uses as a material.
1.	Effect of adhesive quantity on selected physico	2019	Maderas. Ciencia y tecnología 21(1): 113 - 122, 2019	This paper investigates the effect of adhesive quantity on selected physico-mechanical properties of bamboo glulam. The study produced bamboo laminated boards using glue applied at three different rates: 150 g/m2, 200 g/m2, and 250 g/m2. The boards were evaluated for their physical and mechanical properties. The results showed that the glue quantity significantly influenced the impact bending strength and modulus of rupture of the boards. The boards produced with glue applied at the rate of 200 g/m2 met all the technical specifications for physical and mechanical properties, hence, concluded to be the optimal glue quantity for bamboo lamination. This research provides valuable insights for the production of high-quality bamboo laminated boards.
3.	Preparation of adhesive for	2006	J. CENT. SOUTH	This paper proposes a technique for preparing adhesive for bamboo plywood

	bamboo plywood using concentrated papermaking black liquor directly ®		UNIV. TECHNOL. Vol. 13 No. 1	using concentrated papermaking black liquor directly, which replaces phenol with lignin from black liquor. The study found that the optimal reaction time for black liquor methylating is 30 minutes, and the ratio of alkali to formaldehyde should be controlled at approximately 0.20 for the best results. The optimal molar ratio of phenol: formaldehyde to NaOH to H2O for preparing phenolic resin is 1.00:1.50:0.50:9.00, and the suitable viscosity is 27-30 Pa.s. The performance of bamboo plywood prepared using this technique exceeds that of excellent bamboo plywood of national criteria, and the cost is reduced by 28.69% without altering the traditional adhesive producing technique flow or using additional equipment.

Table 2-4: Adhesive

CHAPTER 3 : METHODOLOGY

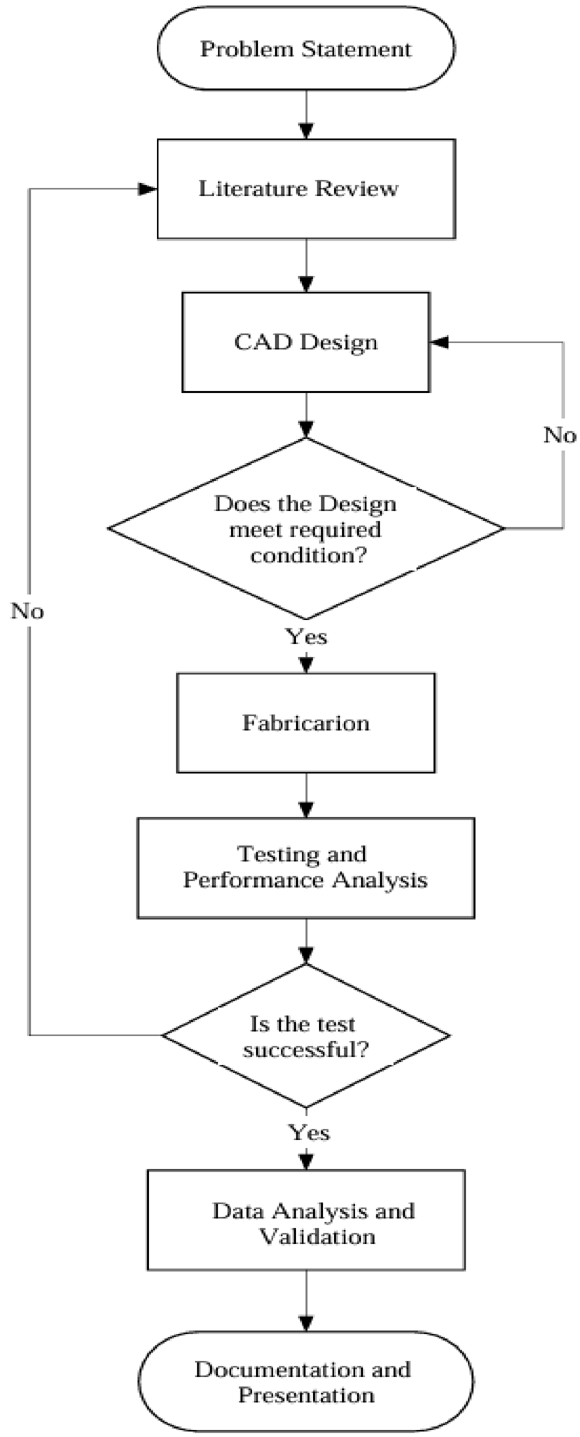


Figure 3-1: flow process

3.1 Production Stages

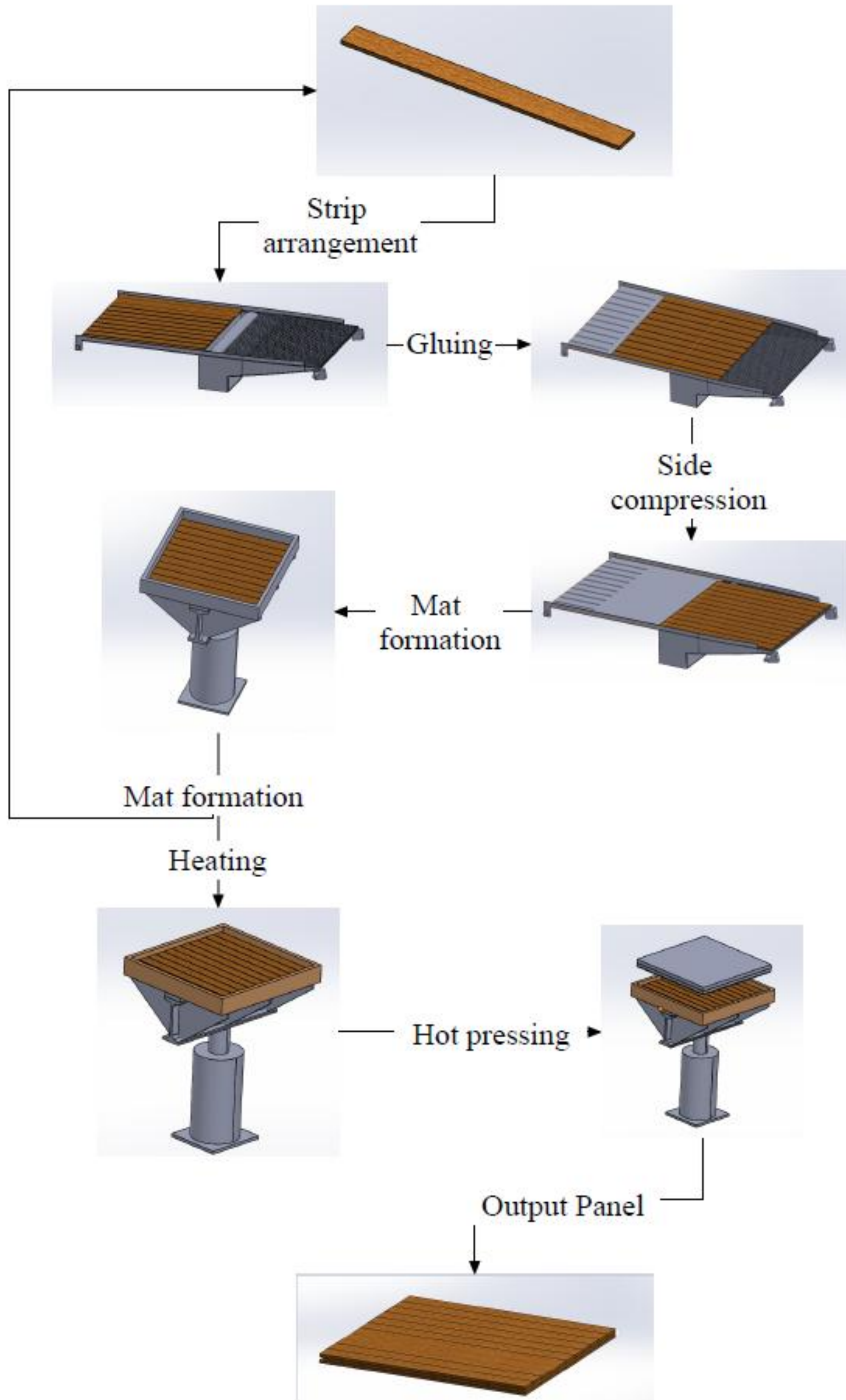


Figure 3-2: Panel production stages

3.2 CAD Design

Firstly, the CAD Model of the gluing and pressing machine will be designed on SolidWorks software and simulating the adhesive flow. Identifying its potential issues such as uneven distribution, blockages, or excessive adhesive usage and adjusting the adhesive application system design as needed based on simulation results and also simulating pressing process.

Applying forces, pressures, and motion to the pressing mechanism components to simulate the interaction between the bamboo strips and the pressing mechanism to ensure even pressure distribution and evaluating the stresses, strains, and deformations occurring during the pressing process. Analyzing the simulation results to identify any design flaws, areas of high stress, or potential performance issues and optimizing the design by making necessary modifications or adjustments to enhance the machine's performance, durability, and safety and the design will be finalized.

3.3 Fabrication

After finishing the design and analysis of the model, the fabrication of our prototype will be started.

- Frame: A sturdy frame will be constructed using metal sheets and angle plates to provide structural support for the machine.
- Chain and Sprocket: A motor will be mounted onto the frame and connected to a chain sprocket mechanism, which will convert rotational motion into linear motion. This assembly will be responsible for pushing the bamboo sticks through the machine.
- Rollers: Rollers will be installed on the frame for gulling application.
- Heater: A heating system will be integrated into the machine. Heating elements or heated plates will be positioned strategically to activate or cure the adhesive during the pressing process, achieving the desired temperature for effective bonding.

- Hydraulic Press: A hydraulic press mechanism will be incorporated into the machine to apply pressure to the bamboo sticks during the gluing process.
- Controls and Safety Features: Controls such as switches and buttons will be installed to operate and control the machine. Safety features, including emergency stop buttons and safety guards, will be implemented to ensure operator safety during machine operation.

3.4 Testing

After completion of the fabrication process, functional testing of the machine will be performed. This includes testing the adhesive application system and pressing mechanism.

Adhesive application testing:

It is done to ensure evenly distributed adhesive onto the bamboo strips. Checking for any blockages, irregularities, or excessive adhesive usage and verifying that the adhesive adheres well to the bamboo and forms a strong bond.

Pressing performance testing:

Testing the pressing mechanism to ensure it applied the desired pressure evenly across the bamboo strips during the stack pressing process. Evaluating the force, pressure, and duration of the pressing to ensure they meet the requirements for different panel thicknesses. Checking for any issues such as misalignment, uneven pressure distribution, or excessive deformation of the bamboo strips.

3.5 Documentation and Presentation

The recording and presentation of the research findings and results will be the project's last step. This stage is essential for keeping an exhaustive record of the project and disseminating its idea and outcomes to stakeholders, industry experts, and members of the academic community. Future field research projects will find great value in the documentation and presentation.

Research objectives, methodology, data collection, analysis, and findings, as well as other pertinent project material, will all be organized and summarized as part of the documentation process. In order to ensure that all components of the project are sufficiently documented for reference purposes, this will be done in a clear and straightforward manner. The writing of the documentation shall follow accepted academic standards and procedures.

The results of the research will also be presented to diverse audiences in a polished and interesting way. Academic conferences, seminars, workshops, and other appropriate venues might be included in this. The presentation will be created to successfully convey the project's goals, process, and results to a wide range of viewers. Slides, graphs, and other visual aids can be utilized to improve the presentation and encourage more participation and understanding.

CHAPTER 4 : DESIGN ANALYSIS

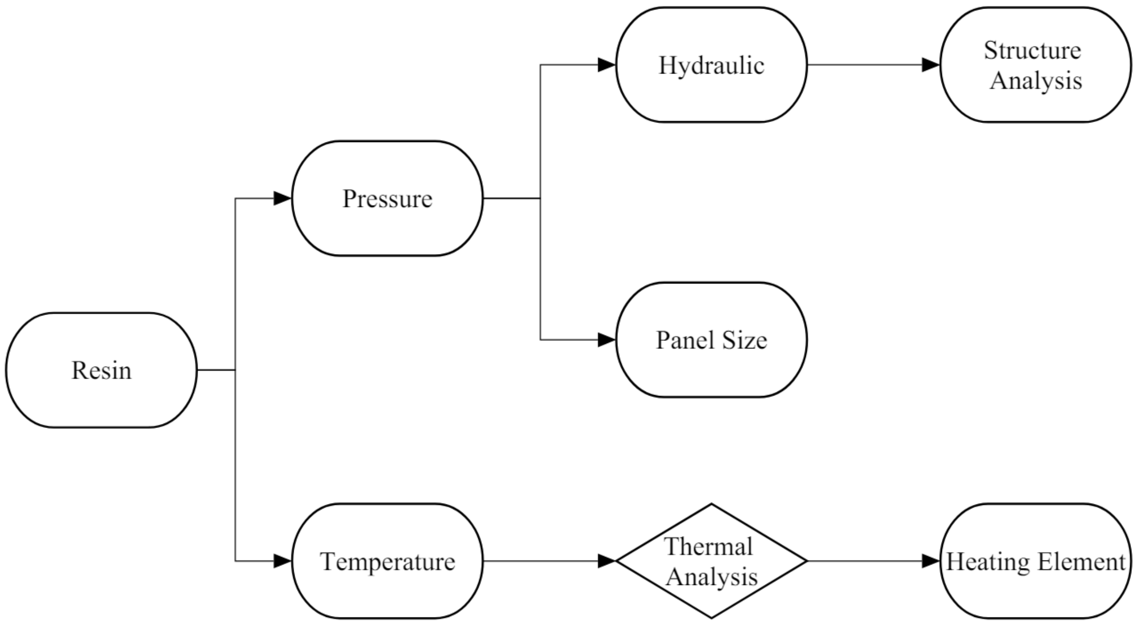


Figure 4-1: Design flow

The selection of resin was done on the basis of the literature, Physical mechanical properties of laminated bamboo panels, (2019). Based on the pressure and temperature required for effective setting of resin and bamboo sandwich we proceed to structural and thermal analysis.

The pressure required is 2.452 MPa. For the purpose of designing a model we selected panel size of (285*285) mm and force 199 kN bottle jack for pressing operation. The temperature required was 120 degree Celsius. As a functional and structural frame to withstand the pressure at that temperature a structural frame and was designed and simulated in ANSYS. Also type, placement and calculation of heating element was carried out. Both thermal and structural simulation and analysis was carried out. After series of iteration and successful structural design was finalized. Glue:

Phenol-formaldehyde	
Solids content (%)	48-51
Viscosity- cP (25℃)	400-800
pH	11.5-13.0

Gel time	6-11 min
Density- gcm^{-3} (25℃)	1.19-1.25
Coating	180 g/m^2
Setting temperature	120℃

Table 4-1: Glue specifications

4.1 Hydraulic:

Pressure	25 kgf/cm2(2.452e+6 N/m^2)
Panel Size	(285*285) mm
Force	199163.7 N

Table 4-2: Hydraulic Sizing

4.2 Motor Sizing

Calculation of force multiplication in bottle jack:

Since we couldn't measure the ratios of area of piston cylinder and ram cylinder, we calculated force multiplication by measuring advancement in ram when piston was pumped completely for n times.

The position of piston displaced in 1 complete pumping = 22 mm (calculated geometrically)

When the piston was pumped for 215 times the ram was displaced by 155 mm.

Therefore multiplication factor

$=\frac{215*22}{155}$

=30.5

Then the hydraulic lever has varying length between load and fulcrum with max length of 3 cm

For a lever with 60 cm length, reduction due to lever $=\frac{60}{3}$ =20

With approximate angle traversed of 15 degree, vertical displacement of follower = 60*sin (15) =15.5 cm.

We designed cam follower with vertical advancement of 15cm.

Since there is constant rate of ascendance average force and instantaneous force are equal.

Work done = Torque (τ) * θ = $\frac{Force}{20*30.5}$ * vertical advancement (h)

Since the follower advances for 315 degrees and descends for 45 degrees.

$\tau = \frac{F*h}{\theta*610}$

For 200000N force

$\tau = \frac{200000*0.15}{(7\pi/4)*610}$

= 8.95 Nm

Again for the reduction in gear pinion

D_{Gear} =220 mm

D_{Pinion} =44 mm

Reduction = $\frac{220}{44}$ = 5

Therefore, torque required at pinion = $\frac{8.95}{5}$ = 1.8 Nm

Calculation for rotational speed of motor:

For a cycle in motor,

Cam has $\frac{1}{5}$ cycle

⇒The follower advances by 30mm

⇒Smaller piston advances by $\frac{30}{20}$ = 1.5 mm

⇒Hydraulic Ram advances by $\frac{1.5}{30.5}$ = 0.049mm

Since we need to press approximately 30mm

Cycles required =$\frac{30}{0.049}$ = 612.24 cycles

To complete the process in 5 min,

Speed of motor required = $\frac{800612.24}{5}$ = 122.4 rpm.

Selection of motor:

This criteria is for max torque and average speed.

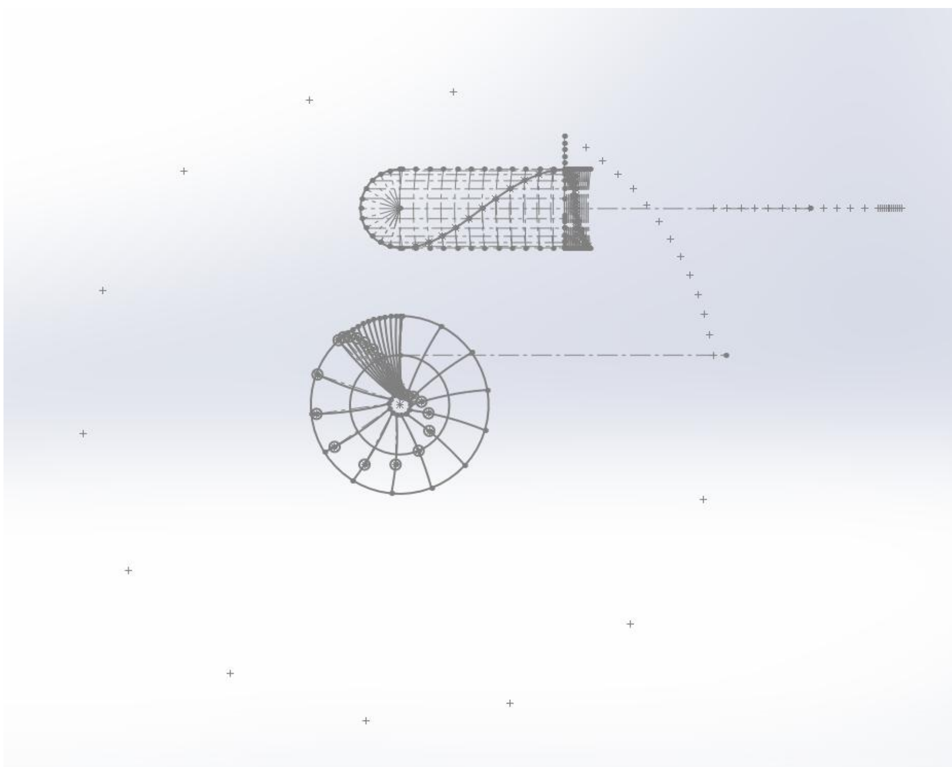
Also including friction and losses,

We assume the max torque of motor to be greater than 1.8 Nm and average speed to be greater than 122.4 rpm.

4.3 Cam follower mechanism:

We selected cam follower mechanism to convert rotary motion of motor to reciprocating pumping of the bottle jack.

The cam follower mechanism allows us to trace a desired motion of follower. We designed the cam for 15 cm advancement of the follower. The profile was designed in solid works for the follower lever rotating with arm length 60 cm as in figure below. The follower advances for 315 degrees of cam rotation at constant rotation of follower lever and returns back for 45 degrees at constant angular acceleration of follower arm.



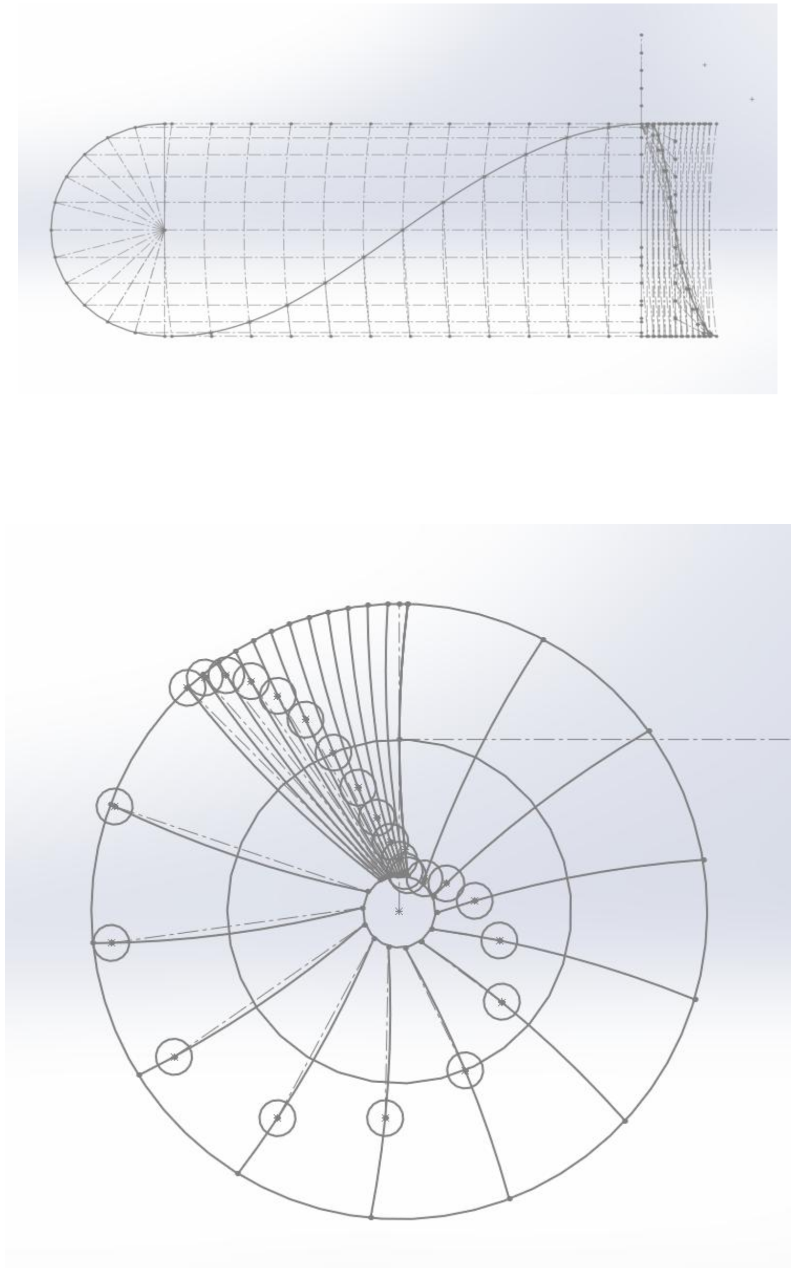


Figure 4-2: Cam follower profile drawing

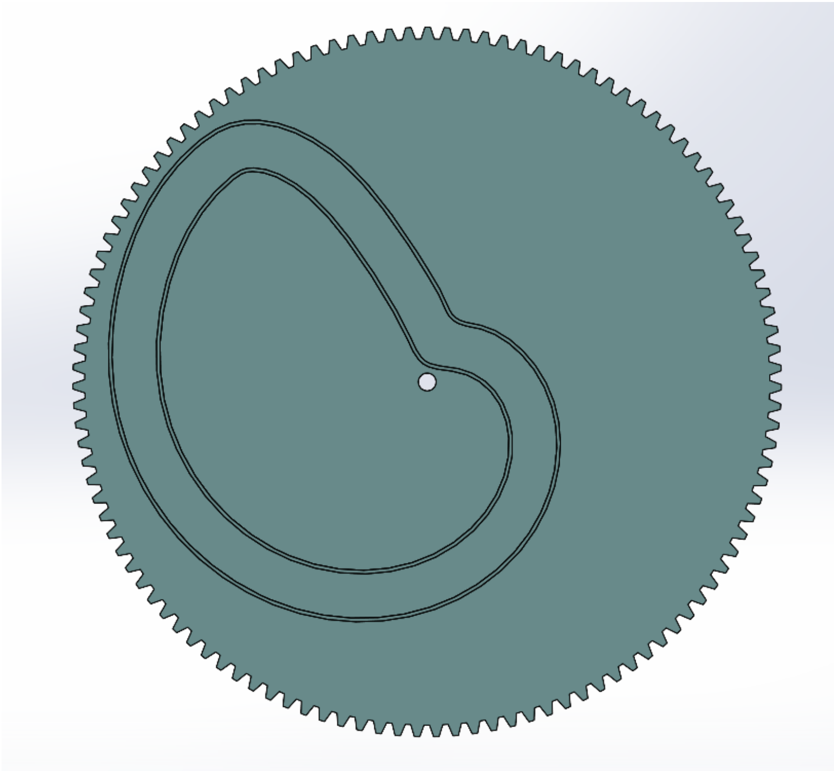


Figure 4-3: Cam follower profile

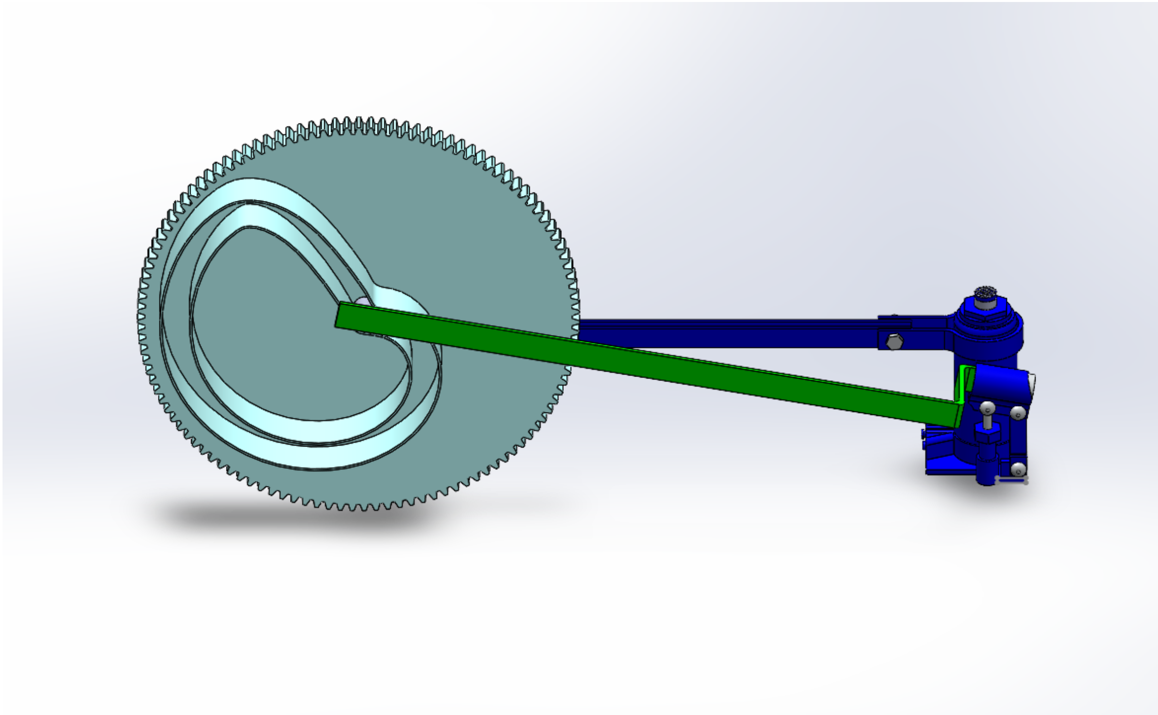


Figure 4-4: Cam follower and bottle jack assembly

4.4 Structure:

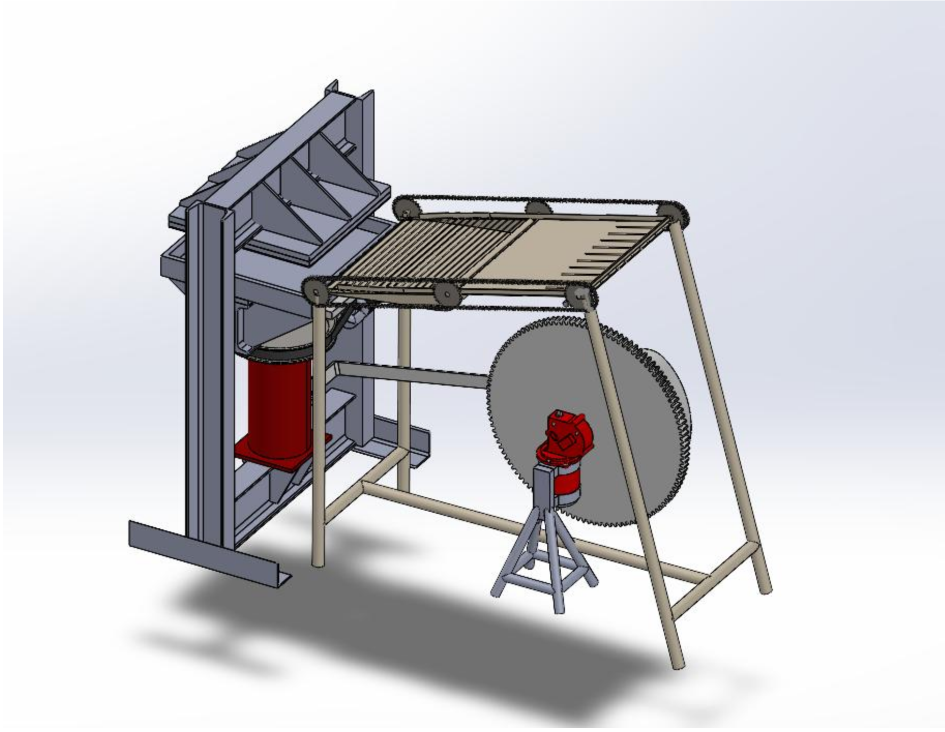


Figure 4-5: Isometric View

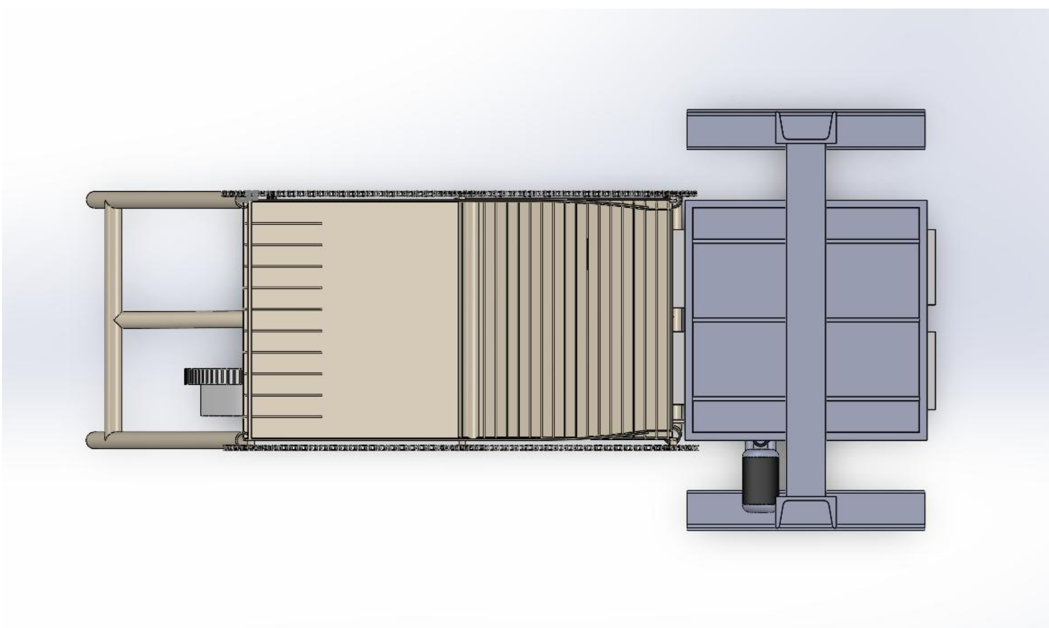


Figure 4-6: top view

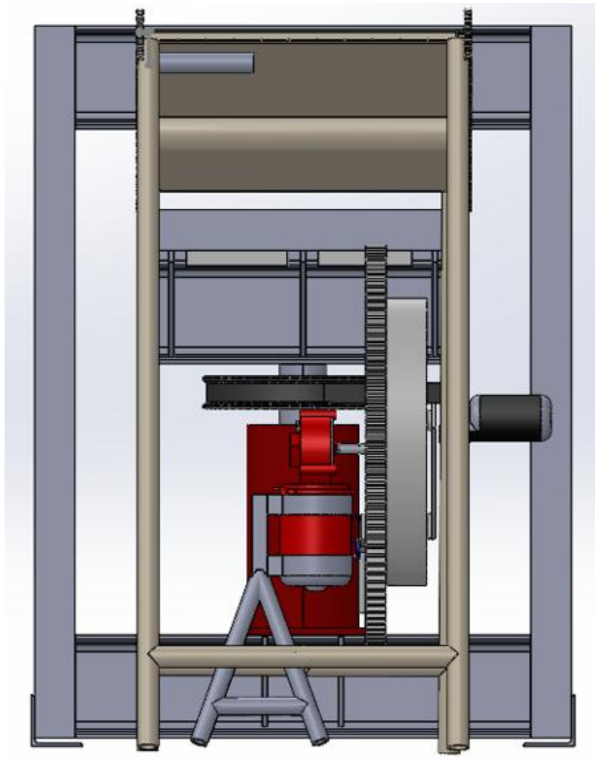


Figure 4-7: left side view

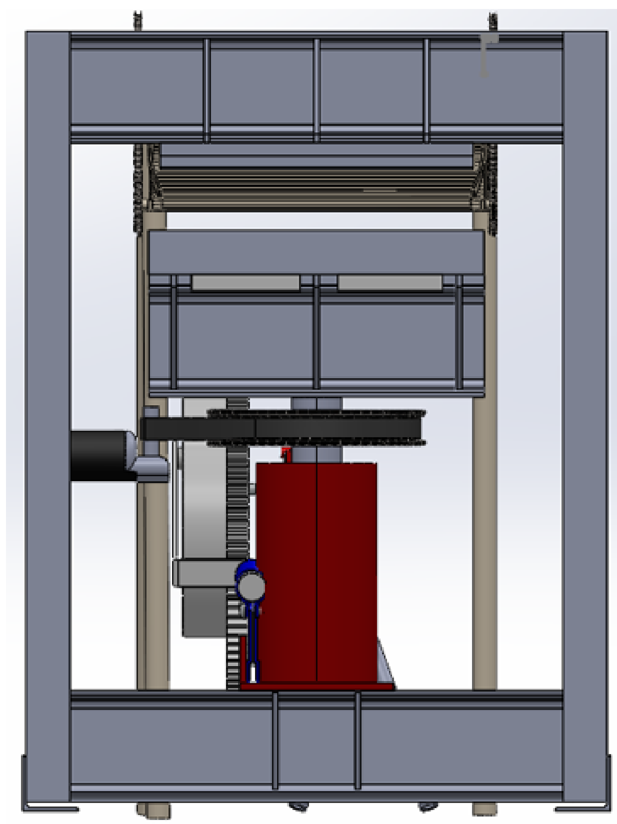


Figure 4-8: right side view

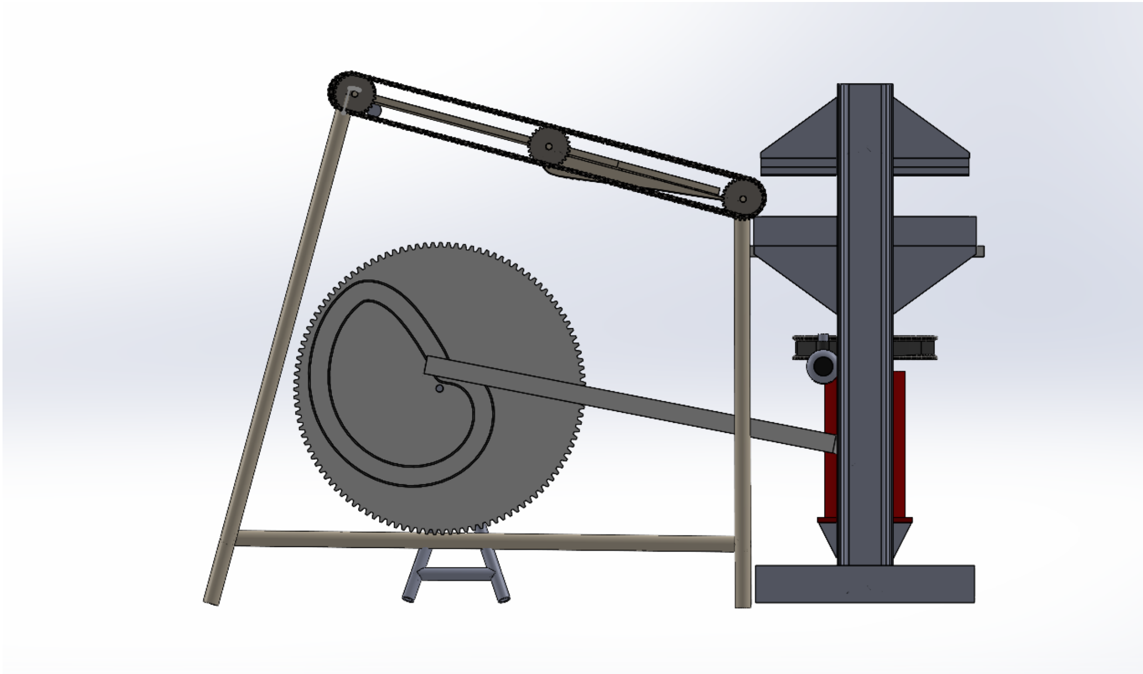


Figure 4-9: back view

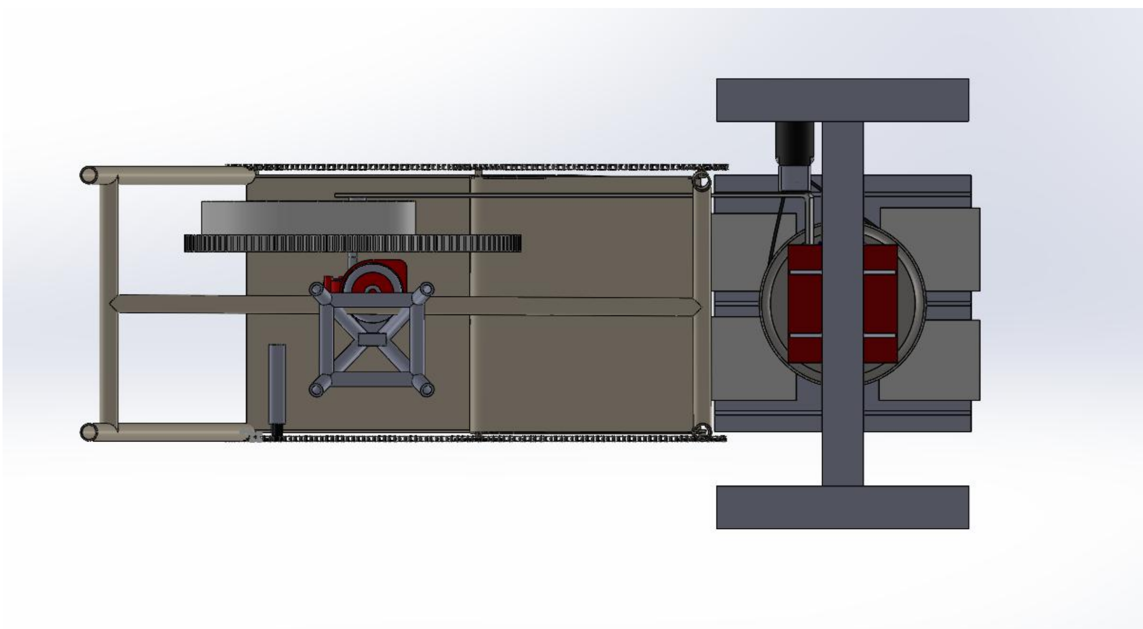


Figure 4-10: bottom view

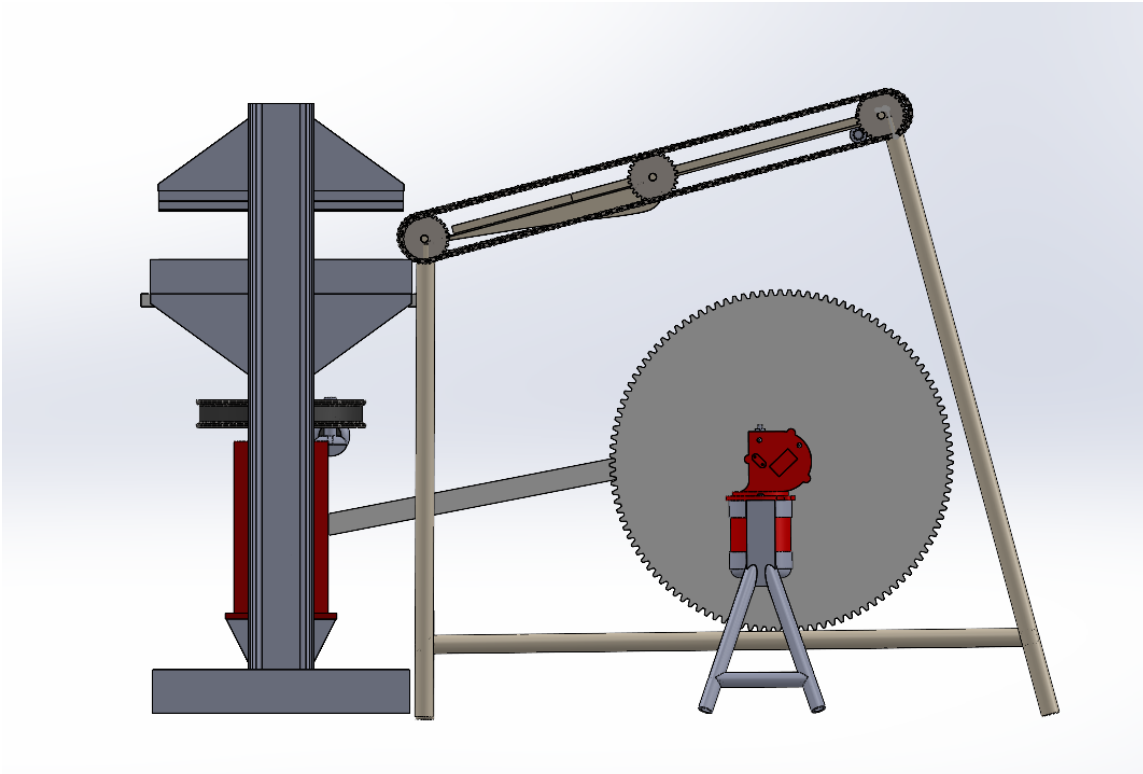
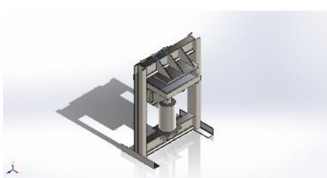
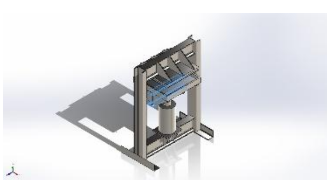


Figure 4-11: front view

Document Name and Reference	Treated as	Volumetric Properties
Gusset top(x6) 	Solid Body	Mass:0.318721 kg Volume:4.03445e-05 m^3 Density:7,900 kg/m^3 Weight:3.12347 N
I-Beam mid 	Solid Body	Mass:3.24515 kg Volume:0.000410778 m^3 Density:7,900 kg/m^3 Weight:31.8025 N
Gusset mid	Solid Body	Mass:0.379192 kg

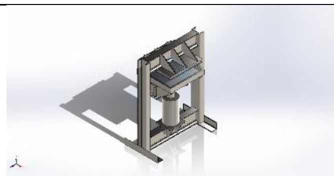
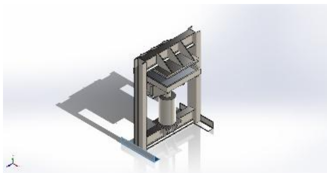
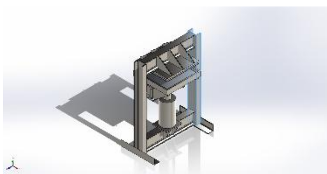
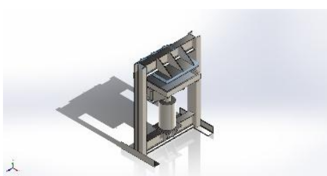
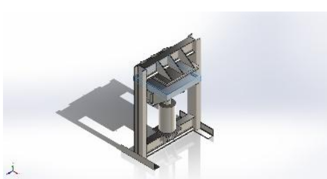
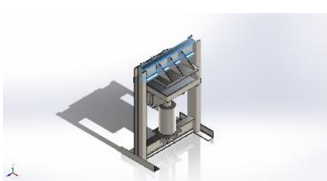
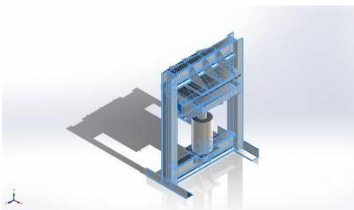
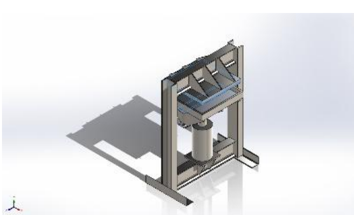
		Volume:4.7999e-05 m^3 Density:7,900 kg/m^3 Weight:3.71608 N
Angle stand 	Solid Body	Mass:0.741938 kg Volume:9.39162e-05 m^3 Density:7,900 kg/m^3 Weight:7.27099 N
C-chanel (x2) 	Solid Body	Mass:4.98032 kg Volume:0.00063042 m^3 Density:7,900 kg/m^3 Weight:48.8071 N
12mm plate 	Solid Body	Mass:7.70013 kg Volume:0.0009747 m^3 Density:7,900 kg/m^3 Weight:75.4613 N
Compartment 	Solid Body	Mass:11.4289 kg Volume:0.0014467 m^3 Density:7,900 kg/m^3 Weight:112.004 N
I-Beam (x2) 	Solid Body	Mass:4.7709 kg Volume:0.000603912 m^3 Density:7,900 kg/m^3 Weight:46.7548 N

Table 4-3: Structure volumetric properties

Model Reference	Properties	Components
	Name: **AISI 1020** Model type: **Linear Elastic Isotropic** Default failure criterion: **Max von Mises Stress** Yield strength: **3.51571e+08 N/m^2** Tensile strength: **4.20507e+08 N/m^2** Elastic modulus: **2e+11 N/m^2** Poisson's ratio: **0.29** Mass density: **7,900 kg/m^3** Shear modulus: **7.7e+10 N/m^2** Thermal expansion coefficient: **1.5e-05 /Kelvin**	**I-Beam top** **I-Beam compartment** **I-Beam bottom** **C channel left** **C channel right** **Angle left** **Angle right** **12mm sheet top** **12mm compartment** **Gusset (x6) top** **Gusset (x6) compartment** **Gusset (x4) hydraulic**
	Name: **Glass** Model type: **Linear Elastic Isotropic** Default failure criterion: **Mohr-Coulomb Stress** Tensile strength: **7e+06 N/m^2** Compressive strength: **1e+09 N/m^2**	**Compartment**

	Elastic modulus:	**6.8935e+10 N/m^2**	
	Poisson's ratio:	**0.23**	
	Mass density:	**2,457.6 kg/m^3**	
	Shear modulus:	**2.8022e+10 N/m^2**	
	Thermal expansion coefficient:	**9e-06 /Kelvin**	

Table 4-4: Structural component properties

4.5 Heating and Insulations:

To facilitate the adhesive bonding process, it was essential to attain a temperature of 120 degrees Celsius for the glue. To achieve this, a plate heater was employed as a heat source. Simultaneously, it was imperative to ensure that the temperature of the hydraulic jack remained below 60 degrees Celsius to prevent damage to the hydraulic fluid. To address this requirement, glass was utilized as an insulation material, effectively managing and controlling the temperature of the hydraulic jack durin g the operation of the hot-pressing machine.

4.6 Hydraulic System Analysis:

The analysis was conducted to evaluate the thermal and structural performance of the hot pressing machine designed for bamboo panel production. The primary focus was on ensuring safe hydraulic bottle jack temperatures while subjecting the structure to a 20-ton force at a pressing compartment temperature of 120°C.

4.6.1.1 Steady State Thermal Analysis:

- Objective:

Determine temperature distribution and ensure the hydraulic bottle jack temperature remains below 60°C.

- Analysis Conditions:

Ambient temperature	22 ℃
Compartment temperature	120 ℃
Convective coefficient	5.e-006 W/mm²·°C

Results:

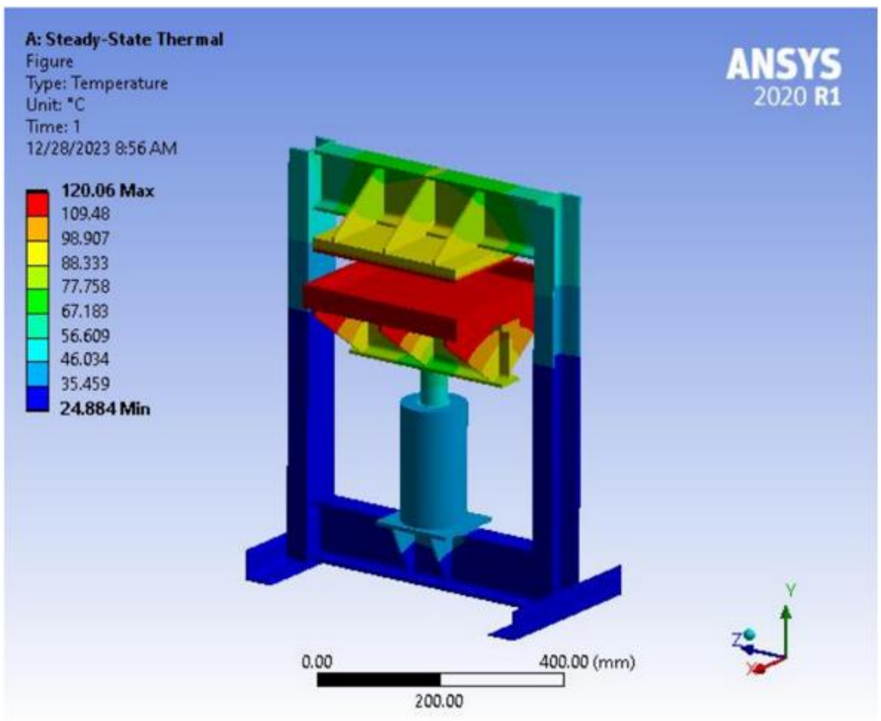


Figure 4-12: Temperature distribution

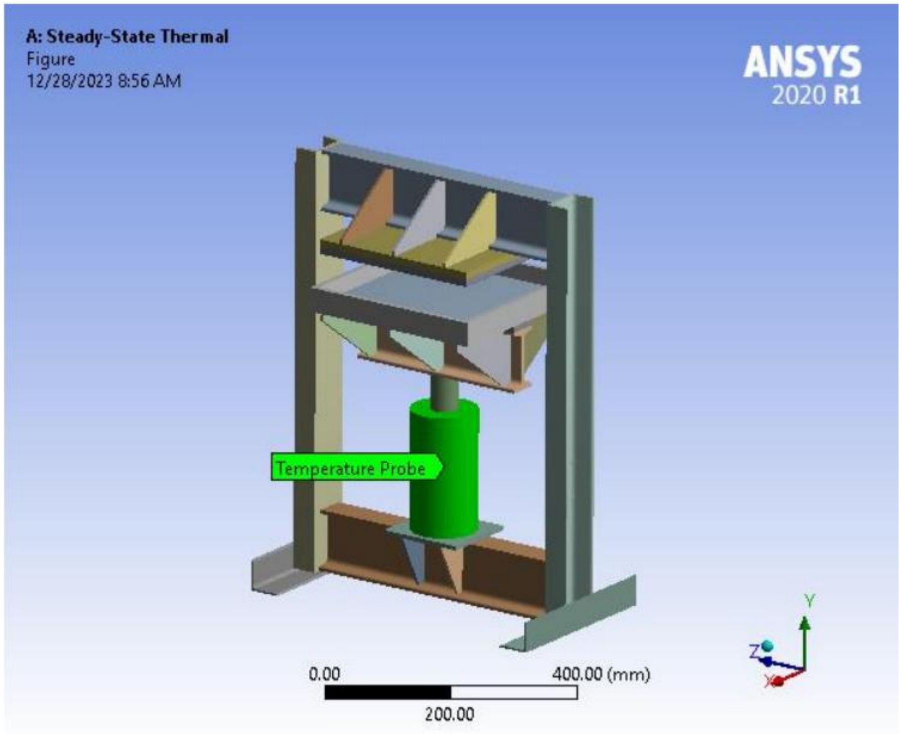


Figure 4-13: Hydraulic bottle jack temperature

Results	
Minimum	24.884 °C
Maximum	120.06 °C
Average	73.375 °C
Hydraulic Botte Jack	48.638 °C

Table 4-5: Structure temperature

4.6.1.2 Thermal-Structural Analysis:

- Objective: Assess structural response under thermal load and 20-ton force.
- Analysis Conditions:

Imported thermally loaded structure into static structural analysis.	
Applied force	2,00,000 N

Table 4-6: Analysis conditions

Results:

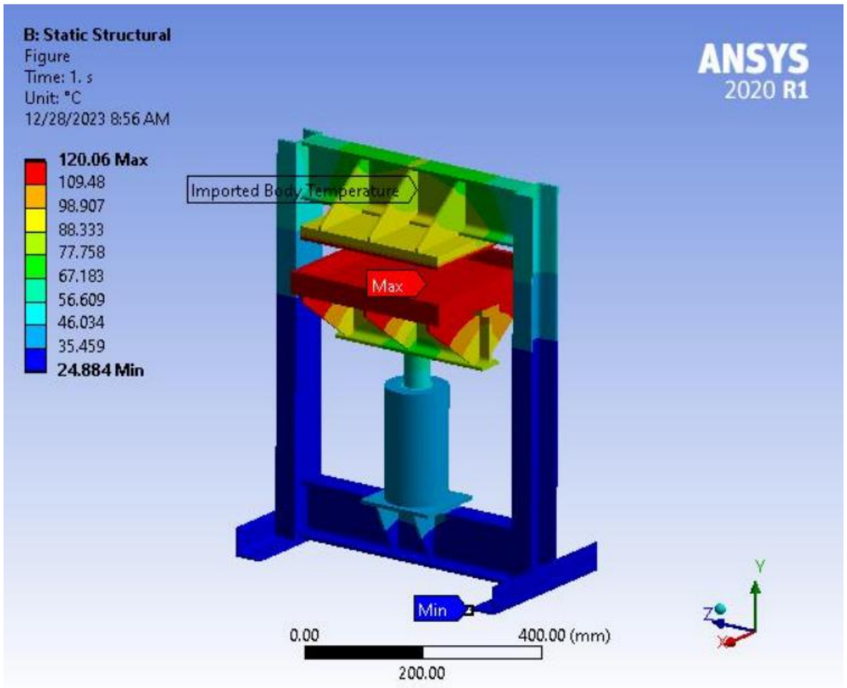


Figure 4-14: Imported thermal load

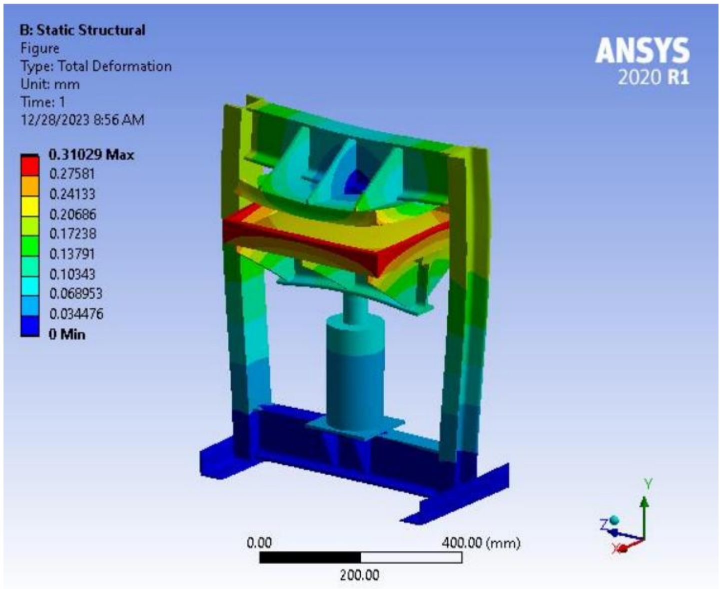


Figure 4-15: Total deformation

Deformation		
Minimum [mm]	Maximum [mm]	Average [mm]
0	0.31029	0.12009

Table 4-7: Structure deformation

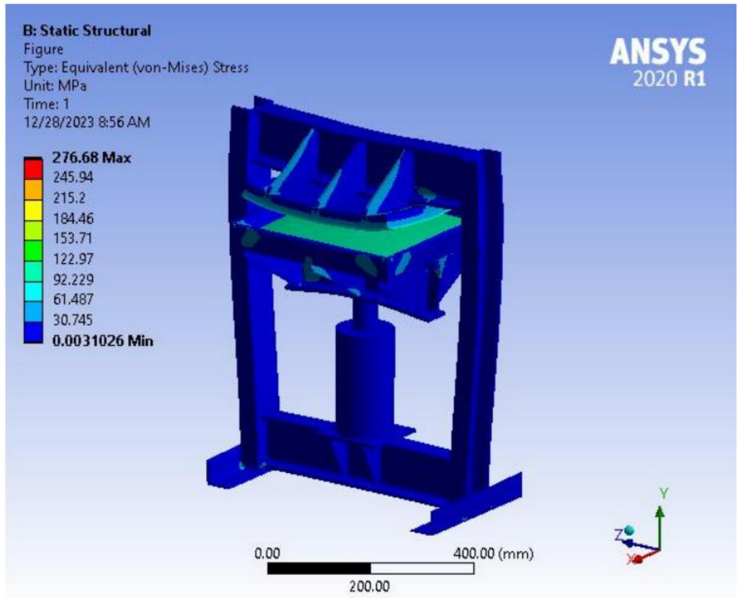


Figure 4-16: Von-Mises Stress

Von-Mises Stress		
Minimum [MPa]	Maximum [MPa]	Average [MPa]
3.1026e-003	276.68	24.026

Table 4-8: Von-Mises Stress

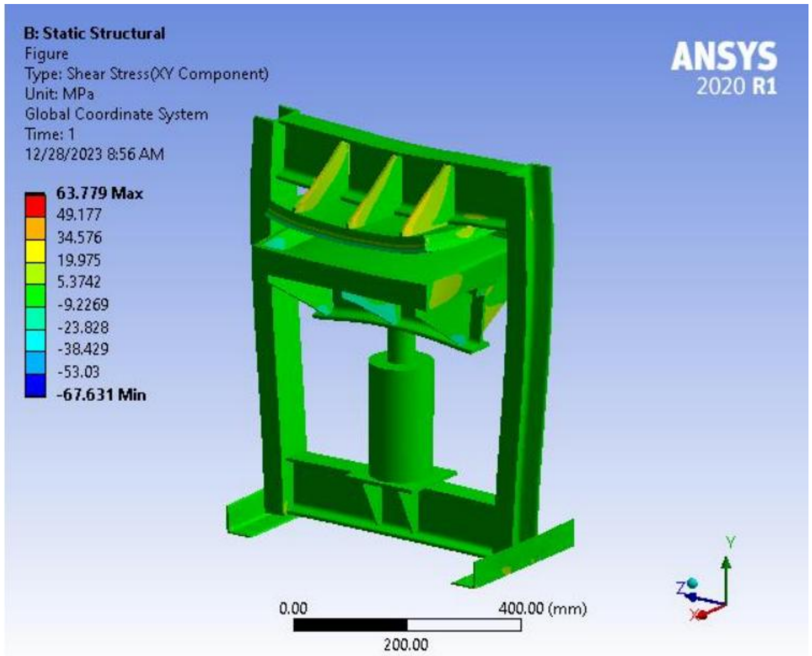


Figure 4-17: Shear Stress

Shear Stress		
Minimum [MPa]	Maximum [MPa]	Average [MPa]
-67.631	63.779	-5.6344e-003

Table 4-9: Shear Stress

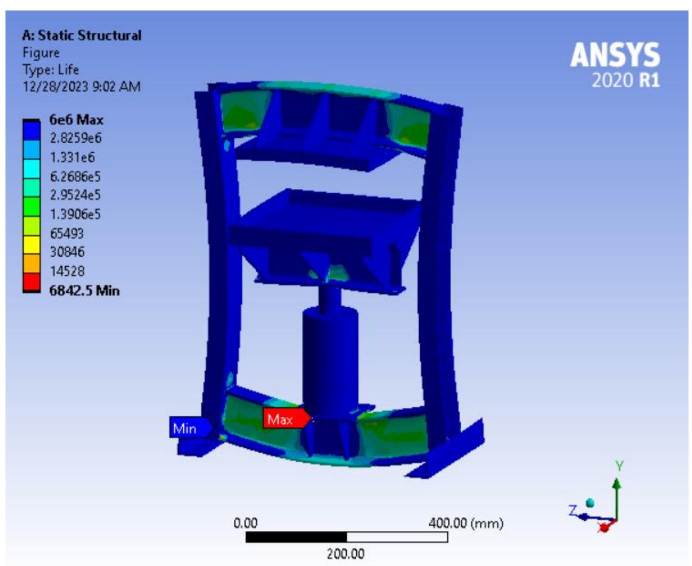


Figure 4-18: Fatigue life

Fatigue life		
Minimum	Maximum	Average
6842.5 s	6.e+006 s	5.2416e+006 s
1140.416 cycle	1000000 cycle	873600 cycle

Table 4-10: Fatigue life

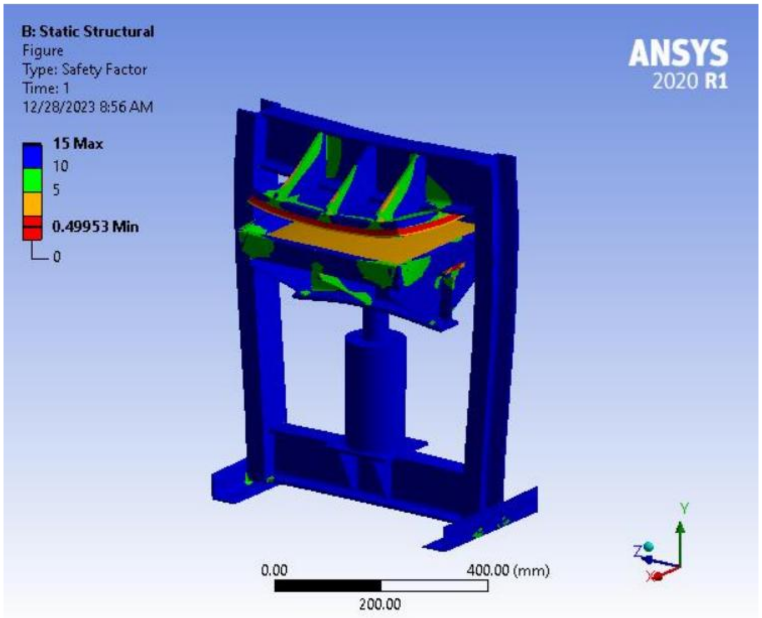


Figure 4-19: SF (Max Shear Stress)

SF (Max Shear Stress)		
Minimum	Maximum	Average
0.49953	15	11.965

Table 4-11: SF (Max Shear Stress)

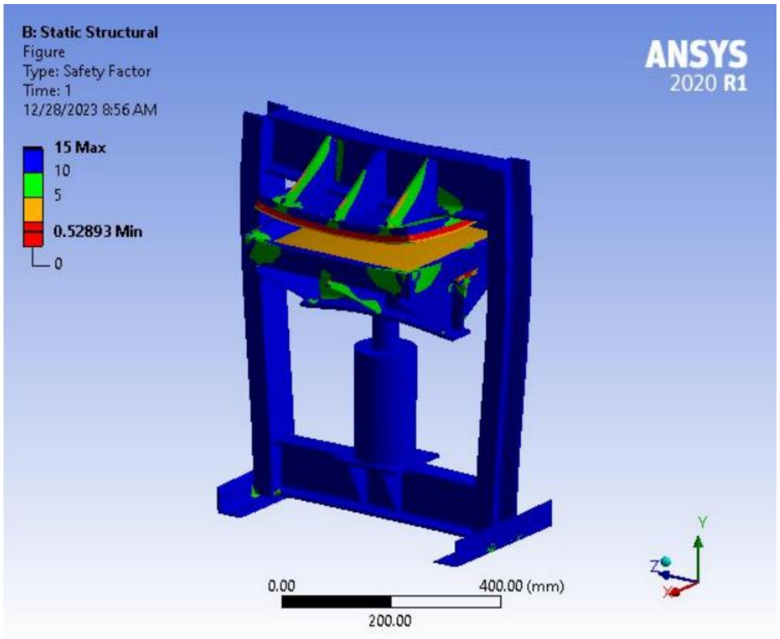


Figure 4-20: SF (Max Equivalent Stress)

SF (Max Equivalent Stress)		
Minimum	Maximum	Average
0.52893	15	12.168

Table 4-12: SF (Max Equivalent Stress)

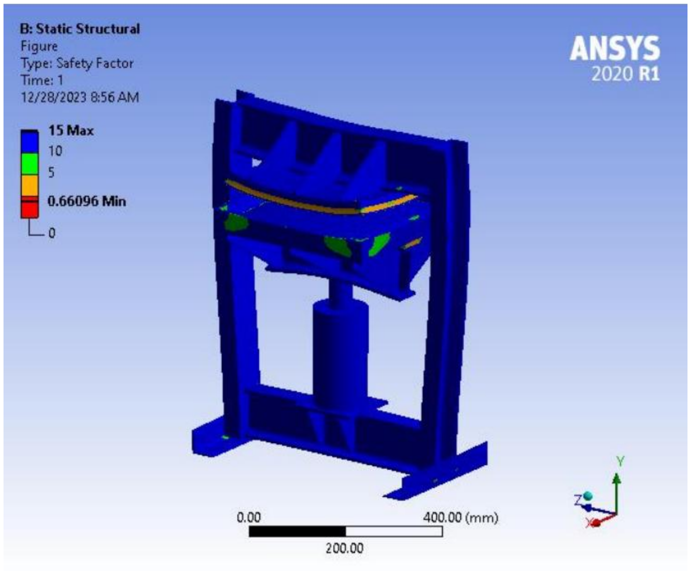


Figure 4-21: SF (Max Tensile Stress)

SF (Max Tensile Stress)		
Minimum	Maximum	Average
0.66096	15	14.286

Table 4-13: SF (Max Tensile Stress)

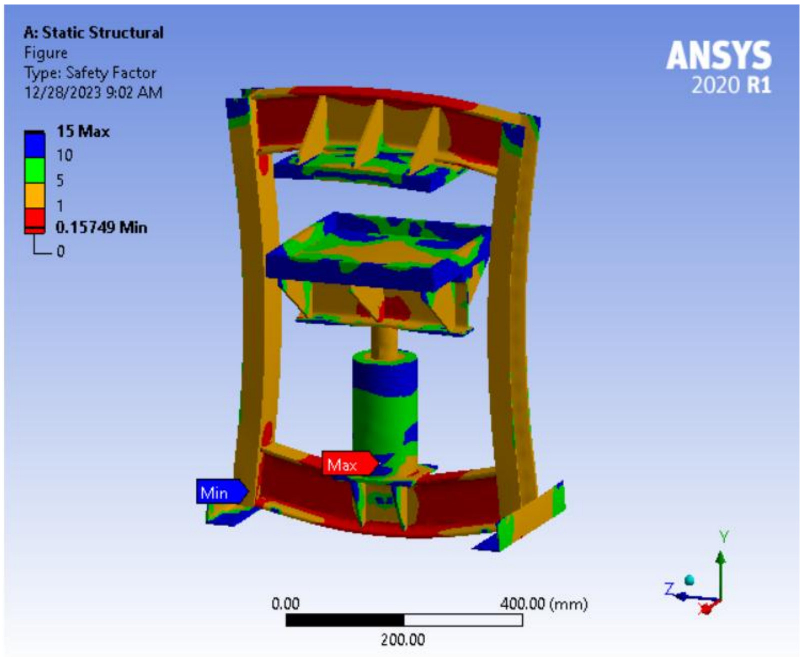


Figure 4-22: SF Fatigue

SF (Fatigue)		
Minimum	Maximum	Average
0.15749	15	4.2816

Table 4-14: SF Fatigue

4.7 Results:

- Thermal Analysis:
    - Hydraulic Bottle Jack Temperature: 48.638°C (within safe limits).
- Structural Analysis:
    - Total Deformation: 0.12009mm
    - Equivalent (von Mises) Stress: 24.026MPa
    - Shear Stress: -5.6344e-003
    - Safety Factors:
        - Max Equivalent Stress: 12.168
        - Max Tensile Stress: 14.286
        - Max Shear Stress: 11.965
    - Fatigue Life: 873600 cycles

The hot pressing system demonstrates satisfactory thermal and structural performance, meeting the specified criteria for temperature control and structural integrity.

4.8 Control Panel:

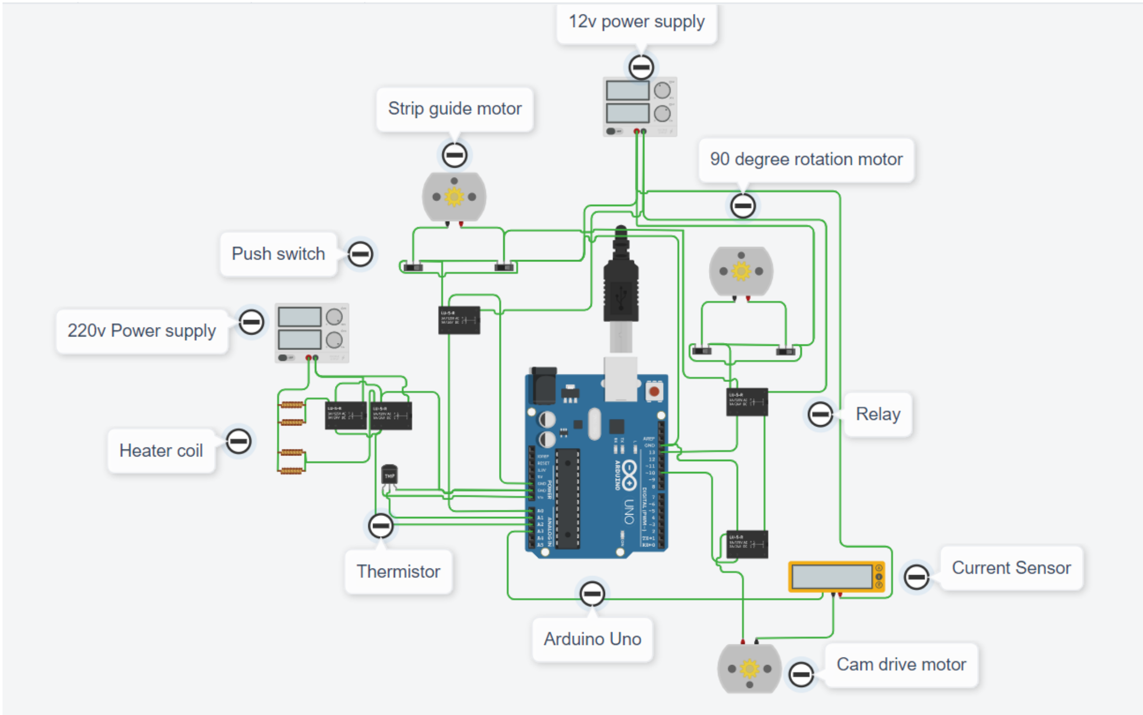


Figure 4-23: Circuit diagram of control panel

Process Overview:

- Motor Loop Execution:

Strip guide motor runs for 4 seconds, then stops for 10 seconds. This loop repeats three times.

- Power Supply to 90^{O} rotation motor:

90^{0} rotation motor receives power for 30 seconds and then stops.

- Current-Limited Power Supply to Cam motor:

Cam motor receives power, and the current is measured using the current sensor. If the current exceeds 20 Amps, the power to cam motor is stopped.

- Heating Coil Control Loop:

The heating coil is powered based on feedback from the NTC thermistor. It maintains the compartment temperature at 120°C for 10 minutes.

- End of Loop:

All power supplies are stopped, and the process waits for another loop to start.

4.9 Component Selection:

4.9.1 Structure:

4.9.1.1 I-Beam:

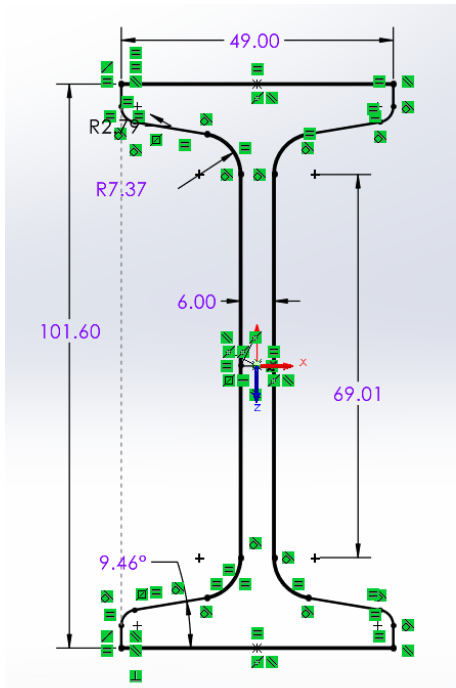


Figure 4-24: I-beam Specification

4.9.1.2 C channel:

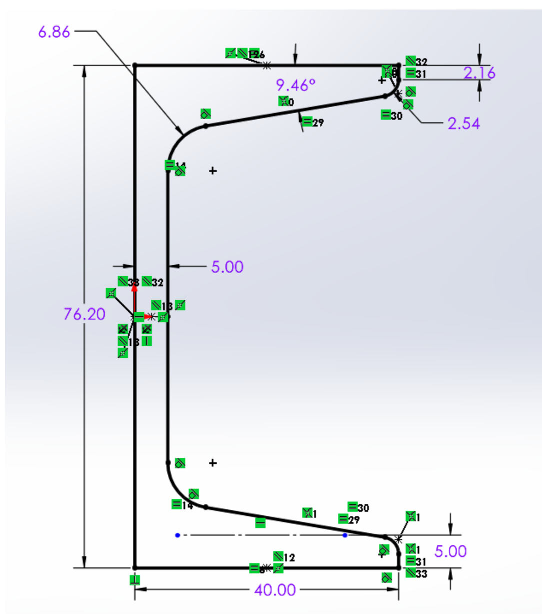


Figure 4-25: C-channel Specification

4.9.1.3 Angle rod:

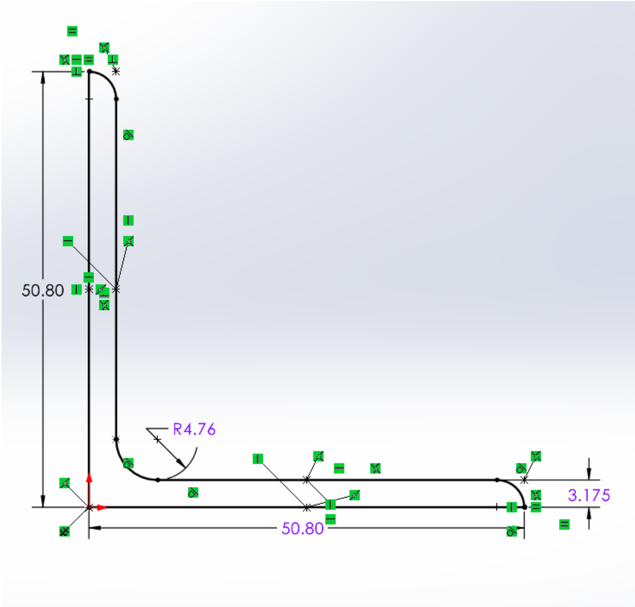


Figure 4-26: Angle rod Specifications

4.9.1.4 Hydraulic Bottle Jack:

Figure 4-27: Hydraulic Bottle Jack

Model No.	ST2002
Capacity(ton)	20
Minimum Height(mm)	244
Lifting Height(mm)	145
Adjust Height(mm)	60
Max. Height(mm)	449
N.W.(kg)	10.2
Material	Alloy steel, Carbon steel

Table 4-15: Hydraulic Bottle Jack

4.9.1.5 Insulator (Glass):

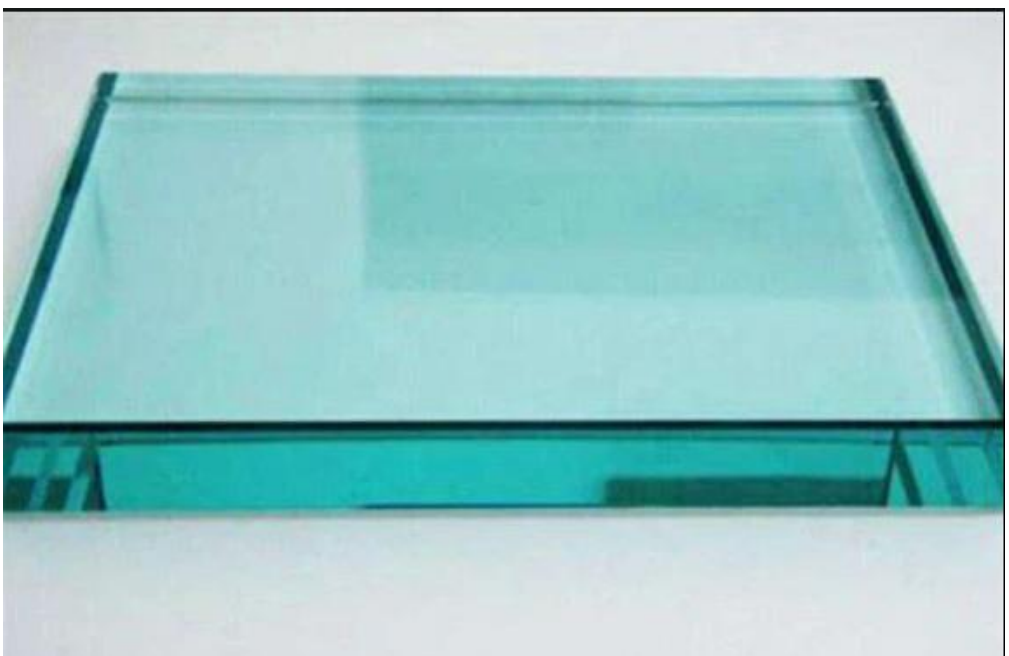


Figure 4-28: 10mm glass

Thickness	10mm
Density	25 kN/m^3
Young’s modulus	70,000 MPa
Shear modulus	28,000 MPa

Poisson's ratio	0.23
Hardness (Mohs scale)	6
Coefficient of thermal expansion	$9*10^{-6}$ K^{-1}
Tensile strength	45 MPa
Compressive strength	800 MPa

Table 4-16: Glass Specifications

4.9.1.6 Resin:

Phenol-formaldehyde	
Solids content (%)	48-51
Viscosity- cP (25℃)	400-800
pH	11.5-13.0
Gel time	6-11 min
Density- gcm^{-3} (25℃)	1.19-1.25
Coating	180 g/m^2
Setting temperature	120℃

Table 4-17: Resin Specification

4.9.1.7 Chain and Sprocket:

Figure 4-29: Chain and Sprocket

Sprocket diameter- 56mm

Chain length- 1283.2mm

Chain No.	Pitch	Chain width	Pin diameter	Pin length	Distance from hole center to tooth	Plate depth	Plate thickness	Guide type	Number of plates	Tensile strength	Average tensile strength	Weight per meter
	P	b max	d2 min	L max	h1	h2 max	t/T max		n	Q min	Q0	q
	mm	mm	mm	mm	mm	mm	mm			kN/lbf	kN	kg/m
CL04-2×3	6.35	4.35	2.50	6.05	3.94	6.80	1.04/0.75	Outside	5(2 3)	5.19/1179	5.4	0.22

Table 4-18: Chain specification

4.9.1.8 Bearing:

Figure 4-30: Bearing

Item	Value
Type	BALL
Structure	Deep Groove
Applicable Industries	Hotels, Garment Shops, Building Material Shops, Manufacturing Plant, Machinery Repair Shops, Food & Beverage Factory, Farms, Restaurant, Home Use, Retail, Food Shop, Printing Shops, Construction works , Energy & Mining, Food & Beverage Shops, Other, Advertising Company

Model Number	standard 608
Precision Rating	p6
Seals Type	ZZ 2RS
Number of Row	Single row
Place of Origin	China
Material	Gcr15 Chrome Steel
Size	8*22*7mm
Service	Support OEM Service
Lubrication	Grease Lubrication
Quality	High Quality 100% Tested

Table 4-19: Bearing specification

4.9.1.9 Arduino Uno:

Arduino Uno is a microcontroller board based on the ATmega328P (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

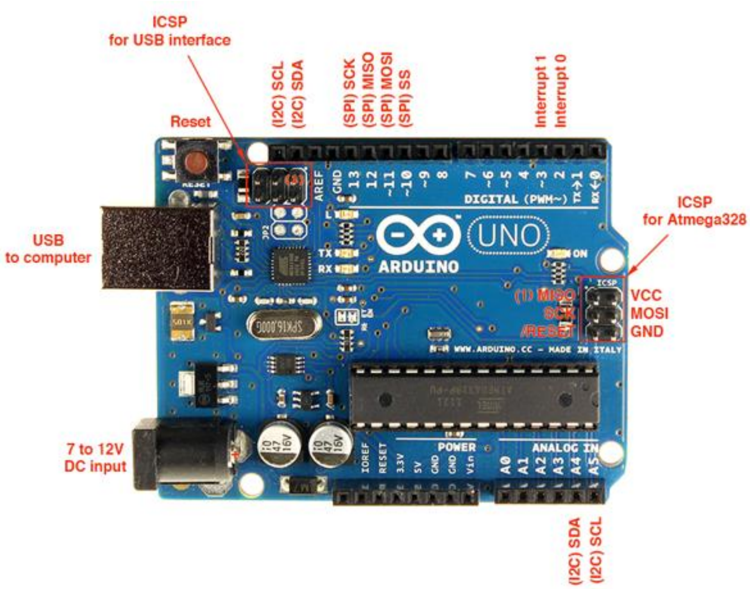


Figure 4-31: Arduino uno

Technical details :

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB of which 0.5 KB used by bootloader
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz
LED_BUILTIN	13
Length	68.6 mm
Width	53.4 mm
Weight	25 g

Table 4-20: Arduino uno Technical details

4.9.1.10 5V 5-Pin Relay

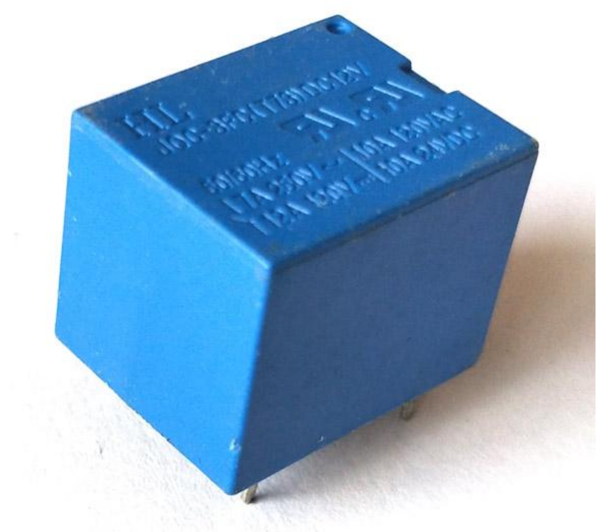


Figure 4-32: relay

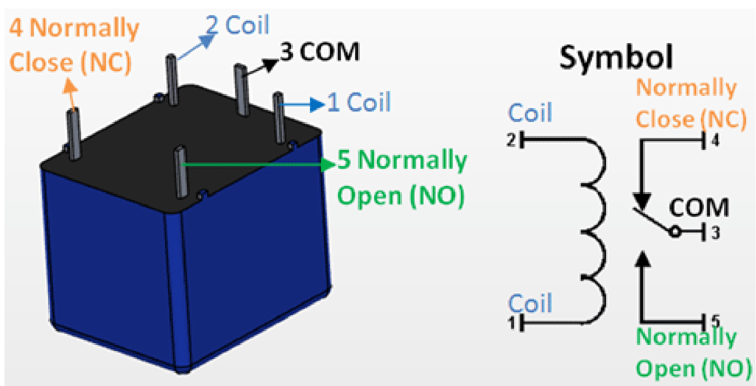


Figure 4-33: relay pin configuration

Pin Number	Pin Name	Description
1	Coil End 1	Used to trigger(On/Off) the Relay, Normally one end is connected to 5V and the other end to ground

2	Coil End 2	Used to trigger(On/Off) the Relay, Normally one end is connected to 5V and the other end to ground
3	Common (COM)	Common is connected to one End of the Load that is to be controlled
4	Normally Close (NC)	The other end of the load is either connected to NO or NC. If connected to NC the load remains connected before trigger
5	Normally Open (NO)	The other end of the load is either connected to NO or NC. If connected to NO the load remains disconnected before trigger

Table 4-21: relay technical data

Features of 5-Pin 5V Relay

- Trigger Voltage (Voltage across coil) : 5V DC
- Trigger Current (Nominal current) : 70mA
- Maximum AC load current: 10A @ 250/125V AC
- Maximum DC load current: 10A @ 30/28V DC
- Compact 5-pin configuration with plastic moulding
- Operating time: 10msec Release time: 5msec
- Maximum switching: 300 operating/minute (mechanically)

4.9.1.11 DS18B20 Temperature Sensor

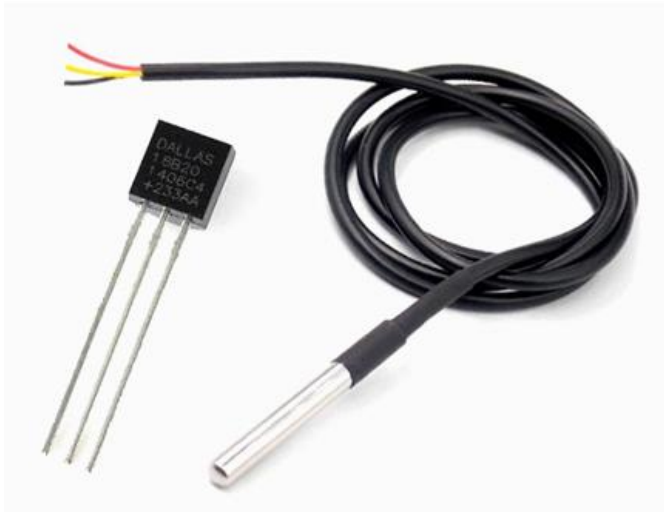


Figure 4-34: Thermistor

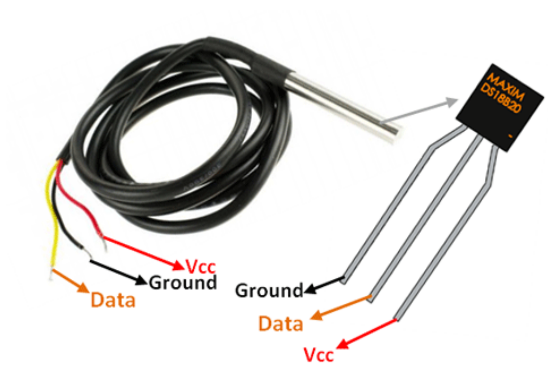


Figure 4-35: temperature sensor pin out

Pin Configuration

No:	Pin Name	Description
1	Ground	Connect to the ground of the circuit
2	Vcc	Powers the Sensor, can be 3.3V or 5V

3	Data	This pin gives output the temperature value which can be read using 1-wire method

Table 4-22: temperature sensor technical data

DS18B20 Sensor Specifications

- Programmable Digital Temperature Sensor
- Communicates using 1-Wire method
- Operating voltage: 3V to 5V
- Temperature Range: -55°C to +125°C
- Accuracy: ±0.5°C
- Output Resolution: 9-bit to 12-bit (programmable)
- Unique 64-bit address enables multiplexing
- Conversion time: 750ms at 12-bit
- Programmable alarm options
- Available as To-92, SOP and even as a waterproof sensor

4.9.1.12 ACS712ELCTR-05B-T

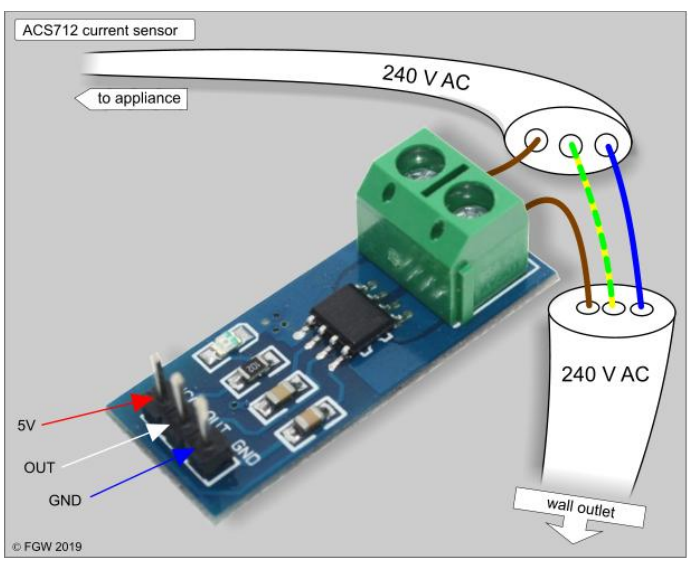


Figure 4-36: ACS712ELCTR-05B-T

ACS712ELCTR-05B-T can measure 5 to -5 Ampere current. Where 185mV change in Output voltage from initial state represents 1-Ampere change in Input current.

The ACS712 sensor module has 3 pins:

VCC: Power supply – 5v

GND: Ground

OUT: Analog output voltage

The features of ACS712 current Sensor are followed,

- 80kHz bandwidth
- 66 to 185 mV/A output sensitivity
- The low-noise analog signal path
- Device bandwidth is set through the new FILTER pin
- 1.2 mΩ internal conductor resistance
- Stable output offset voltage.
- Near zero magnetic hysteresis

4.9.1.13 Lema Kw7-12 Lever Electrical Snap Action Micro Switch 16A 250VAC

Figure 4-37: Lema Kw7-12 Lever Electrical Snap Action Micro Switch 16A 250VAC

Rating		3A, 8A, 16A/250VAC, 125VAC 0.6A/125VDC 0.3A/250VDC
Initial contact resistance		≤25mΩ
Initial insulation resistance (At 500V DC)		≥100mΩ
Dielectric strength	Between non-consecutive terminal	1000Vrms, 50/60Hz, 1min
	Between current carrying and non-carry metal parts	1500Vrms, 50/60Hz, 1min
	Between ground and each terminal	1500Vrms, 50/60Hz, 1min
Max. Shock resistance	Mechanical durable	1000m/s2
	Malfunction	300m/s2
Vibration resistance		10-55Hz, 1.5mm double amplitude
Expected life	Mechanical	20000000
	Electrical	100000
Ambient temperature		-25 to +85
Ambient humidity		85%RH max
Operating frequency	Mechanical	60 times/min
	Electrical	25 times/min
Operation speed		0.01mm-1m/s

Table 4-23: Lema Kw7-12 Lever Electrical Snap Action Micro Switch 16A 250VAC

4.9.1.14 Belt and Pulley

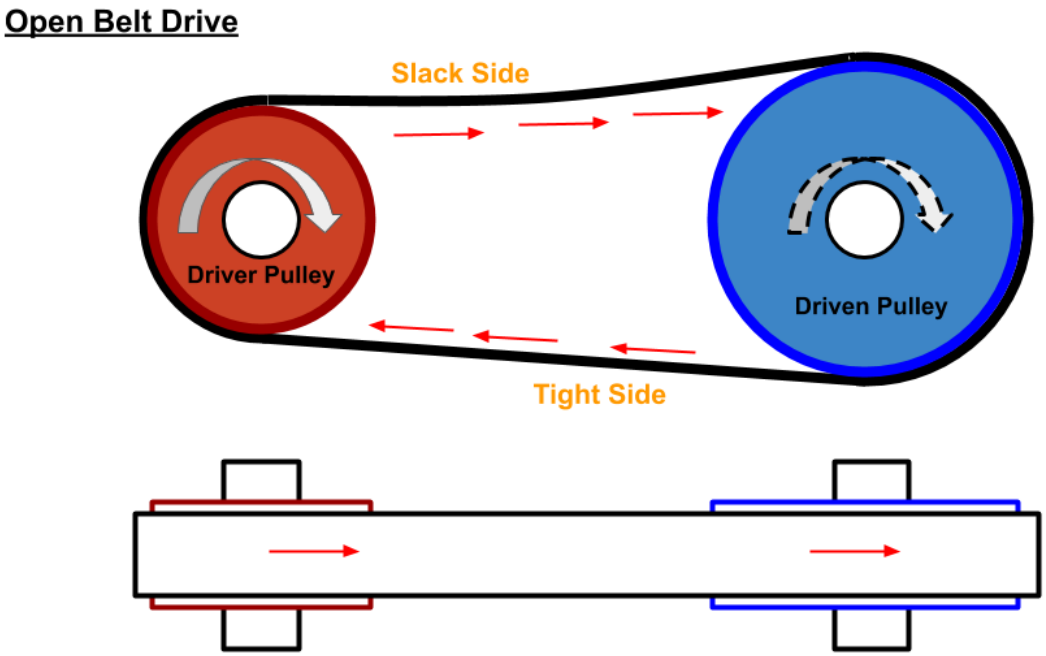


Figure 4-38: Belt and pulley drive

4.9.1.15 12V 100RPM DC Gear Motor

Figure 4-39: 12v 100RPM DC Gear motor

- Product Name : Gear Motor; Rated Voltage: DC 12V;Rated Current: 50mA
- Great replacement for the rusty or damaged DC gear motor on the machine.
- Used for automatic window curtain, safe box, robot, optic equipment, electronic game machine, coin refund devices, etc.
- RPM:100RPM;

- Length: 70mm; Diameter: 25mm; Shaft length: 9.5mm; Shaft diameter: 4mm;

  Specification:
  Voltage: DC12V;
  Rated Current: 50mA
  RPM:100RPM;
  Length: 70mm; Diameter: 25mm; Shaft length: 9.5mm; Shaft diameter: 4mm;
  Weight: 88g

4.9.1.16 PN01007-10038 - 3/8" D Shaft Electric Gear Motor 12v Low Speed 100 RPM Gearmotor DC

Figure 4-40: PN01007-10038 - 3/8" D Shaft Electric Gear Motor 12v Low Speed 100 RPM

Features:

- Rated Voltage: 13.5 VDC
- Rated Current: 6 A
- Speed: 100 RPM
- Rated Torque: 3 N-m (2.2 ft-lb)
- Mounting: M6 screw holes
- Shaft: 3/8" shaft with 1 flat ("D" shaft) where flat to OD is 0.322" and the length of the shaft is 0.886" long

4.9.1.17 Nichrome heater

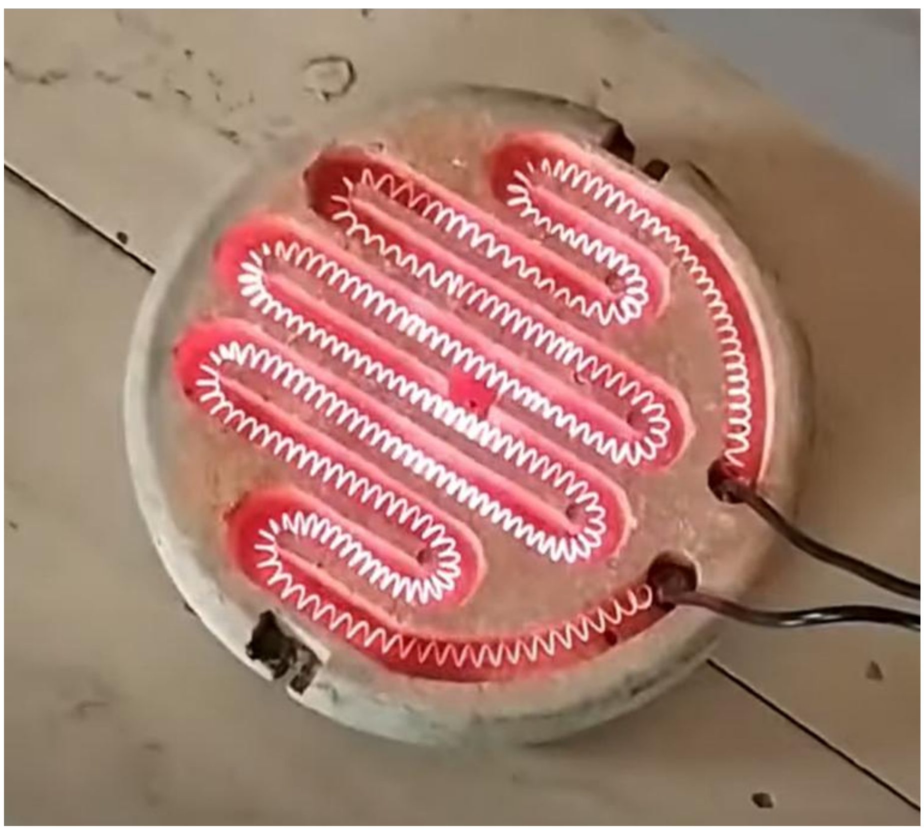


Figure 4-41: Nichrome heater

Power-1000W

4.9.1.18 Pillow Block

Figure 4-42: Pillow Block

NP20 RHP 20mm Pillow Block Bearing

NP normal duty pillow/plummer bearing unit complete with fully sealed bearing insert. The cast iron housing includes a grease nipple for re-lubrication.

The bearing insert has two grub screws for tightening against the shaft once fitted. The inserts can be removed allowing you to replace with a new insert once required which can be ordered separately.

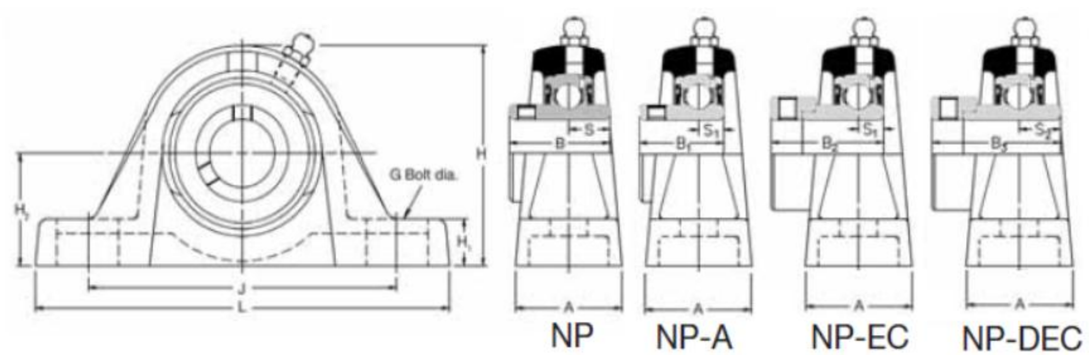


Figure 4-43: Schematic diagram of pillow block bearing

4.9.1.19 Steel Grill

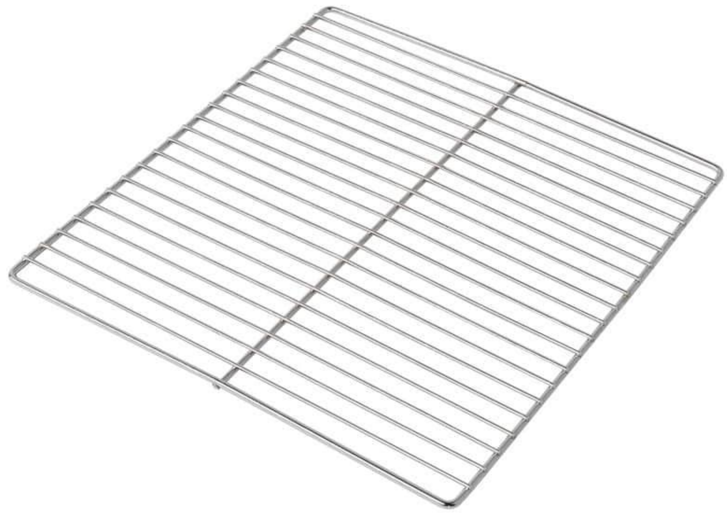


Figure 4-44: Steel grill

4.9.1.20 Gear and Pinion

Figure 4-45: Gear train

4.9.1.21 Sheet Metal

Figure 4-46: Sheet metal

Thickness-1mm

CHAPTER 5 : RESULT AND DISCUSSION

5.1 Fabricated machine:

Figure 5-1: fabricated machine

Figure 5-2: front view

Figure 5-3: top view

Figure 5-4: front view

Figure 5-5: back view

Figure 5-6: left side view

Figure 5-7: cam follower

Figure 5-8: pressing chamber

5.2 Panel testing:

The bamboo panel produced from three layers of bamboo stripes bonded with urea formaldehyde was tested in a UTM placed with their vertical alignment, the following results were the output of the test. The compressive strength was found to be 45.971 Mpa. Which is greater than that of bricks of same cross-sectional area. Hence a compared to a brick wall, walls having larger cross-sectional area can be replaced by panels with smaller cross-sectional area or thickness.

.

Figure 5-9: panel specimen 1

Figure 5-10: panel specimen 2

Figure 5-11: panel specimen 3 (cross section)

Figure 5-12: panel testing in UTM

Maximum force (f_m) (kN)	78.15
Original length (mm)	100
CSA (mm^2)	1700
Compressive Strength (Mpa)	45.971
Increase in Area	41.18%
Maximum displacement (mm)	6.6
Displacement at f_m (mm)	2.6

Table 5-1: vertical compression (urea formaldehyde)

Figure 5-13: test specimen after failure 1

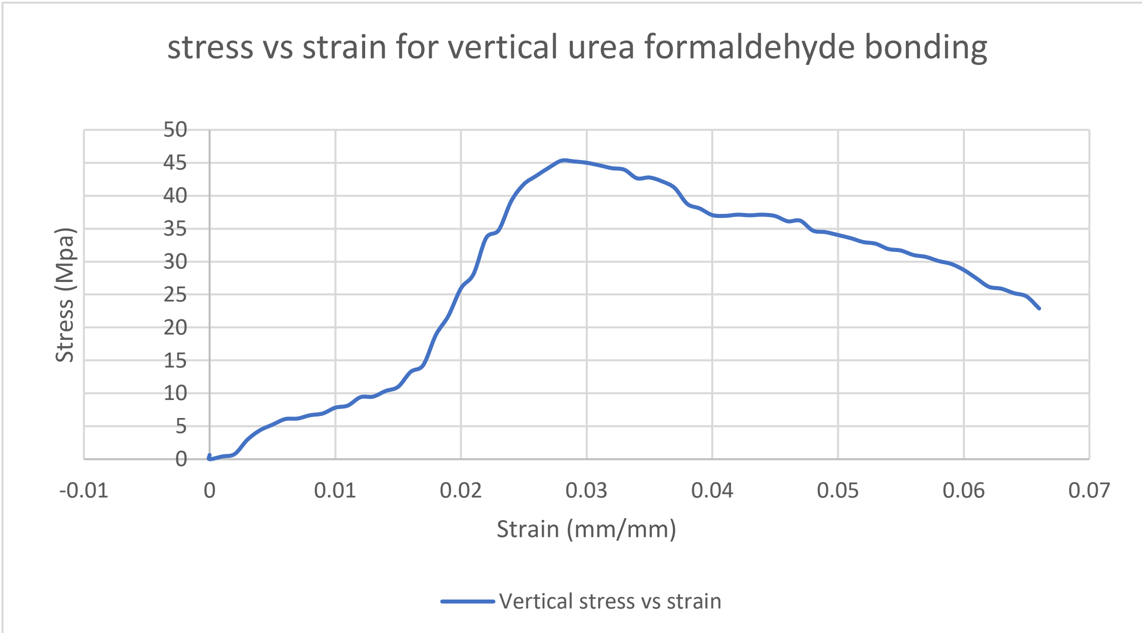


Figure 5-14: Stress-strain diagram of three-layered bamboo panel using urea formaldehyde aligned vertically

The same specimen was tested aligned horizontally and the test result showed the compressive strength reduced to almost half of that aligned vertically. It was found to be 24.324 Mpa.

Maximum force (f_m) (kN)	41.35
Original length mm	100
CSA (mm^2)	1700
Compressive Strength (Mpa)	24.324
Increase in Area	88.24%
Maximum displacement (mm)	7.4
Displacement at f_m (mm)	1.6

Table 5-2: horizontal compression (urea formaldehyde)

Figure 5-15: test specimen after failure 2

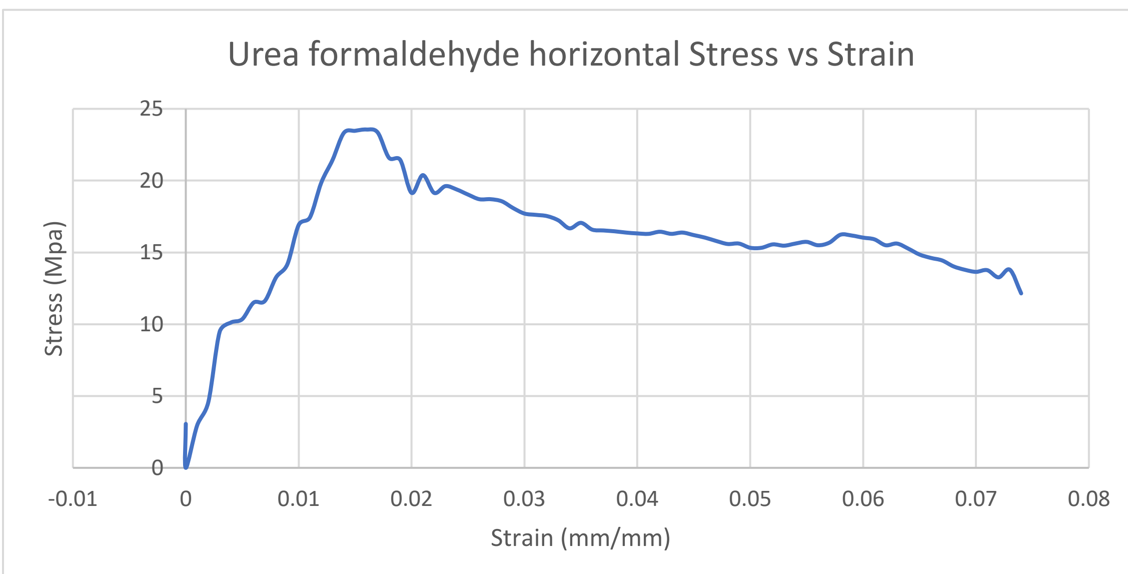


Figure 5-16: Stress-strain diagram of three-layered bamboo panel using urea formaldehyde aligned horizontally

Similarly, another specimen was created with two layers of bamboo stripes using poly synthetic resin and tested in the same UTM used before. The compressive strength was impressively larger for only two stripes as it was found to be 22.4112 Mpa.

Maximum force (fm) (kN)	17.75
CSA (mm^2)	792
Original length (mm)	70
Compressive Strength (Mpa)	22.4112
Increase in Area	21.47%
Maximum displacement (mm)	3.8
Displacement at fm (mm)	2.1

Table 5-3: compression (poly synthetic resin)

Figure 5-17: test specimen after failure 3

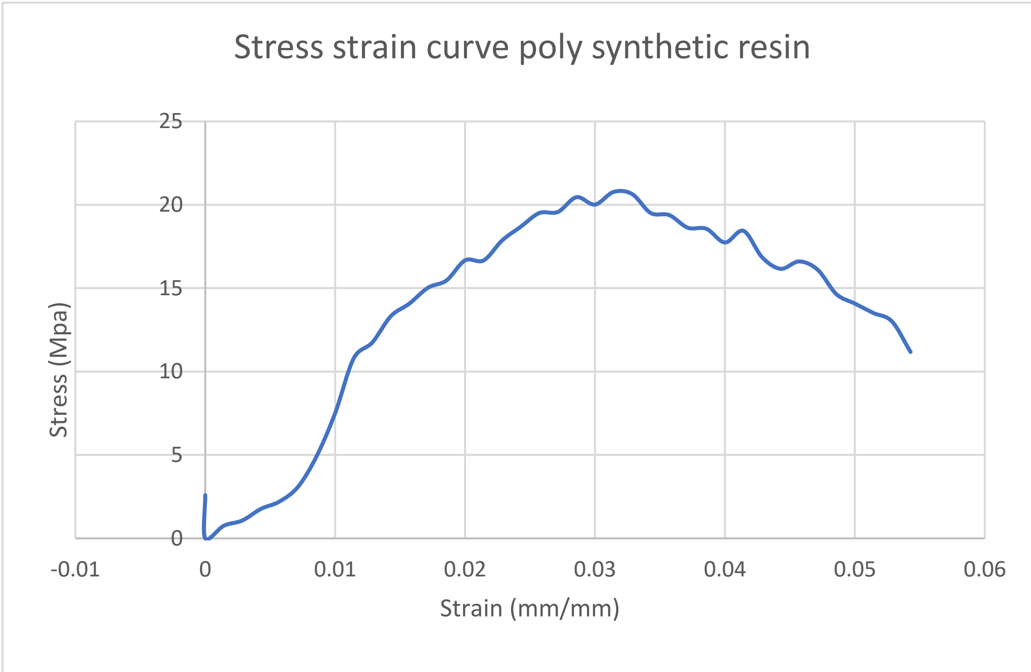


Figure 5-18: Stress-strain diagram of two-layered bamboo panel using poly synthetic resin

Third specimen with only two stripes and bonded with alicyclic & ketonic solvents (commercially sold as dendrite) were tested. The compressive strength was found to be greater than that of poly synthetic resin as it was 27.318 Mpa. These solvents were anticipated to be the best alternative for strength but they are not economically feasible.

CSA (mm^2)	1111
Original length (mm)	104
Maximum force (fm) (kN)	30.35
Compressive Strength (Mpa)	27.318
Increase in Area	11.16%
Maximum displacement (mm)	4.8
Displacement at fm (mm)	1.7

Table 5-4: compression (dendrite)

Figure 5-19: test specimen after failure 4

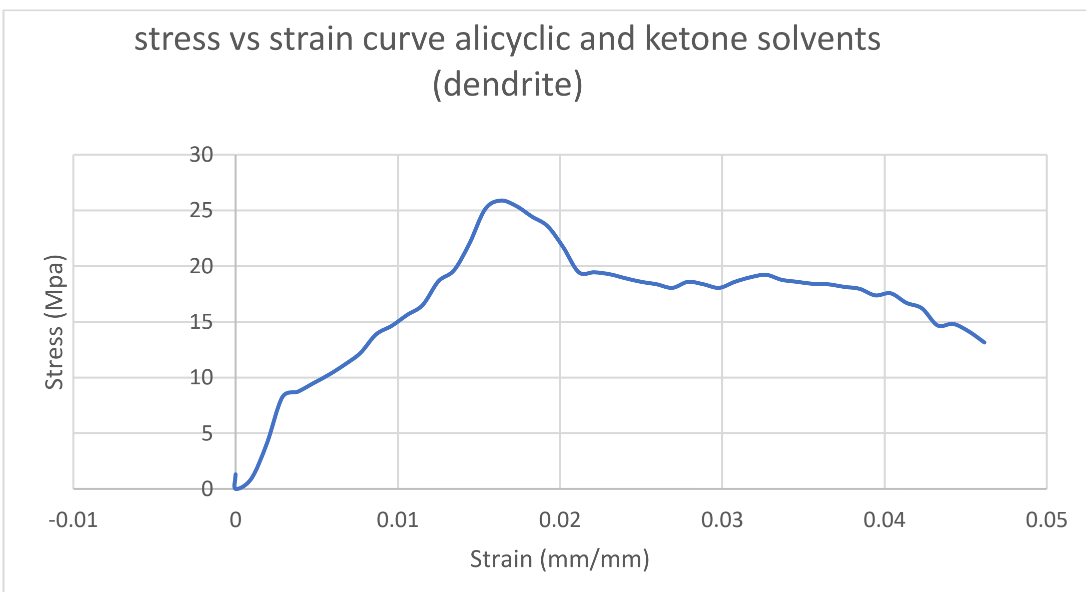


Figure 5-20: Stress-strain diagram of two-layered bamboo panel using alicyclic and ketone solvents

5.3 Limitations:

The limitation of the project includes:

- Bamboo panel size constrained to $280 \times 280 mm^2$.
- Ineffective measurement of pressure.
- Non-uniform heat distribution across base plate.
- Inability to test specimens for phenol formaldehyde.
- Deviation from intended cam follower design.

5.4 Problems Faced:

- Inability to conduct buckling tests for specimen due to equipment limitations and resource constraints
- Unavailability of phenol formaldehyde adhesive in the local market.
- Difficulty in manufacturing the cam follower profile
- Challenges in controlling temperature fluctuation, difficulty in maintaining consistent temperatures within the project environment.

5.5 Cost Analysis:

S.N	Components	Size	Quantity	Rate (NRs.)	Net Amount (NRs.)
1	Hydraulic Bottle Jack	20 ton	1	8625	8625
2	I-beam	4"	4'(15kg)	140/kg	2100
3	12mm metal sheet	12"*12" (8.5kg)	2 (17kg)	200/kg	3400
4	C-channel	3"	5' (10.6kg)	140/kg	1480
5	6mm metal sheet	5 sq. ft	21.2kg	200/kg	4240
6	3mm glass fiber	1.1 sq. ft	1	100	110
7	Phenol	500 gm	1	1015	1015
8	Formaldehyde	500 gm	1	510	510
9	Sprocket	Dia.-56mm	6	100	600
10	Chain	1284	3	100	300
11	Arduino Uno	-	1	1050	1050
12	Relay	5v	9	50	450
13	NTC Thermistor	-	1	350	350
14	Current Sensor	5A	1	440	440
15	Push Switch	16A 250V	4	50	200
16	DC Gear Motor	12V 100RPM	1	900	900
17	DC Gear Motor	12V 100RPM 3 N-m	1	5000	5000

S.N	Components	Size	Quantity	Rate (NRs.)	Net Amount (NRs.)
18	DC Gear Motor	12V 200RPM 6N-m	1	7000	7000
19	Nichrome Wire	1000W	4	150	600
20	Heater Plate	Dia.-5"	4	150	600
21	Pillow Block	20mm	2	500	1000
22	Steel Grill	1'*2'	1(1kg)	200/kg	200
23	Gear and Pinion	7:01	1	2500	2500
24	1mm metal sheet	16"*24"	2.66	150	400
25	Welding Rod	E6013	5kg	200	1000
26	Grinding Wheel	3"	20	20	400
27	Bamboo Strip	20mm*4mm*1000mm	50	35	1750
28	Bearing	Internal dia.-6mm	10	100	1000
29	Round Pipe	1"	10'	1200(20')	600
30	Roller	Dia-56	1'	400	400
Total					48220

Table 5-5: Budget Analysis

CHAPTER 6 : CONCLUSION AND RECOMMENDATION

The primary aim of this study was to design a machine for the production of bamboo panels and testing of the produced panels. A rotating roller was designed in SolidWorks and fabricated, which applies the adhesive to the moving strips with its rotating motion. Urea formaldehyde, poly synthetic resin and alicyclic and ketonic solvents were used as an adhesive on the strips of bamboo. The excessive adhesive was stored in the reservoir which was placed just below the roller, this prevents the adhesive from overflow while continuously providing enough adhesive to the roller.

A feeder table was used for feeding the arranged strips into the base plate where a belt and pulley mechanism was used for 90-degree rotation of the plate. Rotating of the plates arranges the bamboo strips into two mutually perpendicular orientation. The change in orientation arranges the fiber inside the strips in required direction for maximum distribution of strength.

A 20 Ton rated hydraulic bottle jack was used for pressing mechanism as 200kN force was required. The bottle jack was driven by a cam and follower mechanism which was connected to a driven gear driven by a pinion attached to a motor. Four ceramic heaters with nichrome wire of 1000W each were used for heating purpose of maintaining 120-degree Celsius.

The experiment was carried out in the scaled down model for the sake of simplicity. One panel of size 280mmx280mm, and other two panels of smaller sizes were manufactured and the testing was carried out in the UTM (Universal Testing Machine) in the university. The testing results showed the compressive strength of the panel to be approximately 45Mpa, for three-layered panel bonded with urea formaldehyde with vertical alignment, 25Mpa with the same panel but with horizontal alignment, 24Mpa for two-layered bamboo panel bonded with poly synthetic resin and 27Mpa for two-layered bamboo panel bonded with alicyclic and ketonic solvents, these results were impressive as compared to RCC which has 17Mpa to 28Mpa compressive strength.

For future enhancement of the machine, phenol formaldehyde as a bonding agent needs to be used which is supposed to be a better alternative to the urea formaldehyde. The most appropriate failure test for this product is buckling test, hence to enhance the results, buckling test and comparison of the obtained value with other alternatives is necessary. Use of a better control system mechanism for automated production and increasing the scale to practical level can bring the project to the mass production level.

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Customizable Timing Chain Sprocket Spare Part 415 420 428 428h 520 530 Motorcycle Chain - Buy Motorcycle Chain,Customizable Timing Chain Sprocket,415 420 428 428h 520 530 Motorcycle Chain Product on Alibaba.com. (n.d.). https://www.alibaba.com/product-detail/Customizable-timing-chain-sprocket-Spare-Part_1600918607613.html?spm=a2700.galleryofferlist.normal_offer.d_image.5ad17b4bROdBTm

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APPENDIX: DRAWING SHEET OF CAD FILE

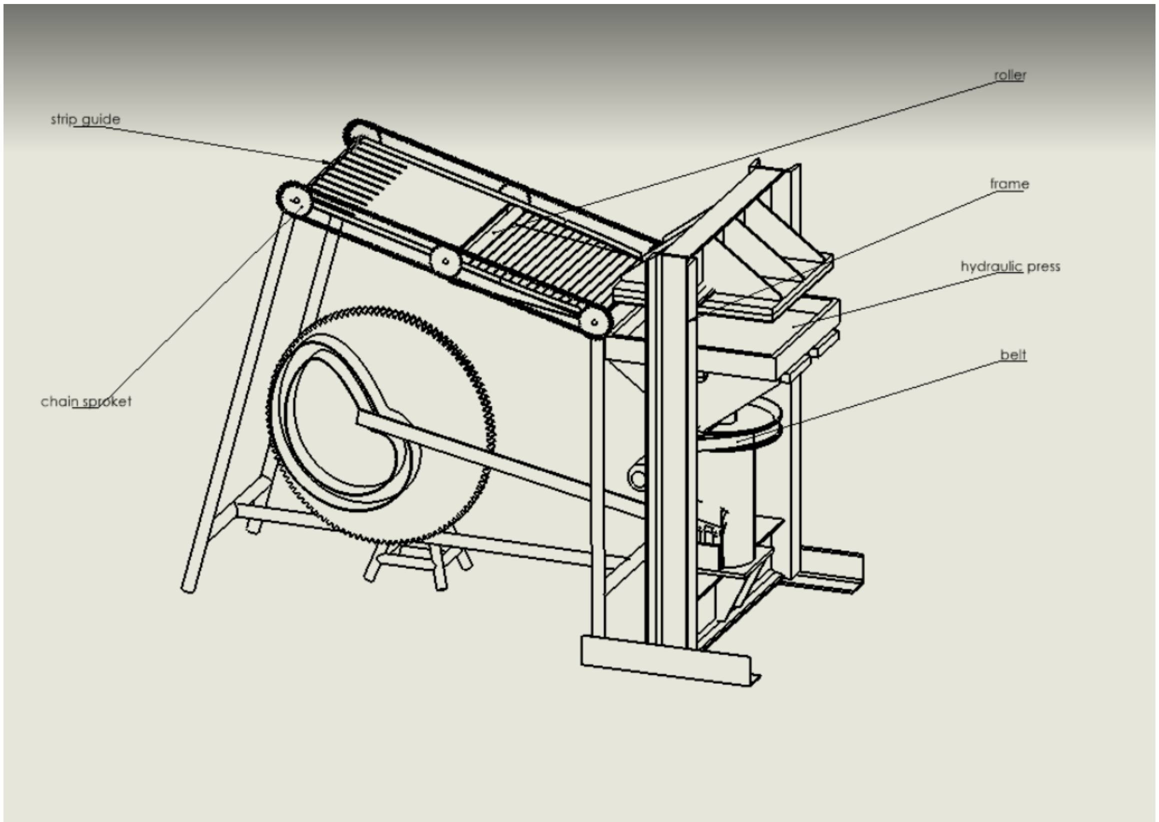


Fig: Parts of system(1)

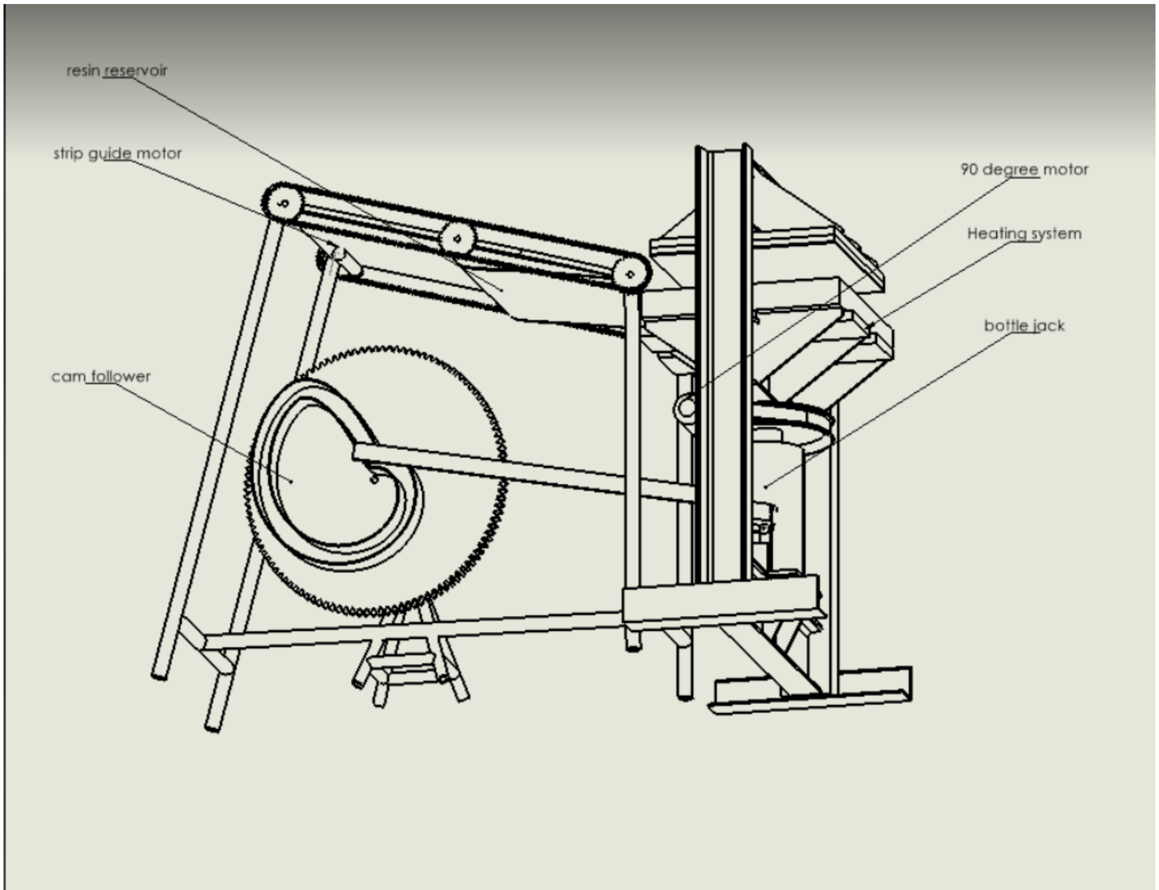
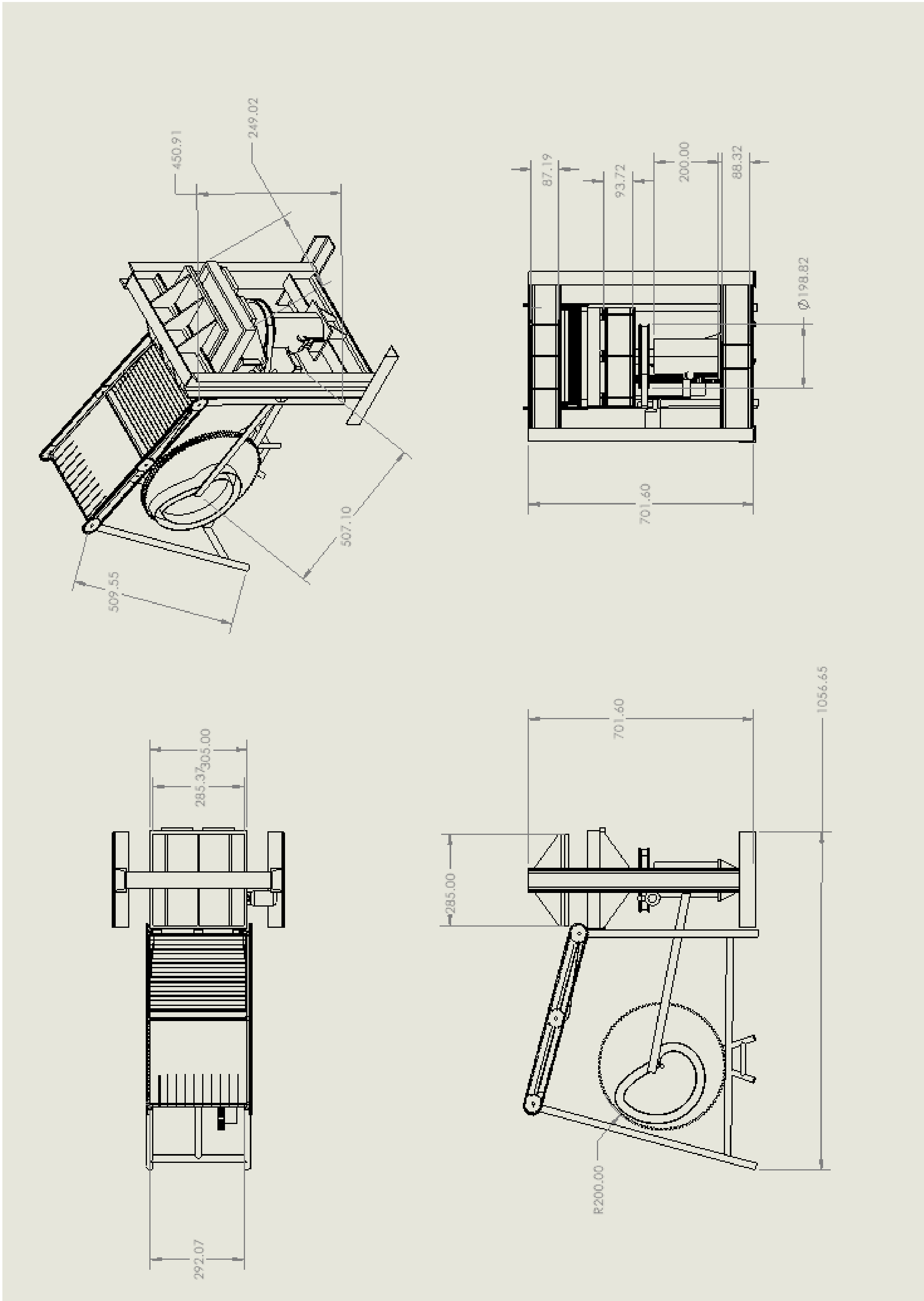


Fig: Parts of System(2)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701.60
305.00
285.37
292.07
701.60
285.00
1056.65
R200.00

APPENDIX: ARDUINO CODE

```
// Define motor control pins
const int motor1Pin = A0;
const int motor2Pin = 13;
const int motor3Pin = 10;

// Define current sensor pin
const int currentSensorPin = A3;

// Define heating coil pin
const int heatingCoilPin = A2;

// Define NTC thermistor pin
const int thermistorPin = A1;

// Define time constants
const unsigned long motorRunTime = 4000; // 4 seconds in milliseconds
const unsigned long motorStopTime = 10000; // 10 seconds in milliseconds
const unsigned long motor2RunTime = 30000; // 30 seconds in milliseconds
const unsigned long heatingTime = 600000; // 10 minutes in milliseconds

// Define variables
unsigned long startTime;
int motorLoopCount = 0;

void setup() {
  // Initialize motor control pins as outputs
  pinMode(motor1Pin, OUTPUT);
  pinMode(motor2Pin, OUTPUT);
  pinMode(motor3Pin, OUTPUT);
```

```
  pinMode(heatingCoilPin, OUTPUT);

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

void loop() {
  // Motor control loop
  while (motorLoopCount < 3) {
    // Run motor1 for 4 seconds
    digitalWrite(motor1Pin, HIGH);
    delay(motorRunTime);
    digitalWrite(motor1Pin, LOW);

    // Stop motor1 for 10 seconds
    delay(motorStopTime);

    motorLoopCount++;
  }

  // Power supply to motor2 for 30 seconds
  digitalWrite(motor2Pin, HIGH);
  delay(motor2RunTime);
  digitalWrite(motor2Pin, LOW);

  // Stop power supply to motor1 and motor2 after 30 seconds
  digitalWrite(motor1Pin, LOW);
  digitalWrite(motor2Pin, LOW);

  // Power supply to motor3 with current limiting
  int currentReading = analogRead(currentSensorPin);
```

```
  float current = currentReading * (5.0 / 1023.0) * (20.0 / 0.185); // Convert analog reading
to current in Amps
  if (current < 20.0) {
    digitalWrite(motor3Pin, HIGH);
  } else {
    digitalWrite(motor3Pin, LOW);
  }

  // Heating coil control loop
  unsigned long heatingStartTime = millis();
  while (millis() - heatingStartTime < heatingTime) {
    // Read temperature from NTC thermistor
    int thermistorReading = analogRead(thermistorPin);
    float temperature = (thermistorReading - 1023.0) / (-10.0); // Convert analog reading to
temperature in degrees Celsius

    // Adjust heating coil power based on temperature feedback
    if (temperature < 120) {
      digitalWrite(heatingCoilPin, HIGH);
    } else {
      digitalWrite(heatingCoilPin, LOW);
    }

    // Print temperature for debugging
    Serial.print("Temperature: ");
    Serial.print(temperature);
    Serial.println(" °C");

    // Delay for stability
    delay(1000);
  }
```

```
  // Stop all power supplies and wait for another loop start
  digitalWrite(motor3Pin, LOW);
  digitalWrite(heatingCoilPin, LOW);

  // Reset variables for next loop
  motorLoopCount = 0;
}
```