COFFEE HARVESTING MACHINE

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College : Mangalore Institute of Technology & Engineering, Moodbidri
Branch : Department of Mechatronics Engineering
Guide(s) : Mrs. Pavitra Kumari
Dr. Kiran Kumar M V
Student(s) : Mr. Punith B N
Mr. Jithesh
Mr. R Rishan
Mr. Adarsh

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Coffee harvesting, semi-automation, field efficiency, portable design, sustainable agriculture, ergonomic harvesting, mechanized farming.

Introduction:
Coffee harvesting is a labour-intensive and time-consuming process, especially in small and medium-scale plantations located in hilly terrains. Traditional manual harvesting requires significant human effort and is affected by labour shortages, increasing costs, and inconsistent picking efficiency. Existing large-scale harvesting machines are expensive and not suitable for uneven terrain or small farms.

To address these challenges, this project proposes a “semi-automated coffee harvesting machine” that is lightweight, portable, and cost-effective. The system uses a rotating shaft mechanism with controlled vibration to detach ripe coffee cherries while minimizing plant damage. An integrated movable and retractable base collector ensure efficient collection of cherries and reduces fruit loss.

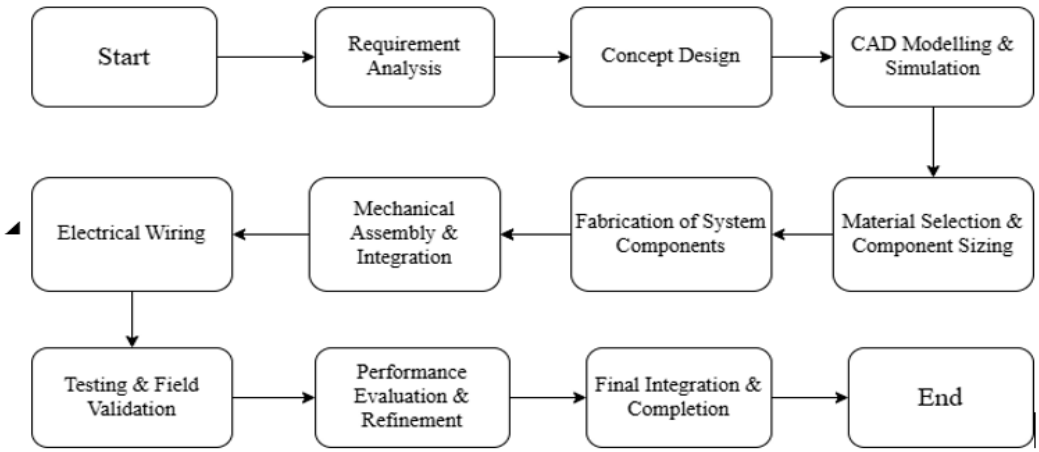
Objectives:

1. To design and develop a semi-automated coffee harvesting machine that improves harvesting efficiency.
2. To minimize plant damage and ensure gentle removal of ripe cherries.
3. To create a machine that is lightweight, cost-effective, and suitable for small and medium-scale farmers.

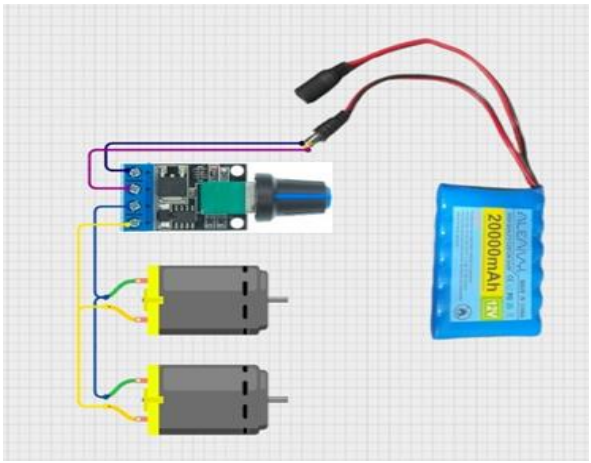
Methodology:

The methodology for this project begins with identifying the limitations of traditional coffee harvesting and defining key requirements such as portability, selective fruit detachment, user-friendliness, and low power consumption. Based on these requirements, a conceptual design featuring a two-arm mechanism with a rotating shaft and an integrated base collection system was developed to ensure both efficient harvesting and minimal fruit loss. Detailed 3D CAD models were created to validate structural alignment, component fitment, and overall feasibility before fabrication. Suitable materials such as PLA/ABS for lightweight components, aluminium for structural parts, and rubber for the stripping mechanism were selected to achieve durability and

operational comfort. The parts including the motor holder, stripping shaft, lever mechanism, and base collector were fabricated using 3D printing, machining, and rubber shaping processes and then assembled with precise alignment. Electrical integration involved connecting the 12V DC motor, PWM speed controller, and lithium-ion battery, followed by installing a user switch for operational control. Bench-level testing was conducted to evaluate vibration behavior, rotational stability, and battery performance, while field trials assessed cherry detachment efficiency, plant safety, ergonomics, and the effectiveness of the base collection system in reducing fruit wastage. Based on these evaluations, improvements were made to enhance vibration transfer, structural rigidity, alignment accuracy, and handling comfort, after which the refined components were integrated into the final prototype ready for field deployment.



Circuit Design:



The Figure shows the electrical layout of the coffee harvesting machine, including the 12V battery, PWM controller, and DC motor connections. It illustrates how power flows through the system and how motor speed is regulated for efficient harvesting.

The circuit design for the coffee harvesting device is built around a simple and efficient motor-control system powered by a 12V rechargeable battery. The battery serves as the main DC power source and is connected directly to a PWM (Pulse Width Modulation) motor controller, which regulates the speed of the motors through adjustable voltage pulses. The positive and negative terminals of the battery are linked to the input terminals of the PWM module, ensuring stable power delivery to the controller.

From the PWM controller, the regulated output is distributed to two DC motors connected in parallel. This configuration ensures that both motors receive the same controlled voltage while operating simultaneously at the speed set by the rotary knob on the PWM module. The motors share common positive and negative lines, allowing synchronized rotation for uniform vibration and plucking performance. The dual-motor setup increases operational efficiency by providing balanced torque and vibration during harvesting.

The PWM controller acts as the interface for the user, allowing manual speed variation to suit different branch densities and cherry ripeness. This prevents excessive vibration that could damage the plant while ensuring sufficient motion for effective cherry detachment. Overall, the circuit is designed to be simple, safe, and efficient, supporting stable motor operation with minimal energy loss and enabling long battery runtime suitable for field conditions.

CAD Design:

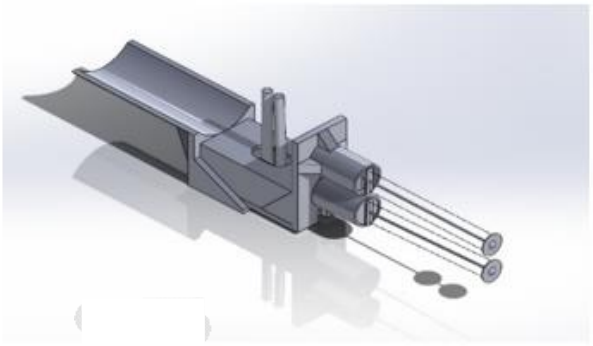


Fig.3 Isometric view

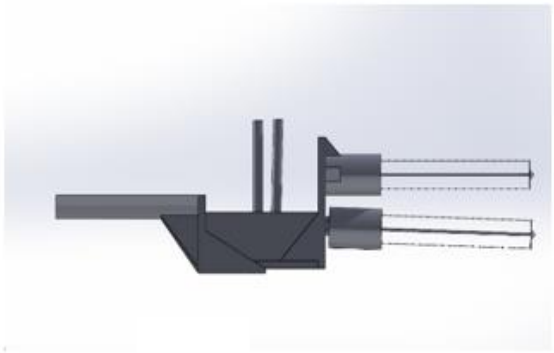


Fig.4 Side view

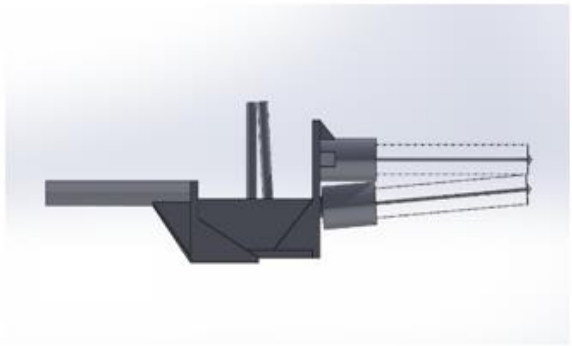


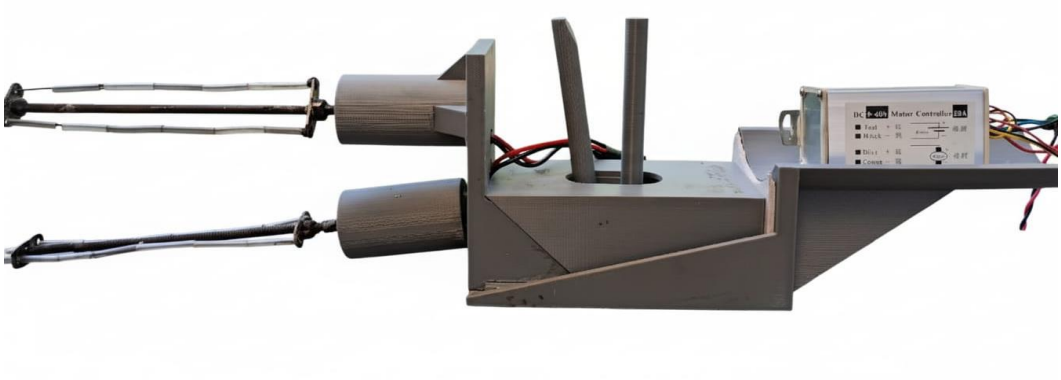
Fig.5 3D Design of the system

Result and Conclusion:

1. The developed semi-automated coffee harvesting machine was successfully designed, fabricated, and tested under real field conditions. The system, consisting of a rotating shaft mechanism, DC motor, PWM controller, battery system, and base collector, functioned effectively as an integrated unit. The rotating shaft generated

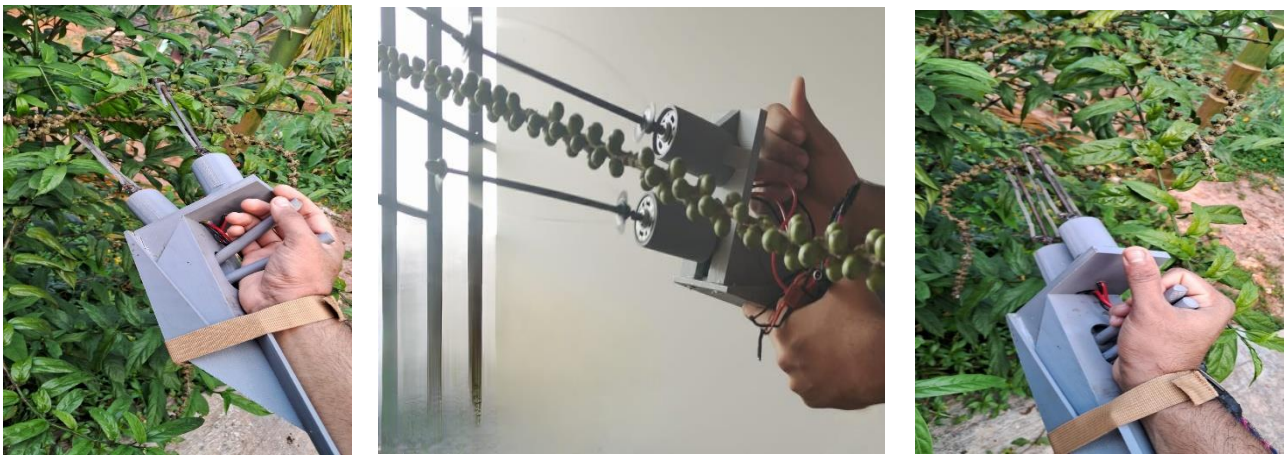
controlled vibrations that enabled efficient detachment of ripe coffee cherries while minimizing damage to the plant. The use of soft covering on the shaft further ensured safe interaction with branches.

2. The inclusion of a movable and retractable mesh-type base collector significantly reduced fruit loss by capturing cherries immediately after detachment. The machine demonstrated improved harvesting speed compared to manual methods, while also reducing physical effort required by the operator. The battery-powered system provided adequate runtime and ensured portability in hilly terrains.
3. Overall, the results indicate that the machine is reliable, efficient, and suitable for small and medium-scale coffee plantations. The project successfully meets its objectives of reducing labour dependency, improving productivity, and offering a cost-effective alternative to traditional harvesting methods.



Finalized Model

Base Collector



Field Testing.

Project Outcome & Industry Relevance:

1. The project resulted in the successful development of a functional prototype of a semi-automated coffee harvesting machine tailored for small-scale agricultural applications. It demonstrates how simple mechanical and electrical systems can be integrated to solve real-world farming problems. The machine offers a practical solution to labour shortages and rising operational costs in the coffee industry.
2. From an industry perspective, the design aligns with the growing demand for affordable agricultural mechanization tools, especially in developing countries. The lightweight and portable nature of the machine makes it suitable for use in uneven and hilly terrains where large machinery cannot operate. Additionally, the integration of a base collector improves efficiency by reducing post-harvest losses.
3. This project has potential for commercialization and can be further developed into a market-ready product, contributing to increased productivity and sustainability in the agricultural sector.

Working Model vs Simulation/Study:

1. The working model developed in this project closely aligns with the conceptual design and theoretical study conducted during the initial stages. While CAD modeling helped in visualizing the structure and ensuring proper alignment of components, the actual prototype provided practical insights into real-world performance.
2. In simulation, parameters such as shaft alignment, component fitting, and structural stability were verified. However, the working model revealed additional factors such as vibration effects, handling comfort, and field adaptability. The real-time testing demonstrated effective cherry detachment and system stability, validating the design assumptions.
3. Minor deviations observed between simulation and actual performance were addressed through iterative refinements, such as adjusting shaft balance and improving the stripping mechanism. Overall, the working model successfully validated the feasibility of the proposed design.

Project Outcomes and Learnings:

1. Through this project, the team gained valuable technical and practical knowledge in multiple areas of engineering. Key learnings include understanding the working principles of DC motors, vibration-based mechanisms, and power transmission systems. The team also developed skills in CAD modeling, material selection, and fabrication techniques such as 3D printing and machining.
2. The project enhanced problem-solving abilities by addressing real-world agricultural challenges and optimizing the design for efficiency and usability. Hands-on experience in assembling mechanical components and integrating electrical systems improved teamwork and coordination.
3. Additionally, testing and field validation provided insights into performance evaluation and system improvement. Overall, the project contributed to both technical knowledge and practical engineering skills.

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Future Scope:

1. The developed coffee harvesting machine has significant potential for further improvement and advancement. Future work can focus on enhancing the automation level by integrating sensors and control systems to detect and selectively harvest only ripe cherries. The addition of vision-based systems or machine learning algorithms can improve accuracy in fruit detection.
2. Integration of a solar-powered charging system can make the machine more sustainable and suitable for remote agricultural areas.
3. The base collector can be redesigned for larger capacity and better adaptability to different plant structures. Additionally, ergonomic improvements can be made to enhance user comfort during prolonged operation.
4. With proper refinement and large-scale production, the machine can be commercialized and widely adopted by farmers, contributing to improved agricultural productivity and reduced labour dependency.