Innovative Approach to the Design and Fabrication of a Portable Electric Tiller Machine for Agricultural Applications

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Abstract—

In the context of Indian agriculture, conventional ploughing is predominantly executed using tractors or cultivator machines. The traditional methods preceding the adoption of these machines were characterized by time-intensive labor, strenuous efforts, and considerable expenses. Recognizing the widespread use of high-priced agricultural machinery in India, often inaccessible to farmers due to cost constraints, we present an innovative solution.

Our newly designed machine addresses the challenge of affordability while significantly enhancing weed removal capacity. To augment the tiller blade's efficiency, we have incorporated additional components, namely three elongated tiller blades for thorough tilling operations, fostering an optimal environment for crop growth. Additionally, a cutter attachment has been integrated for efficient crop and grass cutting. This multipurpose machine seamlessly combines tilling and crop-cutting functionalities.

Keywords: Electric motor, plough, Cutter, Tiller

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1. Introduction

In the current agricultural landscape of India, escalating petrol prices have become a significant concern for farmers, making traditional ploughing operations financially burdensome. In response to this challenge, we have developed an electric power tiller and cutter machine powered by a rechargeable battery, providing an eco-friendly alternative. This innovative solution aims to alleviate the financial strain on farmers while addressing environmental and health issues associated with conventional internal combustion engine-operated machines.

The primary purpose of the power tiller is to facilitate farming operations, specifically in preparing seedbeds on elevated lands. Our portable electric power tiller not only boasts a superior soil mixing capacity compared to other machines but also excels in weed cutting capabilities. In contrast to the existing market options that rely on petrol or diesel engines, our electric power tiller offers a pollution-free and cost-effective alternative.

To enhance the functionality of our portable electric power tiller, we have incorporated valuable accessories, including wheel and cutter attachments. These additions contribute to the machine's versatility, enabling efficient cutting of grown crops and grass in gardening applications.

Given India's prominence in agriculture, the integration of modern technologies into farming practices is imperative. Traditional power tillers, typically operated by internal combustion engines, pose environmental and health hazards. In this project, we focus on designing and developing crucial components such as Chain and Sprockets, Shafts, Belt Drives, Bearings, Transmission Case, and Chassis. These components play a pivotal role in transforming the engine speed into the tilting speed required for effective power tiller operation.

Specifically tailored for weeding operations in sugarcane cultivation on black soil, our power tiller is designed to operate with a minimal inter-row distance of 12 meters. This machine stands out for its ease of operation, affordability, portability, and simplicity in construction and maintenance, with readily available spare parts. The overall objective is to offer a sustainable and efficient solution that aligns with the evolving needs of Indian farmers and promotes responsible agricultural practices.

2. Literature Survey

1. In the study conducted by Prof. Patil Digvijay Pandurang on "Mechanical Power Weeder Design and Development," the impact of unwanted plant growth on overall crop health was emphasized. The paper underscores the critical need for timely farming activities to avoid failures that significantly affect farmers' livelihoods in India. The design stages of the power weeder are thoroughly discussed, highlighting its cost-effectiveness and potential utility for farmers.
2. Prof. Shabbir J and team's research on the "Design, Development, and Fabrication of Mini Cultivator and Tiller" reveals the technology's main advantage—easy handling for any Indian farmer. The mini cultivator demonstrates increased traction and torque for effective tilling at depths of 4-7 inches. The versatility of this machine, capable of performing various functions like plowing, differential cultivation, wrapping, and puddling, makes it affordable and accessible to farmers.
3. Prof. Aravind Raj and colleagues focus on the "Design and Fabrication of Rotary Tiller Blade." Their work highlights the proportional relationship between working width and optimal diameter of a rotary tiller concerning power tillers. The aim is to achieve maximum field efficiency while minimizing material consumption during manufacturing. The presented theoretical method addresses the design considerations for rotary tillers, featuring a specific configuration with a 70 cm width, three flanges on the rotor shaft, and four blades on each flange.
4. In the investigation led by Prof. Abhijit Garje and team on the "Design, Development, and Operation of 3.5HP Power Tiller," the use of chain and sprocket for power transmission is emphasized over gears for cost reduction. The machine is designed with simplicity, accuracy in manufacturing, and the use of standard components, resulting in lower maintenance requirements. With an optimal consideration of materials, this power tiller demonstrates a working capacity of 25 acres per day, requiring only 10 liters of petrol daily and operable by a single operator.

Prof. Wagmode R.S. and team explore the concept of a "Solar Power Tiller" as an alternative to traditional fuel-powered machines. Acknowledging the rise in fuel prices and pollution concerns, this project focuses on utilizing solar energy. While the initial investment is higher, the eco-friendly nature of the system aligns with the goal of reducing pollution and conserving fuel resources.

3. Methodology:

Designing the Aesthetic Look of Power Tiller and Cutter Machine:

- Begin by conceptualizing the visual design of the portable electric tiller machine, ensuring a user-friendly and ergonomic appearance.
- Incorporate feedback from potential users and stakeholders to enhance the aesthetic appeal and overall usability.

Modeling (Solidworks):

- Utilize Solidworks or a similar modeling software to create a detailed 3D model of the electric tiller and cutter machine.
- Implement parametric design principles to allow for easy modifications during the iterative design process.

Considering Number of Forces and Loads:

- Analyze the various forces and loads that the machine will encounter during operation, including those from soil resistance, vegetation, and transportation.
- Employ engineering principles to ensure structural integrity and optimal performance under different working conditions.

Selecting Type of Materials:

- Conduct a materials selection process based on factors such as strength, weight, and cost-effectiveness.
- Consider the environmental impact of chosen materials and prioritize sustainability in the design.

Fabrication:

- Translate the 3D model into physical components through precision fabrication techniques.
- Employ advanced manufacturing processes, such as CNC machining or 3D printing, to achieve high accuracy and consistency.

Assembly and Testing:

- Assemble the fabricated components into the final electric tiller and cutter machine.
- Conduct comprehensive testing to evaluate the machine's performance, including its ability to till soil, cut vegetation, and handle different terrains.
- Assess the machine's energy efficiency and overall effectiveness in comparison to traditional tiller machines.

Result and Conclusion:

- Analyze the results obtained from testing, comparing them against design specifications and performance expectations.
- Draw conclusions regarding the success of the design, identifying strengths and areas for improvement.

Future Scope:

- Explore potential enhancements and innovations for future iterations of the portable electric tiller machine.
- Consider integrating smart technologies, automation, or additional functionalities based on evolving agricultural needs.
- Evaluate possibilities for scalability and adaptability to different agricultural settings.

By following this comprehensive methodology, the design and fabrication of the portable electric tiller machine will undergo a systematic and iterative process, ensuring a well-engineered and user-centric final product. The incorporation of aesthetic considerations, advanced modeling, and rigorous testing will contribute to the success and viability of the innovative tiller machine for agricultural applications.

4. PROBLEM STATEMENT

In the realm of agriculture, traditional methods of tillage have proven to be time-consuming, labor-intensive, and economically burdensome for farmers, particularly in the context of rising fuel prices associated with conventional plowing machinery. The dependence on petrol or diesel-powered tillers not only contributes to escalating operational costs but also raises environmental and health concerns due to emissions. Moreover, the financial constraints of small-scale farmers limit their access to sophisticated and costly agricultural machinery, hindering the adoption of modern, efficient practices.

To address these challenges, there is an urgent need for an innovative approach to the design and fabrication of a Portable Electric Tiller Machine for Agricultural Applications. The envisioned solution must overcome the limitations of traditional tillers by providing a cost-effective, eco-friendly, and user-friendly alternative. This includes addressing the following key issues:

Cost Barrier:

- Traditional tillers and cultivators, powered by internal combustion engines, are often prohibitively expensive for small-scale farmers.
- The challenge is to design an electric tiller that is not only affordable in terms of initial investment but also proves cost-effective in long-term operational expenses.

Environmental Impact:

- Conventional tillers contribute to environmental pollution through the emission of greenhouse gases and other pollutants.
- The objective is to develop an electric tiller that significantly reduces or eliminates emissions, promoting sustainable and eco-friendly agricultural practices.

Energy Efficiency:

- Traditional tillers are not always energy-efficient, leading to increased fuel consumption and operational costs.
- The goal is to design a portable electric tiller with optimal energy efficiency, ensuring maximum output with minimal energy consumption.

Adaptability and Versatility:

- Existing tillers may lack adaptability for diverse soil types and farming conditions, limiting their utility.
- The challenge is to create a versatile electric tiller that can efficiently operate in various terrains, soil types, and agricultural scenarios.

Accessibility and User-Friendliness:

- The complexity of traditional tiller machinery and the specialized skills required for operation may discourage widespread adoption.
- The solution should prioritize user-friendly design and ease of operation to make the technology accessible to a broad spectrum of farmers, including those with limited technical expertise.

By addressing these challenges through an innovative design approach, the Portable Electric Tiller Machine aims to revolutionize agricultural practices, making them more sustainable, efficient, and accessible for farmers across different socioeconomic backgrounds.

5. Working Principle

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The innovative Portable Electric Tiller Machine operates on a streamlined working principle, integrating advanced features for efficient and sustainable agricultural applications.

Soil Gripping Mechanism:

- The machine is equipped with a specially designed wheel featuring welded angles to ensure effective gripping on the soil.
- This wheel is strategically crafted to provide a strong and secure hold on the soil, essential for the smooth operation of the tiller during the tilling process.

Switch-Controlled Activation:

- A user-friendly switch is positioned on the machine's handle, serving as the control mechanism to power on and off the device.
- This switch provides a convenient and accessible way for the operator to initiate and cease the machine's functionality, enhancing overall usability.

Electric Motor Propulsion:

- The machine is driven by an electric motor, chosen for its efficiency, cleanliness, and ease of operation.
- The electric motor serves as the powerhouse of the tiller, converting electrical energy into mechanical energy to drive the machine's essential components.

Sprocket Chain Drive:

- To transmit power from the electric motor to the working components, a sprocket chain arrangement is employed.
- This arrangement ensures a reliable and efficient transfer of rotational energy from the motor to the pulling wheel, facilitating the tilling process.

Battery-Powered Operation:

- The electric motor is powered by a rechargeable battery, providing the necessary force to pull the cultivator forks through the soil.
- This battery-operated system enhances the portability and sustainability of the machine, offering a fuel-free alternative for agricultural operations.

Cultivator Forks for Precision Tilling:

- The machine incorporates three cultivator forks designed for easy and narrow tilling, allowing precise and controlled soil cultivation as required for farming.
- This configuration ensures adaptability to various farming needs and promotes efficient soil preparation.

Portable Lightweight Design:

- The tiller machine is crafted with a portable and lightweight design, allowing for easy control of the machine's direction during operation.
- This feature facilitates effortless transportation by hand or in vehicles, enabling mobility across different agricultural areas.

In essence, the working principle revolves around the synergy of a specialized soil gripping mechanism, electric motor propulsion, sprocket chain drive, and battery-powered operation. This innovative approach aims to deliver a sustainable, user-friendly, and effective solution for modern agricultural practices.

Design Considerations

1. **Functionality and Performance:** Tilling Mechanism: Design a robust and efficient tilling mechanism that can effectively break and aerte the soil. Consider blade type, arrangement, and depth adjustment for various soil types.
2. **Power Source:** Opt for an electric power source for eco-friendliness. Choose the appropriate motor power and battery capacity to ensure sufficient runtime and torque for tilling operations.
3. **Portability:** Ensure the machine is lightweight and easy to transport. Consider foldable or detachable components for compactness during transportation and storage.
4. **Durability:** Use high-quality, durable materials that can withstand rough agricultural conditions and frequent use.
5. **User-Friendly Design:** Ease of Use: Simplify the control interface for user convenience. Intuitive controls and ergonomic design elements enhance usability.
6. **Safety Features:** Incorporate safety mechanisms such as blade guards, automatic shut-off in case of overloading, and ergonomic handles to prevent user fatigue and accidents.
7. **Adjustability:** Allow for adjustable handle heights and tilling depths to accommodate different users and soil conditions.
8. **Maintenance:** Design for easy cleaning, maintenance, and accessibility to internal components for repairs.

Efficiency and Innovation:

1. **Energy Efficiency:** Optimize power consumption for extended battery life. Include energy-saving modes or smart power management systems.
2. **Innovative Features:** Consider incorporating smart sensors for soil moisture or quality assessment, GPS navigation for precision tilling, or IoT capabilities for remote monitoring and control.
3. **Multi-functionality:** Explore the possibility of additional attachments or features for multi-functional use, such as seed planting capabilities or weed removal attachments.

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Environmental Impact and Sustainability:
Use of Sustainable Materials: Consider eco-friendly materials and components in the construction of the machine.

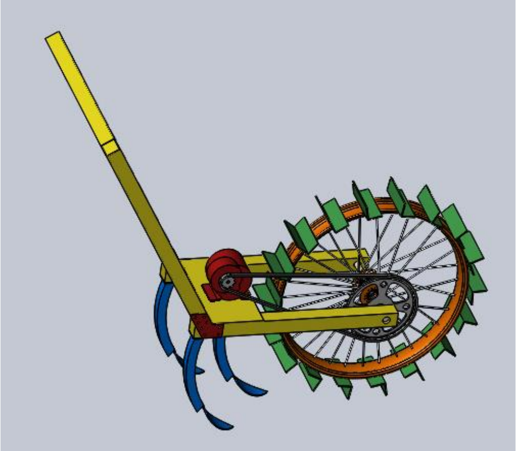
1. **Low Emissions:** Ensure minimal noise and emissions during operation to reduce environmental impact and make it suitable for both rural and urban agricultural applications.
2. **Longevity:** Design for long-term use with easily replaceable parts to extend the machine's lifespan and reduce waste.

Cost-Effectiveness and Accessibility:

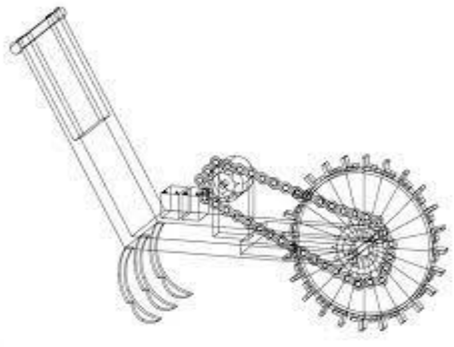
1. **Affordability:** Strive for a balance between performance and cost to make the machine accessible to small-scale farmers.
2. **Availability of Parts:** Ensure availability of spare parts and ease of repairs in local markets to support widespread adoption.
3. Balancing these considerations can lead to the development of a portable electric tiller that is efficient, user-friendly, sustainable, and adaptable to various agricultural needs, ultimately contributing positively to farming practices.

5. Proposed Model

The proposed model for the Electric tiller machine Unit is meticulously crafted using SolidWorks software, ensuring precision and accuracy in design. The intuitive 3D representations showcase the intricate details of the machine, allowing for a comprehensive understanding of its structure and functionality. The innovative design addresses the manual labor-intensive aspects of traditional tilling methods and incorporates features such as motor speed control, efficient waste management, and adaptability for various grain sizes.



1.1 Electric tilling machine



1.2 Electric tilling machine Diagram

6. Fabrication

Design Planning: Develop a detailed design and schematic layout of the machine, considering functionality, ergonomics, and assembly requirements.

Material Preparation: Gather the necessary materials and components based on the design specifications.
Cut and shape the metal or plastic parts for the frame and structural components.

Tilling Mechanism Assembly: Construct the tilling mechanism by attaching the blades or tines to a rotating shaft, ensuring proper alignment and stability.
Integrate the tilling mechanism with the motor, allowing for proper power transmission and torque.

Electric System Integration: Install the electric motor in the frame and connect it to the tilling mechanism.
Set up the battery system, ensuring it fits securely and allows for easy access for charging or replacement.

Control Panel and Handles: Mount the control panel with the necessary buttons, switches, and indicators for operation.
Attach ergonomic handles to the frame, ensuring adjustability and comfort for users.

Wiring and Connections:
Wire the electrical components, ensuring proper connections and insulation to prevent short circuits or malfunctions.
Test the electrical system to ensure proper functionality and safety measures like overload protection.

Assembly and Finishing:
Assemble all the fabricated components together, securing them firmly to the frame.
Conduct a thorough check for any loose connections, structural integrity, and alignment.
Apply finishing touches, such as painting or coating for durability and aesthetic appeal.

Testing and Calibration:

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Conduct rigorous testing of the machine's functionality, including speed control, tilling depth, and safety features.
Calibrate settings and mechanisms for optimal performance and user safety.

Quality Check and Improvement:
Ensure the machine meets design specifications and safety standards.
Make necessary adjustments or improvements based on test results or user feedback.

Electric tilling machines find diverse applications across various agricultural and landscaping tasks due to their efficiency, eco-friendliness, and ease of use. Here are some primary applications:

Agricultural Tilling: Field Preparation: Electric tillers are used to prepare fields for planting by breaking up soil, aerating it, and creating a suitable seedbed.
Crop Cultivation: They aid in cultivating rows for different crops, facilitating better nutrient absorption and root development.
Weeding and Soil Maintenance: Tilling machines help in weed control by uprooting unwanted vegetation and maintaining soil health.
Gardening and Landscaping: Garden Beds Preparation: Electric tillers are handy in creating garden beds for flowers, vegetables, or herbs in home gardens.
Lawn Renovation: They assist in renovating lawns by loosening compacted soil, allowing better water penetration and promoting healthy grass growth.
Landscaping Projects: Tilling machines are useful in landscaping tasks like soil leveling, preparing ground for paving or installing irrigation systems.
Soil Management and Improvement: Soil Aeration: Tilling machines aerate soil, improving its structure and allowing better water and nutrient penetration.
Mixing Amendments: They facilitate the mixing of organic matter, compost, or fertilizers into the soil to enhance its fertility.
Mulching: Tilling machines help in incorporating mulch into the soil, improving moisture retention and weed control.

Specialized Applications: Urban Farming: They find use in urban farming initiatives, rooftop gardens, or community garden projects due to their compact size and ease of use.
Greenhouses: Electric tillers assist in soil preparation and maintenance in greenhouse setups for cultivating various crops.

Benefits of Electric Tilling Machines:
Eco-Friendly: They produce fewer emissions compared to gas-powered alternatives, making them suitable for both rural and urban environments.
Ease of Use: Electric machines often have simpler controls and are lighter, making them accessible to a broader range of users.
Low Maintenance: Generally require less maintenance than gas-powered tillers, reducing downtime and upkeep costs.
Quiet Operation: They operate with minimal noise, allowing for use in noise-sensitive areas.

Considerations:
Soil Type: Effectiveness might vary based on soil types; certain models are better suited for specific soil conditions.
Safety Measures: Proper operation and adherence to safety guidelines are crucial to prevent accidents during use.

7. Advantages

Environmental Benefits:
Zero Emissions: Electric tillers produce no exhaust emissions during operation, contributing to a cleaner and healthier environment.
Reduced Noise Pollution: They operate more quietly compared to gas-powered machines, making them suitable for urban and noise-sensitive areas.
Operational Advantages:
Ease of Use: Electric tillers are typically lighter, more maneuverable, and have simpler controls, making them accessible to a wider range of users, including beginners.
Lower Maintenance: They often have fewer moving parts and require less maintenance compared to gas-powered models, reducing downtime and maintenance costs.
Instant Start: Electric machines start instantly without the need for pulling cords or priming, providing immediate usability.
Economic Benefits:
Lower Operating Costs: Electricity is often more affordable than gasoline, resulting in lower operating costs over time.
Long-Term Savings: Reduced maintenance and fewer operational costs contribute to long-term savings for users.
Safety and Convenience:
Reduced Vibration: Electric tillers generally produce less vibration during operation, resulting in reduced operator fatigue.
No Fuel Handling: Eliminates the need for handling and storing flammable fuels, reducing associated safety risks.
Versatility and Adaptability:
Suitable for Various Soil Types: Electric tillers can be effective on different soil types, offering versatility in agricultural and landscaping applications.

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Compact Design: Many electric models are designed to be compact and easily maneuverable, suitable for smaller spaces and gardens.
Environmental Impact:
Eco-Friendly Choice: Using electricity as a power source reduces reliance on fossil fuels, aligning with efforts to reduce carbon footprint and promote sustainability.
Potential for Renewable Energy Use: Electric machines can be powered by renewable energy sources, further reducing their environmental impact.
Considerations:
Power Supply: Electric tillers require access to power sources, which might limit their use in remote or off-grid areas.
Battery Life: Models with battery-powered systems may have limited runtime, necessitating recharging during extended use.

8. Disadvantages

Power Dependency:
Limited Mobility: Electric tillers rely on a power source, requiring proximity to electrical outlets or extension cords, limiting their range and mobility compared to gas-powered models.
Off-Grid Limitation: In remote areas without access to electricity, using electric tillers might be challenging unless supplemented with generators or alternative power sources.
Battery-Operated Models:
Limited Runtime: Battery-powered electric tillers might have limited runtime per charge, requiring recharging breaks during extended use.
Charging Time: Charging batteries can take several hours, impacting continuous workflow if spare batteries are not available.
Performance Considerations:
Less Power: Electric models might have less power compared to gas-powered counterparts, impacting their performance in challenging or compacted soil conditions.
Tilling Depth: Some electric tillers might have limitations in achieving deep tilling depths compared to heavy-duty gas-powered models.
Adaptability:
Soil Type Sensitivity: Certain electric tillers might be less effective on particularly tough or rocky soils compared to gas-powered machines.
Size Limitation: Smaller electric tillers might not be suitable for large-scale agricultural applications or heavy-duty tasks.
Initial Cost:
Higher Initial Investment: High-quality electric tillers with advanced features can have a higher upfront cost compared to basic gas-powered models.
Cost of Replacement Batteries: If using a battery-powered model, replacing batteries can add to the long-term ownership costs.
Infrastructure Requirements:
Extension Cord Limitations: Corded electric tillers are restricted by the length of the power cord, which might limit their usability in larger areas or create inconvenience due to cord management.
Environmental Impact:
Energy Source Impact: While electric tillers produce zero emissions during use, the environmental impact might depend on the source of electricity (e.g., fossil fuel-powered grid vs. renewable energy).
User Considerations:
Learning Curve: Beginners might need some time to adjust to electric tiller controls and operation if they are new to this type of machinery.
Accessibility: Availability of power outlets or recharging stations might limit usage in certain settings or areas without easy access to electricity.

9. Conclusion

Environmental Friendliness: Electric tillers produce zero emissions during operation and operate with significantly reduced noise levels, contributing to a cleaner and quieter environment.

Ease of Use: They are generally lighter, more maneuverable, and easier to operate, making them accessible to a wider range of users.

Lower Maintenance: Electric models often require less maintenance compared to gas-powered alternatives, resulting in reduced downtime and upkeep costs.

Operational Efficiency: With instant start capabilities and lower operating costs, they provide a convenient and cost-effective solution for soil preparation and maintenance.

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