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Design and Development of Semi-Automatic Solar Weeder

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ABSTRACT:

In this thesis an attempt is made to develop a semi-automatic prototype weeder of low cost and ergonomically designed using the renewable energy source. Solar energy is more practical type of energy due to its abundant availability and it is derived directly from the sun. It is a clean, cheap and renewableenergy which is inexhaustible, freely available in adequate quantities.

This project implements solar panel, DC motors, battery, rotor shaft, blades, handles and wheels. Complete assembly is resting on adjustable four wheels. Solar panel converts solar energy into electrical energy and this energy is stored in battery. Battery supplies energy to the DC motors for producing rotational mechanical energy to the weeding tool. Weeding tool pulls out the weed along with their roots and aerates the soil. The developed prototype is compact in size & involves a low development cost. It involves a lesser number of parts and least number of manufacturing processes which reduces the cost of product and makes it affordable with mass production. It can be operated by an age group and is tested for is for the field performance and resulted in 0.4 acre per day which is higher when compared to 0.125 acre per day using manual weeding using human labor. Thus, this device saves time and reduces human fatigue and increases productivity.

KEYWORDS: Solar energy, Weeder, DC Motors, Battery, Semi-automatic, prototype, farmers, ergonomic design, Power Weeders.

1. Introduction:

Agriculture is the major occupation in India and employs more than 50% of Indian work force. India being a developing nation, agriculture and agro-industries play an important role in the growth of the economy. As per the economic survey conducted during 2020-21 the GDP share of agriculture has contributed to 20%. India lags behind many countries in agricultural productivity due to various reasons such as traditional farming methods, size of fields, irrigation facilities, uncertainty of rains, crop diseases etc.

According to a study by researchers, India lost agriculture produce worth $11 billion in the year 2017-18 annually to weeds in 10 major crops and also 1/3 cost of cultivation is being spend for weeding alone and presence of weeds reduces the crop yield.

Weeds are the plants which are undesirable, persistent, damaging and interfere with crop growth. They obstruct growth by competing for CO_2, space, moisture, sunlight and finally diminish the crop yields. Weeds can be toxic to humans; livestock and they also choke the navigational and irrigation canals and decrease the level of water in water bodies [1].

2. Challenges in present weeding methods:

Farmers in India are managing weed control with their knowledge of frequent tillage, animal grazing, manual weeding burning and cultivating cover cops. Most of Indian farmers own only small pieces of land and remove unwanted plants by using manual weeding and bullock power. Manual weeding involves high cost, tedious, time-consuming process and causes human fatigue.Manual weeders consist involves push and pull type of operation. During the push and pull operations, farmers experience shoulder pain over the period and result of

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field coverage would be less, it can't work in case if there are any obstacles and becomes less effective in presence of moisture.

Chemical weed control majorly uses herbicides which prevents the growth pattern of weeds. This method is time and cost effective, it's also advantageous in managing the weeds when compared to manual and mechanical methods. Major concern of this method is the adverse effect on the environment, living organisms due to its usage.

Biological control uses bio-agent such as insects, pathogens and other animals that affect the growth of the weed. These infiltrate weeds and they diminish their growth. This method can reduce weeds but not possible to completely eliminate them [2].

Market has also wide range power or mechanised weeders. These weeders not only kill weeds but also keep the soil surface loose ensuring better soil aeration and water holding capacity. Power weeders are compact and light weight machines which is powered by either petrol or diesel engines. Main disadvantage of these gasoline power weeders is the increasing fuel costs day by day, periodic maintenance and harmful emissions which seem to be unaffordable for small scale farmers.Another major issue in this type of gasoline operated weeders is having more vibration to human body while operating resulting in high heart and oxygen consumption rate [4]. Tractors or tillers are large in size and cannot be used for low inter row spaced crops for weed control.

3. Need of this project:

Customer needs was collected by conducting interviews with farmers and their requirements were established along with their expectations and disadvantages of existing methods. There is a requirement of small hand semi-automatic weeder for medium size dry farmlands. Weeder should be cost effective, increase field coverage, simple in design and construction. Ergonomically designed so it can be easy to be operated by any age group or gender. Various working principles, cutter shapes and power mechanism to drive were evaluated by using Pugh concept selection. Based on concept scoring for the required customer needs, solar operated weeder was selected for prototype development.

4. Working Principle and Hardware:

4.1 Working Principle

Semi-automatic solar weeder consists of solar panel, DC motors, and rotor shaft with cutting blades, frame with an extended handle, wheels and control switches. A solar panel is used to harvest solar energy and it converts sunlight into electrical energy due to photovoltaic effect. Electrical energy generated is stored into a 12V, 7.2Ah battery and drives the DC motors by converting electrical energy into mechanical energy. Two DC motors drives the wheel for forward and backward motion and one DC motor is connected to the shaft that has blades/tines welded on to the rotor shaft. Control switch is used to control the forward and reverse direction of the weeder.

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Figure 1: Prototype build of solar weeder

4.2 Component Description:

The major components involved in fabrication of semi-automatic solar weeder are:

- Frame/Chassis
- DC motors
- Battery
- Solar Panel
- Control Switches
- Weeding Blades & rotor shaft

4.2.1 Frame/Chassis

The frame is most critical part of this product and it's a structural member on which all other equipment's are mounted. Mild steel (MS) frame is arc welded to join the metals of different shapes. The top part of the frame is provided with a handle for push-pull movement for the users. Provisions are provided on the frame to fix the solar panel along with control switch & battery. Four cast iron wheels are coupled to the frame with help of fastening bolts and nuts which helps the weeder to move on uneven surfaces easily. Also, attachments are made on the frame to bury the weeded crop in the soil.

- Material: Mild Steel
- Dimension: 25 x 25 x 2mm, Length = 2mts

Figure 2: Frame

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4.2.2 DC motors

DC motors is a device that is used to convert electrical vitality to mechanical energy and it provides required rotating motion for work creation. DC motors that are used to operate small electric appliances, portable electrical tools are used in this product and fitted on the frame. Speed of this DC motors varies widely between the number load or the voltages. Three DC worm gear motors are used, one motor is connected with rotor shaft with cutter blades and other two DC motors are used for forward and backward motion of the frame.

- Motor voltage: 12V
- Speed: 45 rpm
- Rated voltage: 13.5V
- Speed (on load): 38rpm
- Power: 14 HP
- Shaft dimensions: dia. 10mm, length: 29mm
- Weight: 1280gms

Figure 3: DC motor

4.2.3 Battery

Lead acid batteries are a rechargeable battery used for storing electrical energy and have a relatively high power to weight ratio. It compromises of at least one electrochemical cell than changes over stored chemical energy into electrical energy.

- Battery: Lead acid battery
- Nominal voltage: 12V, 7.2Ah
- Weight: 0.5 Kgs
- Voltage regulation: 14.4V to 14.8V
- Max current: 2.16Amps

4.2.4 Control Switch

Control switch is a mounted on the frame and consists of multiple switches for controlling forward and reverse direction of DC motors and also to control the device starting and ending.

Figure 4: Battery and Control switches

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4.2.4 Solar Panel

Solar panel is made of photovoltaic (PV) cells that convert the solar energy into electrical energy. The photovoltaic effect is defined as the generation of the electro motive force due to absorption of solar radiations. Silicon is one of crucial materials that are used in a photovoltaic cell to convert the sun's energy into electricity. As sunlight strikes on solar cells of silicon the electricity generated can be used to power source motors. Solar panel is mounted on the supporting frame/chassis. Each panel is rated by its DC output power and typically ranges from 5Watts to 300Watts. A single solar module can produce only a limited amount of power; most installations contain multiple modules.

- Power: 10W
- Maximum Voltage: 18.72V
- Max current: 0.56A
- Permissible voltage: 600VDC

Figure 5: Solar panel

4.2.6 Weeder Blades & Rotor shaft

Weeder blades are cutting tools which interacts with soil & weeds. The weeder blades are fabricated from mild steel and of different working depths. Rotor shaft is first made and then the blades are permanently associated to a shaft by means of arc welding. Shaft is driven by a DC motor and can rotate in both forward and reverse directions.

Various forms and shapes of blades such as C form, U form, L form and straight/V type are used in various operating conditions. In this product we have decided to use the V-shaped weeder to reduce torque, impact force and energy required [22].

- Shaft diameter: 152.4mm
- No of blades: 9
- Blade thickness: 2mm
- Pitch: 101.6mm
- Weeding depths: 38mm/762.2mm/101.6mm
- Cutter width: 101.6mm

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Figure 6: Rotor shaft and weeder blades

5. Performance and Testing

Objective was to evaluate the performance of the developed semi-automatic solar weeder [5].

5.1 Experimental site:

Test was conducted on dry land having a moisture content of 13% and prepared for a distance of 5mts on a straight path.

5.2 Measuring tape:

Measuring tape is required for measuring the dimension covered by the weeder in forward direction.

5.3 Stop watch:

Stop watch for calculating the speed of weeder.

Solar operated weeder is placed at one end and switched on and pushing the device in one direction and time taken to reach 5mts was an average of 11.8secs

Table 1: Time trials of prototype testing

Trial No	**Distance covered in Meters**	**Time taken in seconds**
1	5	11
2	5	12.5
3	5	11.75
4	5	12
Average time taken to cover 5mts		**11.8s**

Speed of the weeder (S) = Distance covered by the weeder / Time required to travel

S= 5/11.8

S= 0.42 m/s

Average distance covered in straight path in 1 minute = 25.2m/min

Field friction reduces the further movement due to moisture and land condition about (40% approx.) = 25.2 x 0.6= 15.12m/min

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Straight path distance covered in 1 Hour = 15.12 x 60 = 907.2mts

Straight path covered in 8 hours (1 day) = 606 x 8 = 7257.6mts

One acre = 43560 ft^2

One fts^2 = 0.092903 m2

Field of 60ft x 60ft is considered as one segment = 3600 ft^2 (334.5m2)

Width of one row = 9" (0.23m)

One side of field = 60 ft (18.3m)

No of rows on one side = 18.3/0.23 = 80 rows

Straight distance of one segment = 18 meters x 80 rows = 1440 meters (3600 ft2)

No of segments covered by prototype = 7257/1440 = 5.039

Total no of segments in 8 hrs. = 3600 x 5.039 = 18142 ft2

No of segments = 18142/43560 = 0.4 acre

6. Conclusion

Solar operated weeder average working performance on dry land is 15.12m/min by which it can cover an area of 0.4 acre per day which is better than manual weeding of 0.125 acre per day. Weeding efficiency can vary due to friction and moisture in the land. 0.4-acre achievement can be higher range depending on the soil condition.Prototype is built to demonstrate the form, fit and functionality of the product. Based on this prototype the bill of materials, CAD models, development cost and performance testing wereevaluated. The developed weeder can be used by farmers in dry farmlands for weeding with for following reasons:

- Compact size
- Economical – Low cost compared to market weeders
- Increased productivity of ~68% compared to manual weeding
- Easy to operate and maintenance due to its minimum number of parts and simple mechanisms
- Environment friendly as it minimizes carbon footprints.

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