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Design and Development of Ecofriendly Tilling Machine for Sustainable Agricultural Practices

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Abstract

Agricultural mechanization is crucial for enhancing productivity and reducing production costs through timely operations. In India, where 86 percent of farmers are small and marginal, acquiring heavy machinery like tractors and their implements is often financially unfeasible. However, power tillers present a cost-effective and versatile alternative, well-suited to small-scale farms. Power tillers can handle a wide range of tasks, including plowing, dry-tillage, weeding, intercultural activities, pesticide application (spraying and dusting), crop harvesting (thinning), and post-harvest handling (bagging). They are easy to maintain, and operators can perform on-the-spot fixes without special training. Various external attachments can be used or constructed to tailor the power tiller to specific tasks. This research aims to provide a comprehensive picture of India's power tiller market by examining previous studies and assessing the current state and growth potential of power tillers. It also identifies obstacles to widespread adoption. The study concludes that power tillers can efficiently perform agricultural tasks, boosting productivity and reducing labor intensity due to their versatility.

This paper discusses the design of "Battery-Powered Tiller" embodies a transformative approach to tillage practices by leveraging rechargeable batteries. This initiative aims to revolutionize how farmers cultivate their land, promoting eco-friendly and efficient agricultural operations. Battery-powered tillers offer numerous advantages, including efficiency, labor savings, versatility, precision, time savings, and scalability, contributing significantly to the mechanization of agricultural practices. Suitable for both small-scale and large-scale farming operations, these tillers enhance soil management and crop yields through precise operations. They often come with various attachments and accessories, enabling them to perform a wide range of agricultural tasks. This versatility makes them ideal for diverse agricultural activities. Sowing, the practice of planting seeds in the soil to initiate crop or plant growth, is a fundamental step in agriculture and gardening, marking the beginning of the plant's life cycle. A multipurpose tiller with sowing capabilities is a versatile agricultural tool that combines the functions of both tilling or cultivating the soil and sowing seeds in a single operation.

Keywords: Power tiller, Electric motor, Multipurpose blade, battery management system

1. Introduction:

The introduction of the "Battery-Powered Tiller Machine" marks a significant advancement in agricultural machinery, blending traditional farming practices with modern electrical engineering innovations. Weighing 20 kg and capable of operating for 6 to 7 hours on a single charge, this tiller is powered by a 12V battery and driven by a robust 48V, 250-watt Brushless DC (BLDC) motor. It features a sophisticated BLDC controller with a power rating of 300 watts, ensuring efficiency, durability, and eco-friendliness.

Key components of the **Electrical Power** Tiller Machine include:

- Chain and sprocket mechanisms
- Sturdy wheels for maneuverability

- Adjustable wheel angles for precision control
- Specialized tiller blades designed to create optimal soil conditions for plant growth

These components, supported by robust frames, work in harmony to deliver superior tilling performance while minimizing environmental impact. This project leverages cutting-edge electrical engineering technologies to offer farmers a sustainable and efficient solution for soil preparation and cultivation.

The tiller's motor, powered by the battery, provides enough force to draw the forks through the soil. The three cultivator forks enable precise and easy tilling, ideal for farming. The machine's lightweight and portable design allow for easy control and maneuverability during use. Additionally, it can be easily transported in vehicles or by hand, making it a convenient tool for farm and garden tilling. The electric power tiller offers a smart, fuel-free mechanism, enhancing productivity and yield for farmers around the world.

2. Problem statement

Conventional gasoline-powered tiller machines contribute to environmental pollution and greenhouse gas emissions, exacerbating climate change and environmental degradation. Farmers face increasing pressure to adopt sustainable practices and reduce their carbon footprint, making the transition to cleaner and more eco-friendly alternatives essential. Small-scale and resource-constrained farmers often lack access to modern agricultural technologies and machinery, hindering their ability to improve productivity and livelihoods. There is a need for affordable and accessible solutions to empower farmers to adopt sustainable farming practices and enhance crop production. Conventional tiller machines often lack precision and control, resulting in inefficient use of resources such as water and fertilizer. Improper soil preparation can lead to suboptimal plant growth and reduced crop yields, posing economic challenges for farmers and contributing to food insecurity. Traditional tilling methods require significant manual labor, leading to inefficiencies and increased labor costs for farmers. With a growing shortage of skilled agricultural workers, there is a pressing need for mechanized solutions that can streamline the tilling process and reduce dependency on manual labor.

2.1 Features of proposed tiller

The present work is focused on developing battery-charged electric power tiller machine, examining the techniques employed in traditional agricultural farming. The equipment features a wheel with welded angles to maximize soil grip, ensuring a firm hold on the soil and enabling the cultivator prongs to drag effectively during the tilling operation. The pulling wheel is powered by an electric motor using a sprocket chain system. By adopting a motorized tilling system, this machine minimizes human effort at a very low cost. Its unique portable design reduces the time and cost of tilling, thereby enhancing agricultural output and efficiency. This research involved the design development and fabrication of a mini cultivator and tiller. Traditional farming methods used by farmers are time-consuming, labor-intensive, and expensive. To address these challenges, new technologies have been introduced. In India, machines are commonly employed for farming purposes, leading to higher efficiency. This model aims to solve the challenges associated with traditional farming methods. The developed operating machinery used to till one and a half hectares. With this new technology, the plough can move forward, and the base wheel rotates with blades that provide traction. The portable power tiller is designed for small-scale weeding operations. After preliminary studies, it was found that the power tiller could be adapted for weeding. As a result, the study sought to improve its performance by altering essential components, such as weeding blades and depth blades. This working model of a power tiller addresses the outlined issues by reducing manpower requirements and minimizing risks. The machine is designed to reduce costs and improve soil properties, providing a sustainable and efficient solution for modern agricultural practices.

3. Components of battery powered tiller

(a) Frame

Fig.1: Main Body Frame

The frame of the electric power tiller is built using durable steel as shown in Fig.1. The frame must be robust enough to support the weight of all components and endure the stresses of tilling.

(b) Electric motor

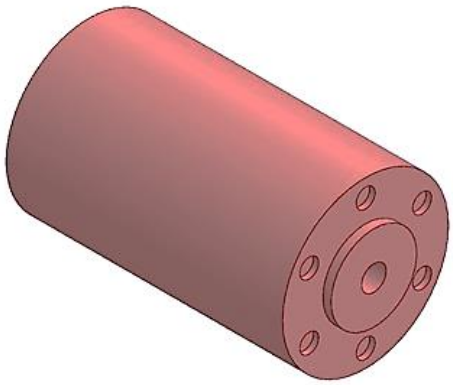

Fig.2: Electric motor

Selection of electric motor that meets the power requirements of the tiller. Securely install the motor onto the frame, ensuring it is properly aligned and mounted. Position the motor to allow for efficient power transmission to the tiller blades.

(c) Multi purpose Blade

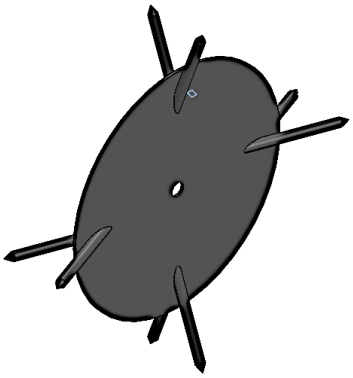

Fig.3: Multi purpose blade

Multi purpose tiller blades shown in Fig.3 are attached to the shaft of the electric motor using the appropriate mounting hardware. Ensure the blades are correctly aligned and securely fastened to the shaft to prevent any wobbling or dislodging during operation.

(d) Assembled model

Fig.4: Assembled model

Handlebars are installed onto the frame, ensuring they provide ergonomic grips and controls for the operator. Position the handlebars at a comfortable height and angle for ease of use, and include controls for starting, stopping, and adjusting the tiller's speed. Safety features such as emergency stop switches, blade guards, and operator presence sensors are installed to prevent accidents and ensure the operator's safety during use. Thorough test on the electric power tiller to confirm that all components are functioning correctly. Calibrate the controller and motor settings to achieve optimal performance and efficiency. Conduct test runs in various soil conditions to assess the tiller's effectiveness. The final assembly and working model shown in Fig.4.

Power and torque requirements

Battery voltage = 12V

Battery current = 7.2 amp

Motor power = 1540.5 watts (or 1.54 kW)

Motor Speed = 300 rpm (Free flow RPM= 1500)

Efficiency (η) = $\frac{0.745 \text{ X } H_p \text{ X load}}{Pi}$

$= \frac{0.745 \text{ X } 2.0658 \text{ X } 90}{1.54} = 89.91\%$

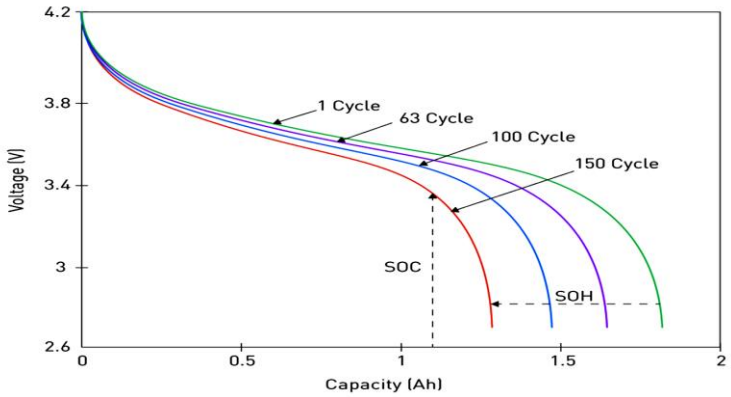

Fig.5: Battery management system

The Battery Management System (BMS) curve depicted in Fig.5 is a vital component of our battery-powered tiller, ensuring the battery pack operates optimally, safely, and with extended longevity. The BMS is responsible for several key functions, including monitoring the state of charge (SOC) and state of health (SOH) of the battery cells, balancing the charge across individual cells, and protecting the battery from exceeding its safe operating limits. By continuously tracking each cell's voltage, current, and temperature, the BMS prevents issues such as overcharging, deep discharging, and overheating, which could otherwise lead to battery damage or failure.

Proposed tiller's BMS also features fault detection and diagnostic capabilities, providing real-time data and alerts about the battery's condition. This allows for prompt issue resolution, reducing downtime and maintenance costs. Additionally, the BMS enhances energy efficiency by optimizing charge and discharge cycles, thus extending the battery pack's overall lifespan. Integrating a sophisticated BMS is essential for maximizing the performance and reliability of the battery-powered tiller, ensuring effective operation across various agricultural conditions while adhering to safety and sustainability standards. This advanced management system is crucial for supporting the transition to electric-powered agricultural equipment and aligns with our project's aim of promoting sustainable and efficient farming practices.

Conclusion

The significant reduction in carbon emissions and noise pollution highlights the environmental advantages of this initiative, while the cost analysis demonstrates long-term economic benefits for farmers through reduced operational and maintenance expenses. Feedback from field trials has been predominantly positive, reflecting strong support from the agricultural community and offering valuable insights for future improvements. The tiller's design, featuring advanced battery technology and ergonomic enhancements, has shown potential in enhancing user experience and operational efficiency.

Moreover, the project's commitment to sustainable agricultural practices underscores the importance of innovation in promoting soil health and minimizing the ecological impact of farming. The successful outcomes of this project not only validate the concept of battery-powered tilling but also pave the way for further research, development, and commercialization. This initiative represents a significant advancement in sustainable agriculture, providing a practical solution that balances environmental stewardship with economic feasibility. Moving forward, the continued refinement and broader adoption of such technologies will be essential for advancing sustainable farming practices on a global scale.

The development of the Battery Powered Tiller Machine marks a major leap forward in agricultural machinery, merging traditional farming techniques with cutting-edge electrical engineering innovations. Powered by a high-performance 48V Brushless DC (BLDC) motor and an advanced controller, this machine provides farmers with a sustainable and efficient solution for soil preparation and cultivation. Its precise tilling capabilities, extended operational hours, and eco-friendly design make the Electrical Power Tiller Machine a transformative tool in

agriculture. It empowers farmers to boost productivity, increase crop yields, and improve livelihoods while reducing environmental impact. As the agricultural sector progresses, adopting innovative technologies like the Electrical Power Tiller Machine will be crucial for advancing agricultural sustainability and ensuring food security for future generations.

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