Design and Fabrication of Solar Power Tiller

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ABSTRACT - The present research focuses on the development of a solar-powered rotary tiller designed for primary and secondary soil cultivation. It explores the disparities between portable weeders and power tillers available in the Indian market. Various approaches to weed removal in crops are also examined. This study demonstrates that the majority of Indian farmers, particularly those with small-scale operations, can only afford portable weeders. Soil tillers and weeders are among the many agricultural mechanizations aimed at enhancing soil cultivation and weed management, particularly given that most farmers own small parcels of land. These tools notably reduce manual labor and are largely self-guided. The project operates on solar panels, utilizing their energy to power the machine, which operates the cutter or tiller. This innovation significantly saves time and expenses in field tasks, proving highly efficient for both tilling and weeding duties. Additionally, proposing the creation of high-capacity, energy-saving, adaptable machines, and integrated equipment aims to enhance labor efficiency, lower operational costs, improve punctuality, and render them suitable for customized leasing.

***Key Words*:** solar, power, tiller, weeder, farming, soil

1. INTRODUCTION

1.1 TILLER MACHINE IN AGRICULTURE

India, being a significant player in agriculture, unquestionably requires modern technologies for its farming practices. Power tillers, which are engine-powered machines with low power, are used for preparing beds. They are compact, convenient, and of medium duty. Currently, power tillers ranging from 8 hp to 10 hp and weighing up to 350 kg are extensively manufactured throughout the country. The power tiller presented in this project specializes in weeding operations, particularly suitable for the black soil found in sugarcane cultivation. This project focuses on the design and development of various components such as Chain and Sprockets, Shafts, Belt Drives, Bearings, Transmission Case, and Chassis, aiming to convert the engine speed to the tilling speed of the Power Tiller. The power tiller described in this report is designed for weeding operations in sugarcane farms with a minimum inter-row distance of 1.2 meters. This machine is user-friendly, cost-effective, portable, and has a straightforward design, making it easy to maintain with readily available spare parts.

Agriculture serves as the backbone of India's economy. As a developing nation, agriculture and industries reliant on agricultural goods play a vital role in the Indian economy. Agriculture and related industries support the majority of India's populace. Among the various mechanization tools used in farming, soil tillers and weed eaters are crucial. Unlike tractors, soil tillers and weeders represent non-traditional methods of labor displacement. They are particularly beneficial for enhancing soil tillage and weed management, especially considering the limited landholdings of most farmers who cannot afford more expensive tractors. Hence, soil tillers and weeders serve as valuable equipment for the internal cleaning of crops and soil excavation in crops with narrow spacing, such as groundnuts, sugarcane, soybeans, paddy cultivation, and other crops in general, catering specifically to the needs of smaller farmers.

Energy is an essential requirement for human survival on Earth. We rely on various forms of energy to meet our needs, including energy from fossil fuels, which are extensively used for electricity generation, transportation, and other purposes. However, fossil fuels pose significant environmental hazards and are not sustainable. Hence, there is a need to explore alternative energy sources to address these concerns associated with fossil fuels. To address this issue, we have developed a solar-powered electric tiller. This vehicle features two-wheel drive and can be utilized for short-distance travel and shuttle services.

In the modern era, all industries, including agriculture, are experiencing rapid expansion. Farmers need to adopt innovative practices that enhance overall crop productivity without altering soil texture to meet future food demands. The primary objective of such innovations is to reduce labor requirements and working hours, which are increasingly difficult to fulfill in today's market. The lack of mechanization or automation remains a significant obstacle to increasing agricultural productivity. Soil cultivation, although time-consuming, is immensely beneficial. It improves soil structure by reducing compaction and enhancing aeration, thereby increasing oxygen availability to plant roots and improving water drainage. Additionally, it facilitates deeper root penetration and enhances plant growth.

An environmentally conscious graduate student specializing in agricultural business, design, and manufacturing proposed the electric tiller. Despite the use of labor-saving machines like tractors and tillers to replace traditional agricultural tasks, human labor remains necessary, especially in narrow spaces where machinery cannot reach.

Figure -1.1: Tractor mount Rotator Tiller

In recent times, Indian farmers are dissatisfied with spending money on seedbed preparation due to the escalating fuel prices. To address this issue, we have developed an electric power tiller powered by an electric motor and rechargeable battery, offering an eco-friendly solution. This power tiller is primarily utilized in the agricultural sector for seedbed preparation on the upper layer of soil. It not only boasts higher soil mixing capacity compared to other machines but also demonstrates excellent weed-cutting capabilities. The utilization of a power tiller enhances soil water, air, thermal, and nutrient content.

We have incorporated an adjustable wheel in the power tiller to accommodate various working depths for soil bed preparation. Additionally, various types of blades, such as L, J, and C shapes, are available in the market. However, conventional power tillers operate on IC engines, necessitating the use of petrol or diesel, which poses environmental pollution and health hazards. To address this issue, we have developed an electric power tiller, offering an economical and pollution-free alternative.

The electric power tiller is equipped with useful accessories, including an adjustable handle to customize the operator's height and an adjustable wheel for blade tilling depth and easy transportation. Moreover, we have integrated a solar panel into the design to recharge the battery when it gets discharged during operation, thereby extending the battery life. Manual labor has long been a fundamental aspect of rural agricultural systems in India. However, due to electricity shortages and the immediate need for farm equipment, solar energy proves to be an effective alternative.

Neglecting or improperly managing weeds can significantly reduce crop yields, sometimes resulting in complete crop failure. Inter-cultivation, the process of removing unwanted plants to protect the main crop, is crucial for soil nutrition and moisture retention, ultimately leading to higher crop yields and increased profits for farmers.

Rotavator Functions include:

- Cultivating the soil between rows.
- Eliminating unwanted plants from the field.
- Enhancing soil aeration to promote higher yields.
- Retaining moisture levels through soil mulching.
- Enabling seed sowing with appropriate attachments.
- Preventing surface water evaporation.
- Facilitating swift rainwater infiltration into the soil.

Designing farm machinery is a complex task. The advent of advanced CAE tools has revolutionized the process, consuming less time than traditional design methods.

1.2 POWER TILLER MACHINE

The Power Tiller, known as a walking tractor, is extensively utilized for rotary or revolving cultivation in moist puddle soil. It stands out as the optimal choice for small and marginal farmers, effectively replacing animal power while also stimulating the demand for human labor. Equipped with a 1.5 HP engine, this machine is adept at propelling various agricultural implements forward or backward. Its versatility extends to performing tasks such as rotary, peddling, leveling, towing trailers, plowing discs, and threshing. A key function of the Power Tiller lies in its ability to prepare precisely seeded beds for crops and warm the soil prior to planting by burying remnants into it. Additionally, it plays a crucial role in weed control, facilitating the proper growth of crops.

1.3 ROLE OF POWER TILLER IN AGRICULTURE

A Power Tiller is a two-wheeled agricultural device equipped with rotary tillers, offering smooth resistance for various farm tasks. Its versatility and benefits are manifold. This equipment aid in soil preparation, seed sowing, planting, application of fertilizers, herbicides, and watering. Moreover, it facilitates tasks like water pumping, harvesting, threshing, and crop transportation. Particularly beneficial for small land areas, Power Tillers are invaluable in hilly regions of India where terrace farming prevails. Their usefulness extends even to uphill terrains.

Primarily employed for land cultivation, a Power Tiller efficiently engages in soil reversal and cutting simultaneously. Its maintenance is cost-effective and occupies minimal space, making it a practical choice.

1.4 TYPES OF AGRICULTURAL TILLER

Power Tillers are categorized into three groups based on their functionality:

1. **Mini Tillers -** ideal for gardeners with limited physical strength.

2. **Mid-Sized Front-line Tillers -** suitable for home gardens and moderate tilling tasks, offering convenience.

3. **Large-Sized Rear-time Tillers -** beneficial for extensive areas requiring tilling.

Figure -1.2: Power Tiller

These machines have emerged as a superior option for farmers. Notably, Power Tillers are accessible to both small and marginal farmers, catering to everyone's needs. In essence, they fulfill essential agricultural requirements, making farming feasible by reducing reliance on tractors and rotavators. They have become indispensable in agriculture, offering ease of use as they simply require balancing and operate automatically.

Power Tillers enable the harvesting of various crops and contribute to soil improvement by enhancing aeration, weed elimination, moisture retention, and activation of microorganisms, thereby enriching soil nutrients.

In terms of benefits, investing in Power Tillers proves advantageous, aiding the government by generating revenue due to reduced subsidies. Efforts should be directed towards granting this user-friendly equipment its rightful recognition and status in the agricultural domain. Undoubtedly, Power

Tillers have significantly eased and streamlined the lives of farmers.

1.5 POWER TILLER COMPANIES IN INDIA

Farmers predominantly use tiller tractors, which are manufactured primarily by farmers themselves. Below, we present the top power tiller available in India.

- VST Shakti Power Tillers,
- Bull Agro Power Tillers,
- Kubota Power Tillers,
- KMW Kirloskar Power Tillers,
- Kranti Power Tillers,
- KAMCO Limited Power Tillers,
- Southern Agro Engines Power Tillers.

1.6 POWER TILLER USES

Would you like to understand the various applications of power tillers?

We aim to provide clarity on tiller agriculture to enhance farm productivity. The uses of power tillers are outlined as follows:

Power tillers are employed for cultivation, sowing, weeding, and tillage tasks. They can be utilized with attachments that augment their functionality, such as sewing machines, spray machines, routers, and plows. Additionally, power tillers find application in diverse agricultural activities including sugarcane farming, rice cultivation, wheat farming, and paddy cultivation.

1.7 OBJECTIVE OF THE PROJECT

1. To reduce the use of non-renewable energy source and to utilize more renewable energy source.

2. This may reduce the investment on the fuel, reduce fuel cost.

3. By using solar energy or renewable energy source this also reduce the maintenance cost.

4. These makes agriculture or irrigation more effective and easier.

2. LITERATURE REVIEW

Ludwig Kronthaler [1], affiliated with EURAC Research at the Institute for Renewable Energy in Bolzano, Italy, introduces a methodology in this paper to assess the economic viability and environmental impact of Vehicle integrated Photovoltaic (ViPV) Systems using various metrics.

Selver Senturk [2], from the Turkish Agricultural Monitoring & Information Center at Istanbul Technical University, emphasizes the importance of employing efficient methods for structuring national irrigation policies and determining the precise yield production shares from both irrigated and unirrigated farmland. Their study investigates mapping capabilities using parcel-based Normalized Difference Vegetation Index (NDVI) and Normalized Difference Moisture Index (NDMI) techniques applied to entire satellite image frames.

Prof. Patil Digvijay Pandurang [3] discusses the “Design and Development of Mechanical Power Weeder” in their research. They highlight the detrimental effects of unwanted plant growth on overall crop health, especially in regions like India where farming is a primary livelihood. The paper addresses the design stages of the machine, emphasizing its cost-effectiveness for farmers.

Prof. Shabbir. J et al [4] present research on the “Design and Fabrication of a Mini Cultivator and Tiller”, underscoring its user-friendly nature for Indian farmers. They focus on enhancing traction and torque for efficient tilling, while also making the machine versatile for various agricultural tasks like plowing and wrapping.

Prof Aravind Raj et al [5] delve into the “Design and Fabrication of Rotary Tiller Blade”, aiming to maximize field efficiency while minimizing material consumption. Their study proposes theoretical methods for designing rotary tillers, with considerations for optimal working width and rotor diameter to enhance performance.

Prof Abhijit garje et al [6] explore the “Design, Development, and Operation of a 3.5HP Power Tiller”, emphasizing the use of chain and sprocket for power transmission to reduce costs. They highlight the simplicity of construction and maintenance of the machine, designed with optimal material considerations and capable of covering 2.5 acres per day with a petrol requirement of 10 liters.

Prof Wagmode R.S. et al [7] introduce the concept of a “Solar Power tiller”, aiming to reduce pollution and fuel dependency by utilizing solar energy. Despite the initial high investment, the project offers an eco-friendly alternative to traditional fuel-powered tillers.

3. METHODOLOGY

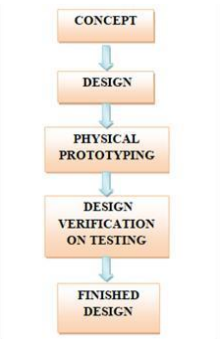

Figure -3.1: Methodology

1. As mentioned there is a use of solar energy as a source of energy to run the tiller, so to absorb the solar energy use of solar panel which is the series and parallel combination of solar cell.

2. After generating electrical energy store that, here use DC storage battery the generating power is DC power and then Buck boost converter is used to convert DC to DC of high voltage range.

3. Then achieving the required range of voltage, this because to run the machine at its rated value of voltage.

4. SOLAR PANEL

A solar panel comprises a series of solar photovoltaic modules that are electrically connected and mounted on a support structure. A photovoltaic module is an interconnected assembly of solar cells. This panel can serve as a constituent of a larger photovoltaic system for generating and supplying electricity in various commercial and residential applications.

Figure -4.1: Solar Panel

Each module is assessed based on its DC output power under standard test conditions (STC), typically ranging from 100 to 320 watts. The efficiency of a module determines its size for a given output; for example, an 8% efficient 230-watt module will occupy twice the area of a 16% efficient 230-watt module.

A single solar module has a limited power output, so most installations incorporate multiple modules. A typical photovoltaic system includes a panel or an array of solar modules, an inverter, and sometimes a battery and/or solar tracker, along with interconnection wiring.

4.1 WORKING AND CONSTRUCTION

Solar modules utilize photons of light energy from the sun to produce electricity through the photovoltaic effect. The majority of these modules employ crystalline silicon cells or thin film cells based on cadmium telluride or silicon. The load-bearing component of a module can be either the top or back layer. It's essential to shield cells from mechanical damage and moisture. While most solar modules are rigid, there are semi-flexible options available, typically using thin-film cells.

These initial solar modules were initially deployed in space back in 1958. Electrical connections are established either in series to achieve a desired output voltage or in parallel to ensure a desired current capability. The conducting wire used to carry current off the modules may consist of silver, copper, or other nonmagnetic conductive transition metals.

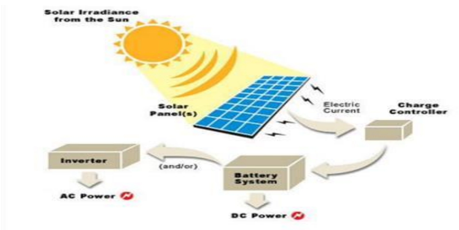

Figure -4.2: Solar Panel Working

Cells must be electrically interconnected with each other and with the broader system. Commonly used terrestrial photovoltaic modules employ MC3 (older) or MC4 connectors to enable straightforward weatherproof connections to the system. Bypass diodes may be integrated or employed externally to maximize output from module sections that are still receiving sunlight even when other sections are shaded. Some recent solar module designs incorporate concentrators, focusing light onto an array of smaller cells using lenses or mirrors. This approach allows for the utilization of cells with a high cost per unit area, such as gallium arsenide, in a cost-effective manner.

4.2 SOLAR CELL

A solar cell, constructed from a monocrystalline silicon wafer, features a contact grid comprising bus bars (larger strips) and fingers (smaller ones). These solar cells are employed in devices like portable monocrystalline solar chargers. Referred to as photovoltaic cells, solar cells are electrical devices that directly convert light energy into electricity through the photovoltaic effect.

Belonging to the category of photoelectric cells, solar cells exhibit alterations in electrical characteristics (e.g., current, voltage, or resistance) when exposed to light. They have the capability to produce and sustain an electric current in the presence of light without the need for external voltage, although they do require an external load for power consumption.

The term "photovoltaic" is derived from the Greek words for "light" and "volt," the latter being the unit of electromotive force named after Italian physicist Alessandro Volta, the inventor of the battery. This phrase has been employed in the English language since 1849.

Photovoltaics encompasses the technology and research surrounding the practical application of photovoltaic cells in electricity generation from light, often specifically referring to solar power generation. Cells can be termed photovoltaic even in instances where the light source is not sunlight (e.g., lamplight, artificial light). In such cases, the cell may function as a photodetector, detecting light or electromagnetic radiation near the visible range or measuring light intensity.

The operation of a photovoltaic (PV) cell relies on three fundamental attributes:

1. Absorption of light, resulting in the generation of electron-hole pairs or excitons;

2. Separation of charge carriers of opposite types;

3. Extraction of these carriers separately to an external circuit.

5. DESIGN AND WORKING

5.1 DESIGN

The 3D design is made with Sketch up software and the designs listed below:

5.1.1 ISO VIEW

Figure -5.1: Tiller Machine ISO View

5.1.2 FRONT VIEW

Figure -5.2: Tiller Machine Front View

5.1.3 SIDE VIEW

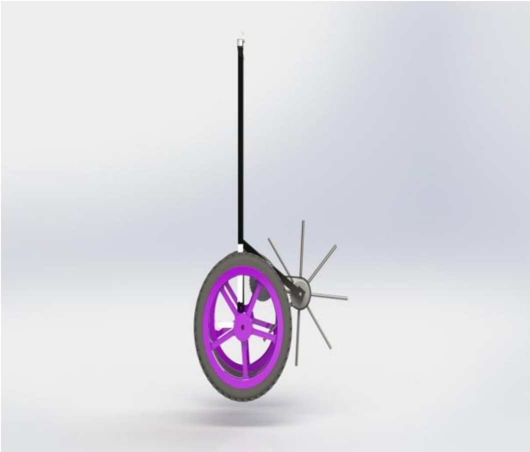

Figure -5.3: Tiller Machine Side View

5.2 METHODS

A rotavator is a tool utilized to remove unwanted plants in crops with wide row spacing. Rotavator blades play a crucial role in achieving better weed control and more effective inversion and mixing of trash. These blades are the primary components of the rotary rotavator, engaging with the soil during the weeding process. Unlike traditional ploughs, these blades interact with the soil in unique ways, experiencing impact and high friction, which ultimately leads to unbalancing forces on the rotavator and blade wear. Proper design analysis of components is essential to minimize design optimization and manufacturing errors. Specifically, the blades must demonstrate reliability in field performance against operational forces. Predicting stress distributions among the blades is critical for designers and manufacturers to optimize power requirements.

5.2.1 ENERGY DESIGN PARAMETERS

The electronic circuit designed aids the battery in powering the D.C. motor, thus facilitating the mechanical rotation of Rotavator blades.

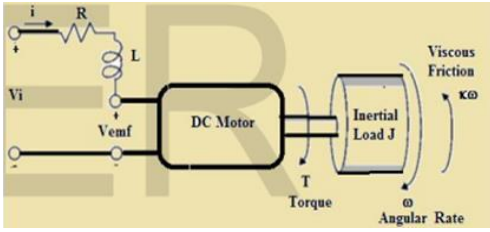

Figure -5.4: Energy Model

The torque (T) of the electric motor is given by the equation:

$T= K * i$…………………… (1)

where K represents the torque constant, and i denotes the armature current.

The back electromotive force (Vb) is dependent on the angular velocity (ω), and can be expressed as:

$Vb= K* \omega = K* d\theta/dt$…….. (2)

Given a power consumption of 40 watts, a rotational speed (N) of 100 rpm, a rotor inertia (J) assumed to be 0.01, and an input voltage (Vi) of 12 volts, we can calculate the value of K using the equation:

$\omega m =Vi/K=2\pi N/60.$

This yields K= 1.146 and ω=10.47 rad/sec.

A solar battery with a voltage of 12.8v and a current of 7.0 Amp can power a 20-watt load for a theoretical maximum of 5-6 hours. To fully charge the battery, a 2-watt solar panel will require approximately 8-10 hours. Alternatively, selecting a slightly larger solar panel, such as a 3W, can provide sufficient charging capability.

Considering the specifications of the Rotavator motor, with a drive motor voltage of 12v, an expected current draw of 1.1 amps, and a utilization rate of 100%, the total power consumption by the motor is calculated as:

Total Power consumption by motor: $(V * I) *T$= 13.2 watts.

Based on the provided data, the Solar Powered Rotavator can operate for approximately 5-6 hours.

6. COMPONENTS AND WORKING

6.1 COMPONENTS

6.1.1 BLDC MOTOR

A brushless DC electric motor, also referred to as an electronically commutated motor or synchronous DC motor, operates using a direct current (DC) power source. It employs an electronic controller to vary DC currents flowing through the motor windings, generating magnetic fields that rotate efficiently, guiding the permanent magnet rotor. The controller modifies the phase and magnitude of the DC current pulses to control the motor's speed and torque, providing a substitute for the conventional mechanical commutator found in numerous electric motors.

The construction of a brushless motor system typically mirrors that of a permanent magnet synchronous motor, though it can also manifest as a switched reluctance motor or an induction motor. These motors may utilize neodymium magnets and can be categorized as outrunners, inrunners, or axial.

Brushless motors offer advantages such as a high power-to-weight ratio, swift speed and torque control, high efficiency, and minimal maintenance needs. They find applications in computer peripherals, handheld power tools, and vehicles, including model aircraft and automobiles. In modern washing machines, brushless DC motors enable the replacement of rubber belts and gearboxes with a direct-drive configuration.

Figure -6.1: BLDC Motor

6.1.2 12V 7.5A BATTERY

The lead-acid battery, initially developed in 1859 by French scientist Gaston Planté, stands as the inaugural rechargeable battery model. Although lead-acid batteries possess comparatively modest energy density compared to contemporary counterparts, their capability to deliver robust surge currents results in a notably substantial power-to-weight ratio. These characteristics, coupled with their affordability, render them appealing for automotive applications, particularly in supplying the hefty current demanded by starter motors.

Figure -6.2: 12V 7.5A Battery

6.1.3 ROTATORY TOOL

A tiller, also known as a till, serves as a lever employed for steering a vehicle. This mechanism finds its primary application in watercraft, where it is connected to an outboard motor, rudder post, or stock, delivering torque to assist the helmsman in turning the rudder. Additionally, tillers are utilized in non-marine vehicles and were present in the early days of automobiles.

Figure -6.3: Tiller Blade

6.1.4 SOLAR PANEL

A solar cell panel, also known as a solar electric panel, photo-voltaic (PV) module, or solar panel, is a configuration of photo-voltaic cells arranged within a framework for setup. These panels harness sunlight to produce direct current electricity. A group of PV modules is termed a PV panel, while a grouping of PV panels forms an array. Photovoltaic systems' arrays deliver solar electricity to electrical devices.

Figure -6.4: Solar Panel

6.2 WORKING MECHANISM

In this machine, a power tiller is utilized, specifically a manual push-type power tiller. At the rear side of the tiller, there is a steady static blade equipped with a shaver blade. However, we have modified the tooling system to a rotary configuration, which is driven by an electric BLDC motor operating at 1250 rpm and providing 7.2 N-m torque. This motor is powered by a battery pack. The rotary tool rotates in the reverse direction of the entire machine, which proves effective for earth moving between two lines of crops in farms.

This machine incorporates a solar panel that generates energy to operate. Solar radiation is absorbed by the solar panel, converting solar energy into electrical energy. The electrical energy generated by the solar panel is stored in a battery. Subsequently, the battery supplies electrical energy to power the motor. As the motor operates, the rotor also rotates, ultimately performing the necessary work. The machine's ability to easily turn is a crucial feature.

Figure -6.5: Fabricated Model of Solar Power Tiller machine

7. CONCLUSION

Today, fuel prices are on the rise worldwide, leading to increased pollution levels. To address this issue and conserve both petroleum and bio-products, this project has been designed and developed. While this system requires a significant initial investment, it offers a lifetime of energy output with minimal maintenance. Our project focuses on minimizing the harmful effects associated with manual rotators, and we have successfully implemented a new battery-powered rotator.

After reviewing various references, it has been determined that utilizing solar energy is more advantageous compared to other energy sources. Solar energy is captured by solar panels, stored in batteries, and then utilized to power various equipment. Therefore, we have decided to develop a solar-powered blade harrow equipment, which proves beneficial for farmers in their agricultural tasks. Through our project, we have concluded that the use of this machine reduces the need for manpower, lowers risks, and cuts costs. Our primary goal is to assist farmers in their endeavors.

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