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Development and Performance Evaluation` of Solar Powered Lawn Mower

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Abstract: The constant rise in fuel prices and the impact of emissions from fuel into the atmosphere made has it necessary to look at solar energy as a source of power. The fossil fuel-powered lawn mowers have a tendency to freeze and not operate in the chilly and harsh atmosphere besides causing air pollution and noise pollution. The objective of this research was to design and develop a lawn cutting machine powered by solar energy and is user-and environmentally friendly, less noisy and lighter in weight. The designed lawn mower comprises one brushless direct current (BLDC) motor, solar panel, battery and charge controller. The solar lawn mower has an efficiency of 81.33%. The developed model can used in playgrounds, lawns, and golf courses to achieve environmental sustainability goals, save energy, minimise noise pollution.

Key words: Solar energy, Grass, Lawn mower, BLDC motor.

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Improved techniques have remarkably replaced the traditional methods over the years. Machines are replacing human labour either entirely or partially, and automation is entering both home and commercial activities. But all this is an entirely energy intensive process which cause pollution. Solar energy is another field that is growing in popularity over time, along with automation. Efficiency of PV cells to convert solar energy into electrical energy has increased over the years (Patel *et al.*, 2009; Patel *et al.*, 2023). The two contemporary technologies viz. automation and solar photovoltaic electricity have been applied in this study to modify traditional lawn mowers.

Grass maintenance involves pruning or thinning it out to a desired height. Grass is conventionally cut manually with hand tools which are inefficient and take more time (Prasanthi and Balaiah, 2017). Thus many solar grass cutters were manufactured in past decade to cut fuel cost and reduce wear and tear (Shubham *et al.* 2016; Patil *et al.* 2018; Deepak *et al.* 2018). A solar-powered lawnmower tested in 2020 had field efficiency between 71.93 (with a 4 mm blade thickness and a 25 mm cut height) to 78.06 (with blade thicknesses of 3 and 5 mm and 40 mm) (Sinha and Mathur, 2020). Akinyemi and Damilare (2020) have also designed a grass mower which had higher efficiency (85%). A cost-efficient and reliable automated solar grass cutter with sensors and an Arduino for controlling, obstacle avoidance, and power backup aws developed by

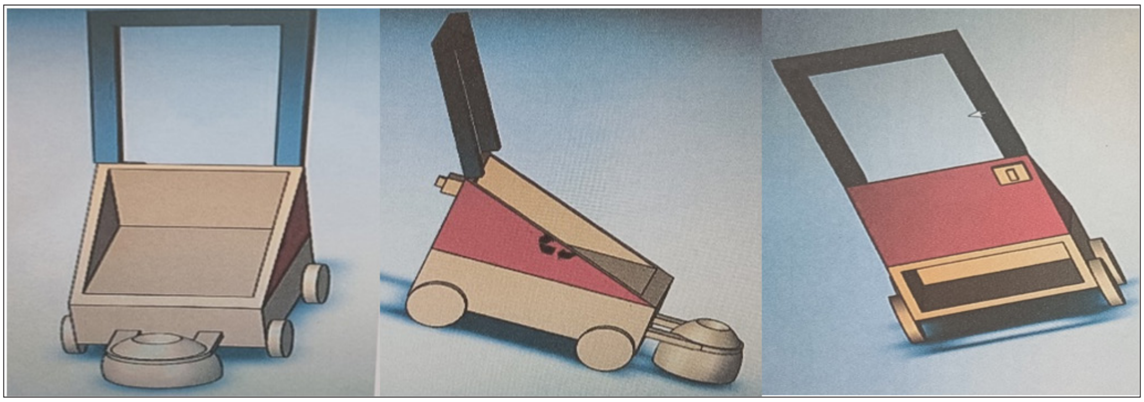

Fig. 1. Isometric views of solar lawn mower.

Titarmare *et al.* (2021). Many more scientists have also attempted to improvise the solar powered grass mower (Soyoye, 2021; Singh *et al.*, 2022; Tunmise *et al.*, 2022). The primary objective of the proposed research work is to develop small solar operated lawn mower and evaluate its performance.

Methods and Materials

Machine conception

The solar lawn mower consists of a machine frame, electric motor, solar panel, mild steel blades, connecting wires, tires, battery, charging circuit, and handle. The solar panel charges the battery, while the electric motor rotates blades at high speed. The handle steers the machine using rotary wheels as shown in Figure 1. The necessary components needed for the fabrication of the machine has been designed following the standard design procedure (Igbokwe *et al.* 2019).

Dimension of frame

Mild steel plate has been used in the frame's construction because to its strength, workability, availability, and affordability. This structure supports the handle frame, battery, and electric motor. Frame height: 86.99 cm, width: 43.18 cm, length: 53.83 cm, slope: 53.54 cm, solar panel angle: 23° according to latitude of Vadodara. The solar-powered lawnmower's isometric perspective is displayed in Figure 1. Additionally, Figure 2 displays a picture and a line schematic of the machine.

Designing of blade

The force required to cut the grass as well as the force acting on the blade have been taken

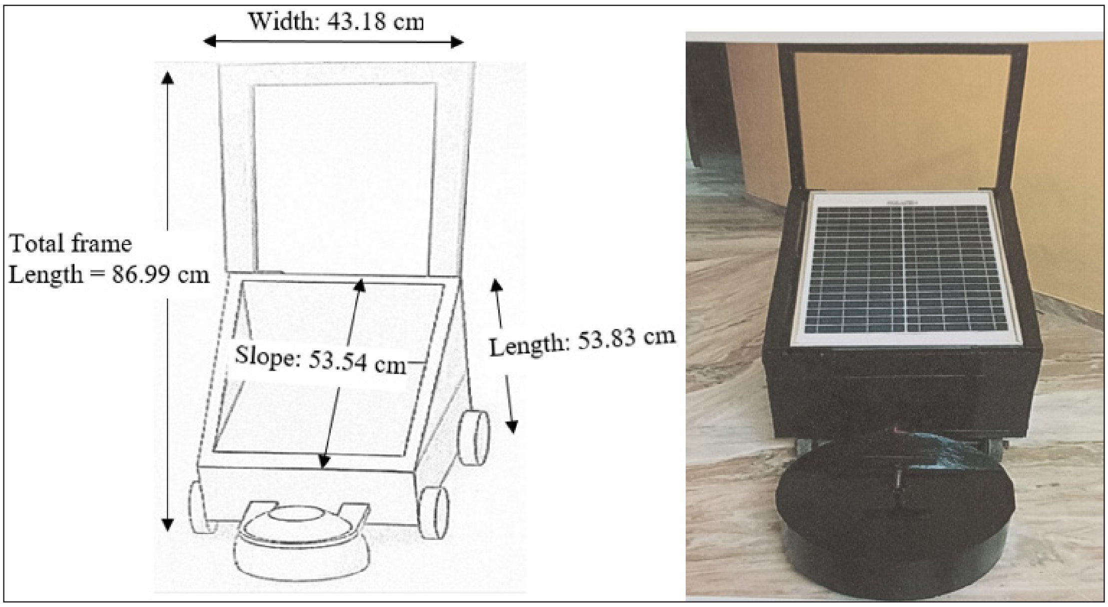

Fig. 2. Line diagram and developed solar lawn mower machine.

into account when designing the cutting blade. The cutting blade has been made from mild steel (density = 7850 kg m^{-3}). The shearing force of most annual and perennial grasses found on most lawns ranges between 9.20 N and 11.51 N, depending on the height of the grass, the species of grass and the density of grass in the area. Cutting height of grass is between 3 to 7 cm.

Area of blade = length × breadth
= 27.94 cm × 5.00 cm
= 139.70 cm^2

Volume of blade = area × thickness
= 139.70 cm^2× 0.30 cm
= 41.91 cm^3

Mass of blade = density × volume
= 7850 × 41.91 x 10^{-6}
= 0.328 kg

Selection of battery

Batteries are available in various volt and ampere hour range. To find the suitable battery first Researchers have to calculate the power required by the machine. The battery used in solar powered lawn mower is shown in Figure 3.

Weight of the blade = Mass (kg) × Acceleration due to gravity
= 10.328 × 9.8
= 3.217 N

Torque produced = Weight × Radius
= 3.217 × 0.279/2
= 0.448 Nm

Angular velocity = 2πN/60
= (2 × 3.14 × 2800)/60
= 293.06 rad/s

where, N = Rotational speed of selected motor 2800 rpm

Power developed = Torque × Angular velocity
= 0.448 × 293.06
= 131.29 W
= 131.29 × 0.00134
= 0.176 hp

The design power has been determined using following equation (Igbokwe *et al.*, 2019);

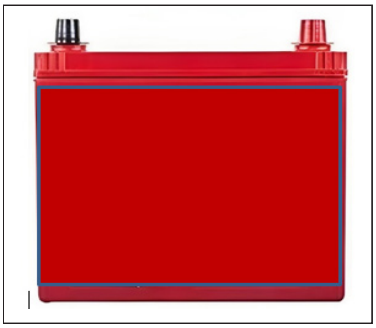

Fig. 3. Battery (12 Volt, 45 Ah) used in solar powered lawn mower.

Design power = (I × V)/(Power factor of the machine)

where,

I = The expected current to be drawn by the motor; V = The expected voltage of the battery (12 V); The power factor = 0.80

I = (Design power × Power factor of the machine)/V
= (131.29 ×0.8)/12
= 8.75 A

According to the computation, 8.75 A is needed to run a BLDC motor and cut the grass with a blade. It is anticipated that the chosen 45 Ah, 12 V battery would drain after 05.14 hours.

Battery drain (hr) = (Battery Ah)/(Required Ah)
= (45 Ah)/(8.75 A)
= 5.14 h.

Selection of solar PV panel

This mower's solar panel is utilised to charge the batteries during day time. To increase the amount of time that the battery can function, it is also charged while working. The mower's available area determines the solar panel that is used. In addition, a suitable Brush Less DC motor with a 12 V operating voltage, 6 Nm of torque, and 2800 rpm is employed to drive the solar mower effectively. This BLDC motor is shown in Figure 4. Solar panel with a capacity of 20 kW and dimensions of 45.72 x 35.56 cm is used for charging the lawn mower.

A solar-powered lawnmower's energy flow diagram is shown in Figure 5. A solar lawn mower's blade, BLDC motor, battery, and solar panel are among the components that get energy from the sun.

Fig. 4. BLDC motor used in solar powered lawn mower.

Forward velocity (m/s)

Forward velocity is defined as the ratio of forward distance travelled to time spent in traveling as per equation given below.

Forward velocity (m/s) = [Forward distance covered (m)]/[Time taken (s)]

Theoretical field capacity

Theoretical field capacity is calculated as the product of forward speed and theoretical blade width. It can be calculated by equation given below.

Theoretical field capacity ($m^2\ s^{-1}$) = Forward velocity × Theoretical width blade

Effective field capacity ($m^2\ s^{-1}$)

The ratio of total area covered to time taken is defined as the effective field capacity as given in following equation.

Effective field capacity ($m^2\ s^{-1}$) = [Total area covered (m^2)]/[Time taken (s)]

Field Efficiency (%)

The field efficiency is defined as the ratio of effective field capacity to theoretical field capacity, as shown in the following equation.

$$\text{Field Efficiency (\%)} = \frac{\text{Effective field capacity } (m^2\ s^{-1})}{\text{Theoretical field capacity } (m^2\ s^{-1})} \times 100$$

Results and Discussion

The forward distance covered, forward velocity, theoretical field capacity, effective field capacity, and field efficiency of the developed lawn mower is been presented in Table 1. Three distinct observations have been made. The first observation has been a 10 m distance covered in 20 seconds, from which Researchers obtained forward velocity, theoretical field capacity, effective field capacity, and field efficiency of 0.5 m s^{-1}, 0.050 $m^2\ s^{-1}$, 0.042 $m^2\ s^{-1}$, and 88%, respectively. The second observation shows that reducing the time required to cover a 10 m distance by 1 second increases forward velocity, theoretical field capacity, effective field capacity and filed efficiency by 0.53 m s^{-1}, 0.053 $m^2\ s^{-1}$, 0.042 $m^2\ s^{-1}$, and 79%, respectively. The third observation shows that a solar powered lawn mower covers 10 meters with speed of 0.55 m s^{-1} and average time of 19.33 seconds at a 0.52 m s^{-1} speed.

After analysing three observations, it was derived that the field efficiency of the machine and the amount of time needed to complete the forward distance are inversely related. In other words, a machine's field efficiency will rise if the forward distance is completed in a shorter amount of time than it is required to, and it will decrease if it takes longer.

Theoretical and practical times for mowing a one-hectare lawn are displayed in Figure 6. The effective time taken has been found to have a maximum of 24.17 hours and a minimum of 22.78 hours. The theoretical time taken has been estimated to take a maximum of 19.80 hours and a minimum of 18.85 hours, respectively.

The designed solar lawn mower's theoretical and effective field capacity is depicted in Figure 7. The observed effective time taken has been 0.042 and 0.052 for the average effective field capacity and theoretical field capacity, respectively.

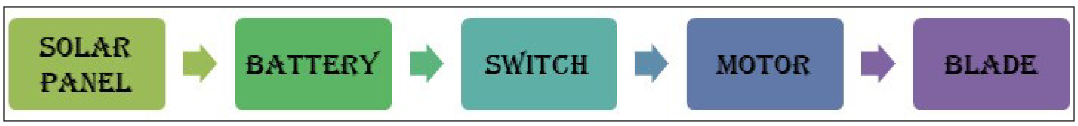

Fig. 5. Energy flow diagram of solar powered lawn mower.

Table 1. Performance analysis of solar operated lawn mower

Sr. No.	Area covered (m^2)	Forward speed ($m\ s^{-1}$)	Theoretical time taken ($hr\ ha^{-1}$)	Theoretical field capacity ($m^2\ s^{-1}$)	Effective time taken ($hr\ s^{-1}$)	Effective field capacity ($m^2\ s^{-1}$)	Field efficiency (%)
1	10	0.50	19.80	0.050	22.78	0.044	88
2	10	0.53	18.85	0.053	23.61	0.042	79
3	10	0.55	18.85	0.053	24.17	0.041	77
Avg.	10	0.52	19.16	0.052	23.52	0.042	81.33

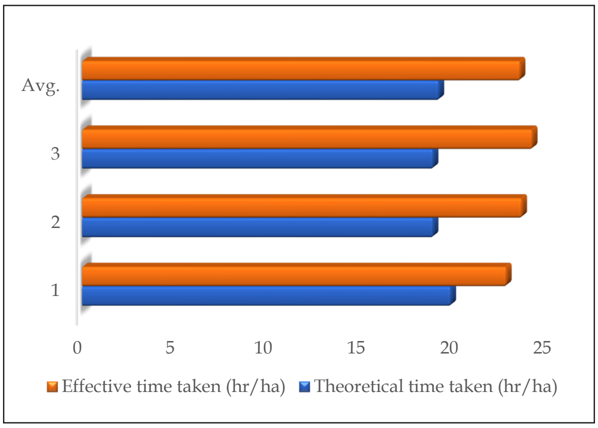

Fig. 6. Theoretical and effective time taken for one hectare area of solar lawn moving.

Conclusion

Machines are currently being developed with the goal of reducing or completely eliminating greenhouse gas emissions, which are the primary causes of climate change. This initiative addressed the issues of environmental contamination and expensive operating costs by creating a solar-powered lawn mower out of locally sorted materials. The average field efficiency and Effective field capacity have been determined to be 81.33 % and 0.042 $m^2\ s^{-1}$. An IOT infrastructure is used to achieve an ideal design, and a productive grass-cutting solution is offered. Mower applications include lawns, gardens, and expansive fields utilised for various sports. This idea may be expanded to accomplish sophisticated functions like object recognition using machine learning and computer vision for completely autonomous operation.

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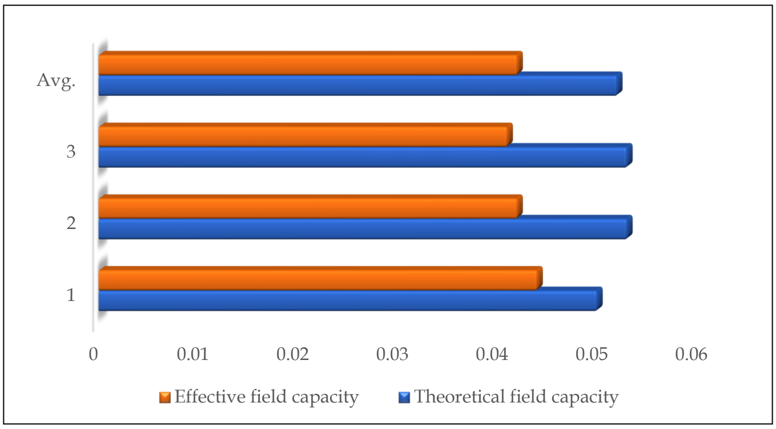

Fig. 7. Effective field and theoretical field capacity of solar powered lawn mower.

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