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"Self-Propelled Multi Tiller for Green Farming"

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Here, the design and performance analysis of a self-driven multi-tiller for small-scale and eco-friendly agriculture is described. The proposed system is designed to run on an electric power source with a voltage of 12V, utilizing multiple DC motors for both propulsion and tilling action. The design calculations involved estimating the total weight of the system, wheel loads, force of resistance due to soil cutting, torque for tilling, as well as the total power requirements for the system under loamy soils. From these calculations, appropriate motor selections, along with gear reduction systems, were made for shallow tilling. A factor of safety has also been taken into account for dynamic loads as experienced in practical agricultural applications. Results show the proposed design is mechanically robust, economical, and power-efficient, thus ideal for sustainable eco-friendly agricultural applications.

1. INTRODUCTION

In agriculture, basic soil preparation activities like tilling and mulching are largely done using labor and fuel-driven machines. While conventional tillers are appropriate for big farms due to their efficiency and power, they are quite expensive and unfit for small farmers. Also, their reliance on fossil fuels increases their operational cost and causes environmental degradation due to pollution. Thus, there is a big technological gap for small and energy-saving agricultural machines that contribute to sustainable agriculture practices.

Modern advances in the development of electric drives and small mechanized systems have Created new possibilities for the development of agricultural machines operating on low voltage and having lower negative impacts on the environment. Electric tillers have numerous advantages, namely low noise level, no exhaust emissions, ease of maintenance, and energy- saving performance. Nevertheless, present models have some drawbacks, namely insufficiency in torque at the tillage blades, uneven load distribution, and low adaptability in various soil conditions.

In this project, a self-powered multi-tiller using a 12V electric system has been designed and analyzed for eco-friendly farming. In the proposed scheme, DC motors have been utilized for propelling as well as tillage purposes. Additionally, a compact mechanical design apt for shallow tillage of soils has been utilized. Primary calculations have been done to determine loading of the wheels, cutting force of soils, torque needed during tillage, and total electric power required.

Tillers are considered important for seedbed preparation as they can aerate the soil, break soil clods, and suppress weeds. Many tillers, both electric or mechanical, are either lacking torque, self-propelled, or designed for a particular use scenario. The instability of the chassis and unbalanced weight can cause poor soil cutting. An efficient mechanical design that uses analytical calculations is, therefore, a priority.

The main task of this research is proving the effectiveness and feasibility of designing and developing a smaller, more efficient tiller powered by an electric motor and equipped with the abilities to perform shallow tillage. The system will not only help in reducing the heavy dependence on human resources but will prove eco-friendly as well.

2. RELATED WORK

Researchers in the past few years have worked on the introduction of electric and autonomous technologies into agricultural tillage equipment. [1]The design and development of a self-propelled electric tiller using GPS and sensor-based control for autonomous navigation is presented. Results indicated that their GPS-based autonomous electric tiller improved operational efficiency and reduced dependence on human intervention compared to conventional tillers, thus demonstrating the practicality of using electric propulsion for small-scale farming. Work reported in [3] focuses on a robotic tiller developed for precision agriculture. The machine learning techniques allowed one to automatically adjust tilling depth and operating speed using the soil conditions. The experimental results show reduced soil compaction and therefore better crop yield, hence the benefits of intelligent control applied to modern tillage operations. In, the authors investigate various energy-efficient control strategies for self-propelled agricultural machines. Through optimization of the motor control and power management strategy, reduced energy consumption was achieved without tilling performance compromise. This study highlights proper selection of motors and efficient drivetrain design as important issues in electric tillers. A wider view of automation in agriculture is given in [4]. The role of the autonomous and robotic systems towards precision farming, labour reduction, and sustainable agricultural practice is discussed by the authors. In this study, self-propelled agricultural platforms have been identified as one of the main solutions for solving labour shortages and challenges of productivity in modern farming. Paper [6]. Discuss the introduction of an electric tiller designed for small and marginal farmers. The study enumerates operating cost advantages, nil exhaust emissions, and ease of operations that further reinforce the appropriateness of a low-voltage electric tiller for eco-friendly farming applications. Finally, the work in [5] performs the structural optimization of the chassis of agricultural machinery using finite element analysis. The authors demonstrate that with an optimized frame design, it is possible to have a big reduction in the overall weight without compromising the structural strength of the frame, which is critical in improving energy efficiency and performance in self-propelled agricultural machines.

3. PROPOSED METHODOLOGY

The evolution of the self-propelled multi-tiller is based on a disciplined engineering approach which involves the analysis of requirements, mechanical engineering, analytical assessment, prototyping, and experiments. Basically, the engineering approach is aimed at designing a compact, electrically operated farm machine that can undertake shallow tillage through minimal human effort and in an environmentally friendly manner.

1. Requirement Analysis and Concept Development

The design procedure commenced with identifying the requirements of farmers while formulating the needs of small and marginal farmers. Parameters like tilling depth, tilling width, forward speed of the machine, carrying capacity of the machine, type of soil, and availability of power supply were identified carefully. A 12 V electric system was chosen to ensure the system was safe for use, easy to use, maintainable, and economical. A conceptual system was identified keeping a mild steel chassis, four wheels connected for power transmission, a rotary tilling system, and a central battery placement.

2. Designation for Chassis and Drive System

"The chassis was designed as a simple rectangular frame made from mild steel sections to give the necessary strength with as light a structure as possible. This framework will support all major items of equipment such as the battery pack, propulsion motors, tiller motor, and lifting mechanism."

Each wheel is driven by a separate 12V DC motor and provides a four-wheel drive system. The design increases traction on soft ground and helps in navigating irregular terrain on farms.

3. Load Distribution and Stability Factors

The total weight of the system was approximated by adding the weights of the chassis, motors, battery, tillage system, and other secondary parts. A margin of safety was added to provide for dynamic loads and field variability. The battery was located near the geometric center of the chassis to provide a low and centralized center of gravity. This increases stability and prevents tipping.

4. Tiller Transmission Mechanism Design

The rotary tilling unit basically consists of a set of steel tines mounted on a horizontal shaft driven by a separate 12 V DC motor through a chain and sprocket transmission system. The required tilling torque was estimated based on calculation considering soil cutting resistance, tine geometry, and working depth in loamy soil conditions. Subsequently, a gear reduction ratio was selected that could give the desired increase in torque input to the tiller shaft with a matching rotational speed suitable for cutting soil effectively.

5. Fabrication and Development of Prototype

After the design and analytical calculations, the prototype was fabricated using conventional manufacturing processes of cutting, welding, drilling, and mechanical fastening. Since many standard components were used, such as bearings, chains, and sprockets, there was a reduction in both manufacturing costs and maintenance effort. Additionally, the lifting mechanism was provided for easy engagement and disengagement during operation and transport.

4. TECHNICAL SPECIFICATIONS AND DESIGN REQUIREMENTS

System Requirements

Parameter	Specification
Power supply	12V, 20Ah lead-acid battery
Energy Storage Capacity	2400Wh(0.24kWh)
Drive Motor	Seven 12 V DC Motor
Operating Speed range	0.25-0.5m/s
Effective Tilling depth	50-100mm
Total Machine Weight	Approximately 120kg
Maximum payload	75Kg

Material Selection

Component	Material used	Selection justification
Chassis Frame	Steel tubing	Provide adequate strength with low fabrication cost
Wheel shaft	Carbon Steel	Offers sufficient load capacity and good machinability
Tilling tines	Spring Steel	Ensure high wear resistance and effective soil cutting
Fasteners	Steel bolts	Suitable for resisting vibration and dynamic loads
Wheel rims	Mild steel	Compatible with standard agricultural tires

5. MECHANICAL DESIGN AND CALCULATIONS

2D sketch

The 2D sketch represents the overall mechanical layout and structural arrangement of a self-propelled multi tiller. It gives a clear view of the relative positioning of major subsystems comprising the chassis frame, wheel assembly, tilling unit, power source, and transmission components.

The primary structure that bears the load inside the machine is the steel rectangular frame. The battery pack, drive motors, and tilling mechanism are mounted on it while it distributes the load uniformly to all the wheels. The frame is fabricated from mild steel tubing, which provides strength and rigidity to the frame; at the same time, it keeps the structure simple,

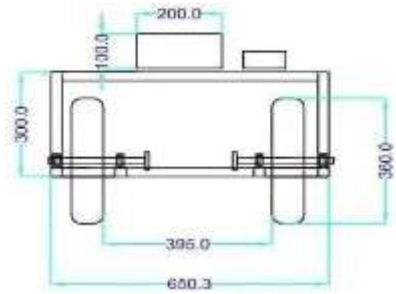

Figure 1: 2D sketch with Dimension

The drawing is a four-wheel configuration where each wheel is powered independently with a 12 V DC motor. Four-wheel drive increases traction, load sharing, and maneuverability over rough agricultural terrain. The wheel shafts are mounted to bearings to reduce friction and provide for smooth, reliable rotation during operation.

The rotary tilling unit is mounted at the rear or lower central portion of the chassis. As shown in the sketch, the tiller consists of steel tines fixed to a horizontal shaft driven with the help of a dedicated DC motor through a chain and sprocket transmission to provide the required torque multiplication for proper soil cutting at a working depth of approximately 50–100 mm.

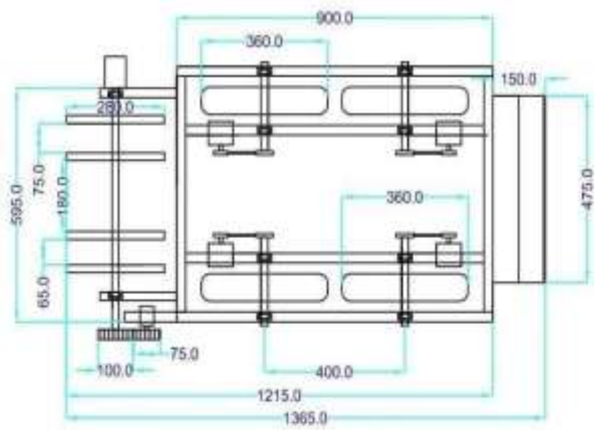

Figure 2: 2D sketch with Dimension

The battery is located near the center of the chassis for a low and central center of gravity. This configuration provides good all- around stability and reduces the possibility of tip-over during tilling or when driving uphill. The drawing also illustrates the use of a lifting mechanism for the tiller assembly, driven by a dedicated motor. Such enables controlled engagement and disengagement of the tilling blades, easing transportation and allowing adjustment of the working depth.

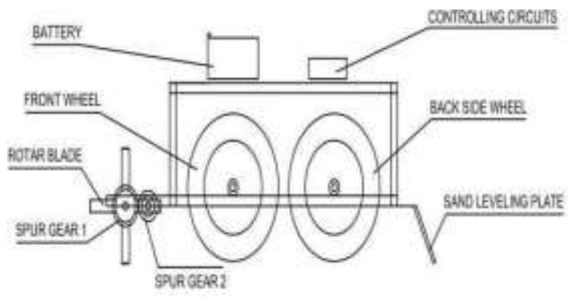

Figure 3: 2D skitch

In general, the 2D sketch makes it easier to see the mechanical architecture, component integration, and functional layout of the self-propelled multi tiller. The drawing is useful for reference in fabrication and analysis, as well as future improvements in design.

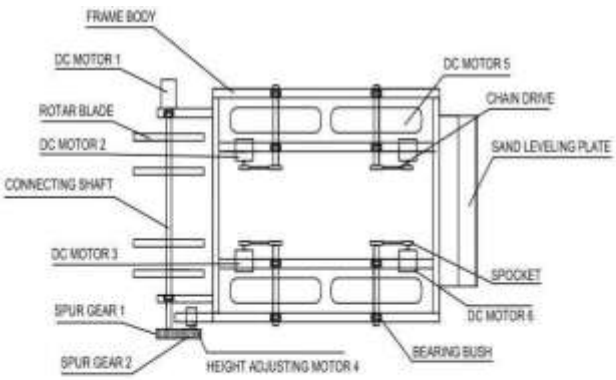

Figure 4: 2D sketch

Calculations:

total mass
m = 88 kg

Design mass (with safety factor) md = 1.35 * 88 = 120 kg

Total weight
W = m * g

W = 88 * 9.81 = 863 N

Static wheel load (4 wheels) Wwheel = W / 4

Wwheel = 863 / 4 = 215.8 N

Inertial force during acceleration
Fi = m * a

Fi = 88 * 0.3 = 26.4 N

Soil cutting force

Fc = (sigma * A) + (Cd * tau * A)

Fc = (1.5e6 * 8e-4) + (1.0 * 0.4e6 * 0.01)

Fc = 5200 N

Force per tine (2 tines)
Ft = 5200 / 2 = 2600 N

Required tiller torque T = Ft * r

T = 2600 * 0.15 = 390 N-m

Effective torque with 5:1 reduction Teff = 390 / 5 = 36 N-m

Mechanical power

P = (2 * 3.14 * N * T) / 60

P = (2 * 3.14 * 150 * 36) / 60

P =565 W

6. RESULTS

A prototype of the self-propelled multi-tiller was developed using the finalized mechanical design and calculations. The outdoor test of the machine was conducted using the prepared soil to assess the propulsion system performance, tillage abilities, power requirements, and overall system stability during operation. During the test process, the system showed stability and consistency in operation as well as during self-propelled movement and tillage. During the field testing, the actual forward speed that the machine was able to achieve varied between 0.25 and 0.4 m/s, depending upon the resistance and throttle input. It was found to closely match the design intention and enable the machine to move without excessive wheel slip. The four-wheel drive system provided the necessary traction, and the machine remained well-stabilized during linear and turning movements. The rotary tilling component ensured a working depth of between 50 mm and 100 mm, which was within the desired shallow tilling depth. The geared DC motor that powers the tiller ensured a consistent speed of 30–35 revolutions per minute. Moreover, there was neither stalling nor overheating of the motor during the testing process, which indicated that the torque and power margins were sufficient for the testing conditions. The chain and sprocket transmission ensured smooth functioning with little vibrations.

Figure 5: Result

that the driving motors utilized moderate powers during the movement process, whereas powering the tiller motor dominated the power utilization during the cutting process of the soil. The total power usage in the tilling process fell within the expected values, including an approximate working time of between 30-40 minutes on a single battery charge.

The lifting mechanism functioned properly for smooth engagement and disengagement of the tiller blades and was able to reduce sudden variations in loads being supported by the drivetrain. Inspections made after testing revealed that there were no visible deformations or loosening of joints in the structure, which proved the mechanical sufficiency of the frame and joints supporting the structure. In conclusion, the experimental results verify the analytical design approach and prove the practicability of a low-voltage self-propelled multi tiller for the purpose of green farming. The low-voltage self-propelled multi tiller is efficient in terms of movement ability, soil cutting, energy conservation, and stability and can be a good alternative in agriculture, especially the sustainable kind, on a small scale.

7. CONCLUSION

This paper presents the design, fabrication, and testing of a self-propelled multi-tiller powered by a 12 V electric system. The test results demonstrate that a low-voltage, compact machine utilizing multiple DC motors can efficiently carry out shallow tillage operations and hence can be suitable for small-scale and environmentally friendly farming applications. All the mechanical design aspects, backed by some basic analytical calculations, ensured proper wheel load distribution, adequate tilling torque, and stable performance during field operation. Field testing demonstrated that the tiller achieved the desirable operating speed and soil working depth without showing any structural or mechanical problems. The geared drive system delivered a consistent torque to the tilling unit, while the electric propulsion system was able to provide smooth and controlled movements with low noise levels and zero exhaust emissions. The closeness of the calculated design values and experimental performance indicates the feasibility of the suggested system. This paper proposes an efficient, low-cost, and eco-friendly solution for tillage operations that can assist in lessening both manual effort and cost associated with smaller scale farming. This design can also be considered an excellent foundation for future development, including approaches concerning the implementation of higher-capacity batteries, multiple farming attachments, and partial automation.

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