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Design and Fabrication of a Solar-Powered Lawn Mower for Health Facility Landscaping

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Abstract:

In recent times, the entire world has been in consistent search of cleaner and safer ways of generating and producing energy. Due to continuous industrialization in different parts of the world, there has been a huge deterioration in the natural state of the environment. This is reflective in different areas and the most prominent has to be Climate change. This paper therefore focuses on the exploitation of the abundant solar energy from the sun to drive a lawn mower. The designed solar powered lawn mower comprises of electric motor, a charge controller, battery (12V), Solar Panel (30W), rotational blade and a control switch. The entire operation frame work is achieved using the electric motor which is able to provide the necessary torque needed for the rotation of the blade which is mounted to the shaft of the motor. The solar powered lawn mower is operated by a switch on the board which closes the circuit and allows current flow to the motor and ultimately, causing the actuation of the blade. Under a very sunny condition battery charges and operates simultaneously, taking a longer time to discharge. Finally, the performance evaluation of the battery was carried out with the machine and it was found to have a theoretical efficiency of 85%.

Keywords: Lawn Mower, Solar energy, electric motor, solar panel

1. Introduction

The use of solar power as an alternative source of energy has been in existence long before now but has not had diverse application methods due to other frequently used sources of energy. Solar energy involves the process of harnessing radiant light and heat from the sun using a range of ever evolving technologies such as solar thermal energy and photo voltaic. These technologies are broadly characterized as either passive solar or active solar depending on how the energy is converted to solar power. The effectiveness of these technologies have made solar energy a very important source of renewable energy and thereby giving room for new developments in its wide range application processes. In the world today, world's power consumption is taking a shift from the use of common sources of energy such as fossil fuel and wood fuels to solar energy. The change in energy consumption trend was due to the awareness of fossil fuel pollution and its contribution to global warming, and also the fact that fuel energy is non-renewable and unsustainable (Oluwatobi Akinyemi et al., 2020). In Nigeria today, like most other developing countries, fossil fuel has been a basic source of non-renewable energy. Pending the fact that we import fuel there is always a tendency of a hike in the cost of fuel as a result of the country's economic instability.

Maintaining the landscaping of health facilities involves the skilled practice of ensuring the health, cleanliness, safety, and aesthetic appeal of lawns, typically found within gardens, parks, institutional settings, or estates. As humans strive to adapt their surroundings to promote survival, landscaping becomes integral to creating a conducive habitat. The inception of lawn maintenance equipment dates back to August 31, 1830, when Edwin Budding introduced the first lawn mower in Thrupp, Gloucestershire, England. Initially designed to trim grass in sports grounds and expansive gardens, this innovation marked a significant advancement over the traditional scythe, which had been the sole method for grass cutting until the 19th century. The scythe, characterized by a simple design comprising a long wooden handle with a curved blade, was a labor-intensive tool for achieving the desired grass height, making lawn maintenance a time-consuming process.

Budding's idea of a lawn mower came after watching a machine in a local cloth mill which used a cutting cylinder mounted on a bench to trim clothes for a smooth finish after weaving (Satwik et al., 2015). Budding assumed that similar concept could be used to cut grass if the mechanism is mounted on a wheel frame to enable the blades rotate close to the lawns surface. These early machines were made of cast iron and featured a large rear roller with a cutting cylinder (reel) in front. The cutting cylinder contained several blades connected in series around the cylinder (Bhadke, 2021). The cast iron gear wheel transmitted power from the rear roller to the cutting cylinder blade. After the development of Buddings lawn mower, he made an agreement with John Ferrabee, a fellow English engineer. After obtaining a patent in 1830, Ferrabee had license to manufacture and sell the product.

During the production of his product, he licensed other companies, allowing them to produce the mower as well. Other companies were finally able to produce their own mowers in the 1850s when the patent was terminated. Thomas Green innovated the first ever chain driven lawn mower in 1859. Since Green used chains to transmit power from the roller rather than gears, it reduced the noise of the mower. Amariah Hills was the first American to obtain a patent for a mower design and innovated the Archimedean Lawn Mower Co. in 1871 (Tanimola et al., 2014). In 1870, Elwood McGuire of Richmond, Indiana designed a human-pushed lawn mower, which had a very lightweight and became a commercial success. This design made it possible for the operator to easily move the mower rather than exerting as much energy as the older push mower designs required. Although a lighter push mower had been designed, mowing grass proved to be an inconvenient and long task. Therefore, a non-man powered mower was desired. Resorting back to horse drawn mowers was not an option in order to keep a pristine lawn and resulted in the next big innovation of motorized mowers.

Mowers employing a blade that rotates about a vertical axis are known as reel lawn mowers, while those employing a blade assembly that rotates about a horizontal axis are known as rotary lawn mowers. The rotary lawn mowers are more effective than the real mowers because of it clean mowing and provision for collecting grass. The most important part of the rotary mower is the cutting blade. Rotary mowers generally have opening by the side of the housing through which cut grasses are expelled. The blade is sharp enough to give a neat cut. The blade simply tears the grass resulting in brown tips. However, the horizontal blades are easy to remove and sharpen or replace. Many different designs have been produced for their various purposes. The smallest types which are pushed by man are suitable for small residential lawns and gardens, while more complex mowers are suitable for large lawns, and the largest multi-gang mowers which are moved by tractors are used for large expanses of grass such as golf courses and municipal parks (Ajetunmobi et al., 2022).

A lawn mower is a grounds keeping device that make use of one or more rotating blades to cut a grass surface to an even height. There are various ways used to power a lawn mower, but the use of solar energy as a source of energy to operate a lawn mower is the main focus of this project. The solar powered lawn mower involves the use of solar energy to charge a direct current battery which supplies the current stored to the motor which in turn enables rotation of the blade for mowing. The solar panel receives energy from the sun, when the sun shines, the solar panel or photo voltaic cell (mono-crystalline) will generate or produce voltage, the energy received from the sun goes into the charge controller. The charge controller is connected in between the panel and the battery. The main function of the charge controller is to monitor and control the flow of current and charge the battery. The charge controller will stop the current flow from the solar panel if the battery voltage exceeds a pre-set level and also stop current flow if the battery voltage drops below a pre-set level.

The primary objective of this paper is to design and fabricate a lawn mower which would be powered by solar energy in addition to the common gasoline engine. The design can be seen as an alternate option to popular and environmentally hazardous gas powered lawn mower (W. A. et al., 2020). Solar lawn mower is advantageous over gasoline powered mowers because its eliminates environmental pollution which is responsible for the emission of gases that results to global warming on the earth surface.

Related work on the study of solar powered lawn mower in the literature were carried out by (Vigneshwaran et al., 2023), (Dauter, 2006), (Tahir et al., 2022), (Jabbar et al., 2022), and (Sharma & Yadav, 2022). Considering, the previous work done by others in line with this study, the methodology used in carrying out this present work differs from the various methods used in related works in the literature

2. Materials and method

2.1. Machine description

The solar powered lawn mower comprises of different components. Solar panel, dc motor, two 12v rechargeable battery connected in series, a diode and mild steel blade. The whole-body part of the lawn mower was made up with angle bar of mild steel and they are connected with each other by welding the joints together to support and strengthen the body. Two bigger sized wheels were mounted at the rear, while two smaller sized wheels were mounted at the front through which the lawn mower will move the blade along. The solar panel was mounted on top of the frame. The solar panel convert solar energy into electrical energy and then electrical energy is stored in a 12v battery. A diode is used, which do not allow the battery to give reverse power to the panel. The Dc motor is connected to the battery, between these two, mechanical circuit breaker switch is provided. It will start and stop the working of the motor. The motor was mounted in vertical downward and fixed in a T-shape joint. From the shaft of motor, a stainless-steel blade was connected from the motor, the power transmits to the mechanism and this makes the blade to slide on a fixed blade thereby cutting the grass at an even length.

2.2. Material Selection

Some factors were taken into consideration before the selection of the materials used in the fabrication of the solar powered lawn mower. This is to ensure the machine's functionality, durability and cost effectiveness. The considered factors are the material's strength, ductility, machinability, weldability, corrosion resistance, availability, and affordability Rajput, R.K. (2010).

Table 1: Material Selection Table

S/N	Components	Suitable Material Used	Reason for Selection
1.	Blade	Mild steel	Strength, Resistance to corrosion
2.	Motor	DC motor	Easily accessible and economical
3.	Battery	12V, 5Ah	Rechargeable, durability and economical
4.	Solar Panel	30Watts	Functionality
5.	Frame	Mild steel	Strength and support
6.	Charge Controller		
7.	Wheels	Plastic	Maneuverability
8.	Handle	Mild steel	Mobility
9.	Switch		Control the power of the lawn mower

2.3. Design of Machine elements

2.3.1. The mower cutting blade

In designing the cutting blade, the force required to cut the lawn mower as well as the force acting on the blade was considered. The force required by any sharp object to have impact on the grass should not be less than 10 Newton. It is also dependent on the height, density and the area covered by the object. Therefore, in designing the blade of the solar powered lawn mower, the force required for effective mowing should be greater than 10 Newton.

2.3.2 Solar Panel

The solar panel used for the solar lawn mower is a 12V, 30Watts panel which consists of 24 high efficiency solar cells resulting to high efficiency per space. There are three basic types; mono-crystalline, polycrystalline and amorphous solar cells. Monocrystalline solar panel was used because it is more space efficient as it consists of lesser silicon crystals. The maximum output voltage produced by a silicon cell is approximately 0.5Volts when there is bright sunlight. Solar panels need direct sunlight to produce greater solar output. Although in situations whereby the weather is cloudy, the solar panel can absorb solar energy but the rate will be significantly reduced to about 25 to 40% when compared to sunny days. The panels will only produce maximum output to charge the battery during the peak sun hours per day. Peak sun hours per day are approximately 4.86hours.

2.3.3 Battery

Batteries are available in different voltages and ampere hour range. To determine the battery selection, consideration was given to the rating of the voltage and current. Since the solar panel is 12V, then a 12V battery was selected. The ampere hour is used to measure the time the battery will take to discharge while it's not charging. A 5 ampere battery was selected and will give 5 amps of current of battery for one hour before it is fully discharged.

2.3.4 The Motor

A DC motor with speed of 3000 rpm was used. The shaft of the motor was fixed into the bearing and threaded at the end to screw the blades. The motor was supported by three rods screwed and welded to the top of the base frame.

2.3.5 The Frame

The mower frame was fabricated from an angle iron, cut and welded with the aid of cutter, grinder and welding machine. Positions of two bearings were also provided on the metal plate at the base of the machine to prevent excessive vibration of machine while it's at work. A space is provided for the solar panel at the top of the frame in such a way that it can easily be removed and slotted in

2.3.6 The wheels

Two round wheels were attached to the front of the machine and two circular wheels were also attached to the back of the machine. This is to enable easy movement of the machine during operation when operated from the handle.

3.0 Design Calculations

Dimensions for the Blade

Length = 330 mm

Breadth = 38 mm

Thickness = 3 mm

Speed of motor = N = 3000 rpm

Density = ρ = 7850 kg/m3

Acceleration due to gravity = g = 9.81 ms^{-2}

3.1. To determine the area of the blade

Area of the blade = length $*$ breadth

Area of the blade = L $*$ B

Area of the blade = 330 mm $*$ 38 mm = 12540 mm^2

3.2. To determine the volume of blade

Volume of the blade = area of the blade $*$ thickness

Volume of the blade = 12540 $mm^2 *$ 3 mm = 37620 mm^3

3.3. To determine the mass of blade

Mass = density $*$ volume

$= 7850 \frac{kg}{m^3} * 3.8\text{x } 10^{-5} m^3 = 0.30\text{kg}$

3.4.To determine the weight of blade

Weight of the blade = mass of the blade ∗acc due to gravity

= 0.30 kg ∗ 9.81 ms^{-2} = 2.9 N

3.5. To determine the torque

Radius of the blade = $\frac{diameter}{2}$

=$\frac{330mm}{2}$

=165 mm = 0.17 m

Torque = weight of the blade ∗ radius of the blade

Torque = 2.9 N ∗ 0.17 m

Torque = 0.49 Nm

3.6. To determine the angular velocity

$\omega = \frac{2\pi N}{60}$

where,
N = 3000

π = 3.142

$\omega = \frac{2*3.142*3000}{60}$

= $\frac{18852}{60}$ = 314.2 rad/s

3.7. To determine power generated at the blade

Power generated at the blade (P) =VI = Torque ∗ angular velocity

=$\frac{2\pi NT}{60}$

= 0.49Nm ∗ 314.2 rad/s

= 153.96 W = 0.15KW

3.8. To convert kilowatt to horsepower

Since 1KW is equivalent to 1.341 hp

Therefore,

0.15 KW is equivalent to 0.2hp

For design purpose 1hp was used for this project, so that it provides the required torque in other to cut all types of grass effectively.

Hence, the centrifugal force

Fc= $m\omega^2 r$

Hence,

Fc = 3.7 × 314.2 × 0.2 = 73.0 kN

3.9. To determine the net force acting on the blade

F= $\frac{Torque}{radius}$

F= $\frac{0.49}{0.17}$

F= 2.9 N

3.10. Design for the Frame

A mild steel plate was used in the construction of the frame due to its strength, workability, availability and cost effectiveness. The frame provides support for the electric motor, battery as well as the handle frame. Each is made of flat metal with five spin hooks to aid the operation. They transmit the load of 20kg to the wheel equally and length of each is 838mm

The bending moment M = $\frac{PL}{4}$

Where P is the load = 20 × 10 = 200N

But the load is equally shared, hence for each it will be $\frac{200}{4}$ = 50N.

Therefore M = $\frac{PL}{4}$

= $\frac{50*838}{4}$

= 10.5 KNmm

Yield stress = 200N/mm2

Allowable shear stress = ultimate stress × yield stress

= 0.53 × 200N/mm^2

= 106N/mm^2

The sectional modulus (z) according to Khurmi and Gupta (2000)

Sectional modulus, z = $\frac{Bending\ moment}{Shear\ stress}$

= $\frac{10.5*10^3}{106}$= 99.05mm

3.11. Structural Analysis

During the design of any engineering product, structural analysis is one of the significant phases.

The product must be able to withstand operating loads for its intended task. In other words, the system's structural integrity must be guaranteed. Solid Works was used for modeling the developed design due to its effectiveness.

The blades, they were made of standard galvanized steel with density of 7850kg/m3, a young's modulus of 200GPa, and yielding strength of 250MPa. The maximum deflection was found to be 1.40mm in the middle of the blade as depicted in fig below

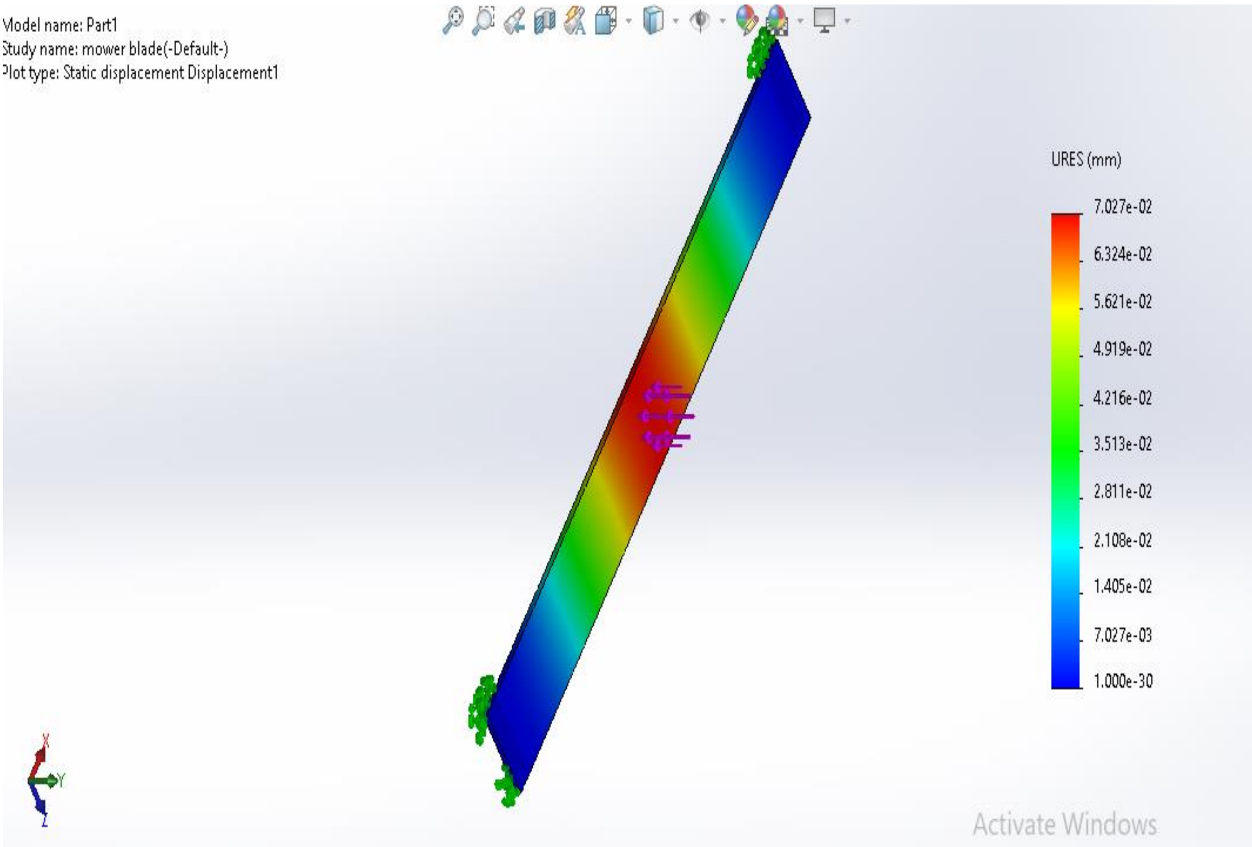

Fig 1: Displacement at the Blade

To validate the numerical results from the software, the analytical value of the calculation will be calculated. From the CAD design, the blade has dimensions 330mm ×38mm ×3mm. The weight of the blade is 3.0 N

The moment of inertia I will be;

$$I = \frac{b*h^3}{12}$$

where;

b is the width of the blade

h is the thickness of the blade

$$I = \frac{38*3^3}{12}$$

$I = 85.5mm^4$ Applying equation for maximum deflection to get the analytical value;

$$\delta_{max} = \frac{PL^3}{48EI}$$

In the above equation;

P is the load

L is the length

E is the Elastic modulus

And I is the moment of inertia

$$\delta_{max} = \frac{3*330^3}{48*200*85.5}$$

$$= 1.31mm$$

By comparing analytical results to numerical results from SolidWorks, the percentage error is

$$\% \text{ Error} = \frac{(analytical-numerical)}{analytical*100}$$

$$= \frac{(1.31-1.40)}{1.31*100}$$

= 6.87%

The maximum equivalent Von Mises stress was found in Solid Works to be 0.22MPa at the location of maximum bending moment as shown. This value is much below the yielding stress and thus the design is safe

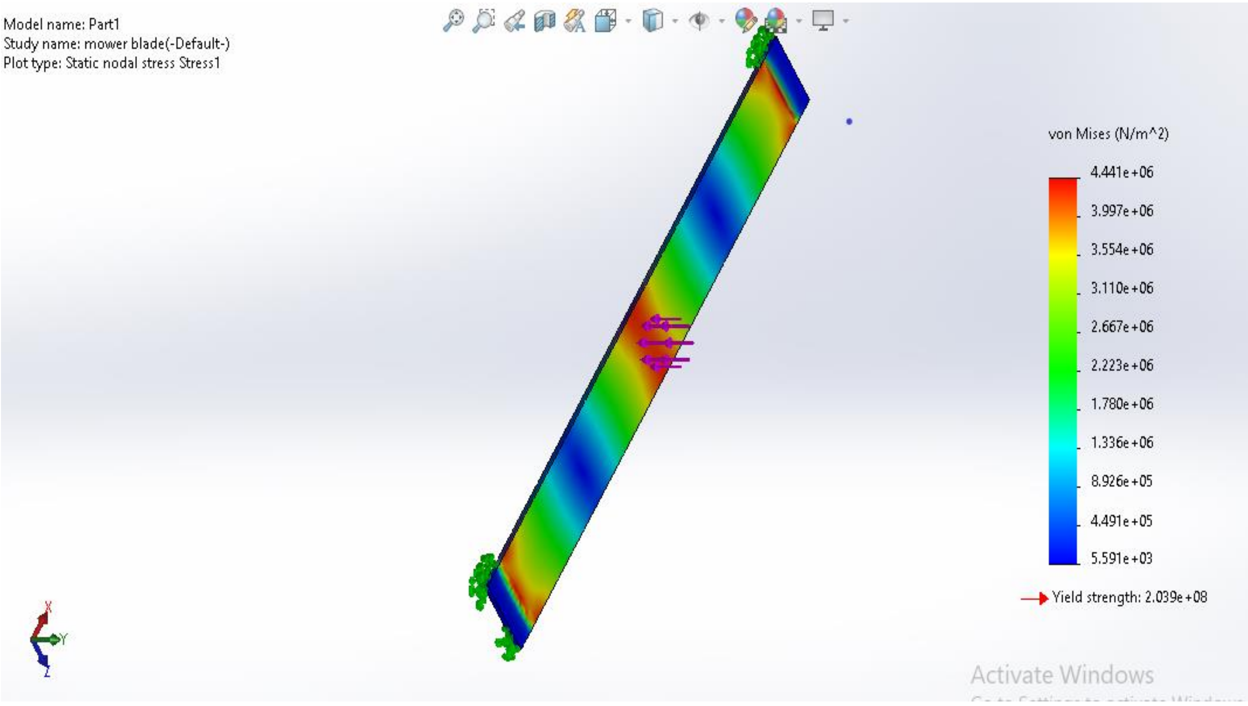

Fig 2: Equivalent Von Mises stress at the Blade

4.0. Principle of operation:

The solar powered lawn mower involves the application of solar power to charge batteries for the purpose of using it to power an electric motor which in turn actuates the blade as the mower is being propelled. When the mower blade revolves it draws air in, the air is drawn into the center of the blade, because the blade is rotating, the air is push down creating a high pressure rating of air underneath the machine. This high pressure rating creates lift, raising the mower on inclusion of air which also allows the mower to be easily maneuvered. When the mower moves the lawn mower blades which are attached to the revolving electric motor it cuts the grass. The electric circuit ensures solar energy from the sun is transferred through a charge controller to charge the battery which in turn supplies power to run the electric motor, while the solar panel power, will continuously recharge the battery while in operation. When the power switch is on, the electrical energy from the battery powers the motor which in turn actuates the blades. The solar panel generates current to recharge the battery, thereby compensating for the battery discharge. A charge controller is mounted separately used for charging the battery. The solar panel is a photovoltaic cell that generates current when light falls on its surface. 30 Watts solar panel is used to charge the battery. The electric motor forms the heart of the machine and provides the driving force for the blade. The solar panel convert Solar energy into electrical energy by photovoltaic effect and will be stored in battery. Electric energy of the battery will be converted to mechanical energy through a set of blade designed to achieve cutting operation. The electric circuit ensures the power transmission from the battery to D.C. motor. The cutting blade is connected to output shaft of the D.C. motor with the help of coupler. The motor is connected to the battery through connecting wires, in this connection on/off switch is provided to start and stop the motor. The rotating blade will continuously cut the grass and mower is propelled forward by the operator

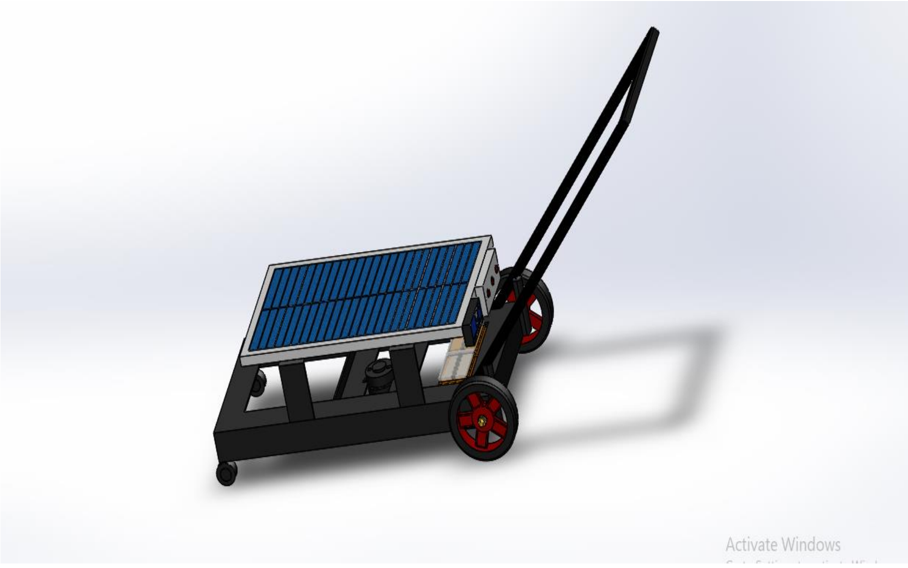

Figure 3: Solar powered lawn mower machine

4.1. Results

The solar powered lawnmower was fabricated and tested. During the machine operation electrical energy of the battery was converted to mechanical energy through the blade to achieve cutting operation. The electric circuit ensured that power was transferred from the battery to run the DC motor, while the solar panel continuously charged the battery during operation. The blade generated power from the DC motor at a speed of 3000rpm. When the switch is on, the electrical energy from the battery powers the motor which in turn actuates the blade. The solar panel generates current to recharge the battery, thereby compensating for battery discharge. The rotating blade continuously cuts the grass as the mower is being propelled. During the operation, it was convenient to cut grasses at different height using an adjustable lever mechanism attached to the deck area of the machine. Lawnmower is 93% efficient on elephant grass, stubborn grass, spare grass and carpet grass and with a good field capacity

4.2 Efficiency of the Solar Lawn Mower

The efficiency of the machine is considered based on the total area covered and time taken. The machine efficiency is calculated as shown below: The machine covers a distance of 30m in 100 seconds.

Forward distance = 30m

Time taken = 100s

Average speed = 30/100 = 0.3m/s

Field efficiency;

Theoretical Field Capacity (TFC) = average speed x Theoretical width of the blade

Theoretical width of the blade = 0.30m

TFC = 0.30 x 0.30 = 0.09m^2//s

The total area covered by the machine is 65m^2; the time taken to cover the total area is 850 seconds.

Effective field capacity (EFC) = total area covered/total time taken

= 65 m^2/850 sec = 0.076 m^2/s

Field efficiency is effective field capacity (EFC) divided by theoretical field capacity (TFC) multiplied by 100:

Efficiency= (0.076 /0.09) x 100

=85%

5. Implication for Health Facility Landscaping

Switching to solar-powered lawn mowers for health facility landscaping can have profound implications for the well-being of patients, staff, and the community as a whole. One of the most immediate benefits is the reduction in air pollution. Traditional gas-powered lawn mowers emit harmful pollutants such as carbon monoxide and volatile organic compounds (VOCs) into the air.

These pollutants can exacerbate respiratory conditions such as asthma, posing a direct threat to the health of patients, especially those with compromised respiratory systems. By transitioning to solar-powered mowers, health facilities can significantly reduce these emissions, creating a cleaner and healthier outdoor environment.

Moreover, the noise reduction offered by solar-powered mowers is particularly important for patient healing. Excessive noise can disrupt sleep patterns, increase stress levels, and hinder the recovery process. In a healthcare setting, where rest and tranquility are vital for patients' well-being, quieter lawn maintenance equipment can contribute to a more peaceful and conducive environment for healing. Beyond the physical health benefits, solar-powered mowers also support mental health and well-being. Well-maintained and aesthetically pleasing landscapes have been shown to have positive effects on mental health, reducing stress and anxiety. Patients, especially those undergoing long-term treatment, can find solace and comfort in a beautifully landscaped outdoor space maintained by sustainable methods.

The adoption of solar-powered lawn mowers also aligns with the principles of environmental stewardship. Health facilities have a responsibility to not only promote healing but also to minimize their ecological footprint. By choosing renewable energy sources like solar power, these facilities demonstrate a commitment to sustainability. This commitment can inspire patients, staff, and the broader community to consider their own environmental impact and make greener choices. Additionally, the use of solar-powered equipment presents opportunities for community engagement and education. Health facilities can host workshops or events to raise awareness about the benefits of solar energy and sustainable landscaping practices. This engagement not only promotes environmental consciousness but also empowers patients and community members to take an active role in their own health and the health of the environment.

6. Conclusion:

A solar powered lawn mower has been developed for the use of residences and establishments that have lawns where tractor driven mowers could not be used. The machine's capacity is adequate for its purpose. The machine has proved to be a possible replacement for the gasoline powered lawn mowers. The frame work of the Lawn mower was designed with mild steel for support and balancing of the system. The lawn mower motor system was designed and fabricated. The solar control system comprising of the battery, solar panel, and the charge controller was integrated into the system. The performance evaluation showed that the machine has a maximum efficiency of 85% cutting hard grasses and a maximum efficiency of 93.33% cutting soft grasses. From the result generated during the testing of the developed machine, it is environmentally friendly, in that there's zero emission of carbon monoxide and the noise generated is relatively low when compared with the noise generated by a lawn mower powered by internal combustion engine. Also, it was observed that the battery was charging during the operation provided the sun ray continues to fall on the surface of the solar panel

References:

1. Oluwatobi Akinyemi, A., Farouq Ayobami, H., & Solomon, A. (2020). Design and Fabrication of a Solar Operated Lawnmower. *International Journal of Innovative Science and Research Technology*, *5*(10), 1161–1197.
2. Satwik, D., Ramalingeswara Rao, N., & G Sreeram Reddy. (2015). Design and Fabrication of Lever Operated Solar Lawn Mower and Contact Stress Analysis of Spur Gears. *International Journal of Science , Engineering and Technology Research*, *4*(8), 2–9.
3. Bhadke, M. S. D. (2021). Design and Fabrication of Solar Operated Car. *International Journal for Research in Applied Science and Engineering Technology*, *9*(VII), 1177–1180. https://doi.org/10.22214/ijraset.2021.36307
4. Tanimola, O. A., Diabana, P. D., & Bankole, Y. O. (2014). Design and Development of a Solar Powered Lawn Mower. *International Journal of Scientific*

& Engineering Research, *5*(6), 215–220. http://www.ijser.org

5. Ajetunmobi, O. &, Bello ; Ajetunmobi, D. T., Odede, M. M., & Bello, T. (2022). Development of an Improved Solar Powered Lawnmower. *International Journal of Women in Technical Education and Employment (IJOWITED)*, *3*(1), 12–18. https://fpiwitedjournal.federalpolyilaro.edu.ng
6. W. A., I., B, A., R. O., A., I. N, O., J. O., F., & O. B., O. (2020). Design, Fabrication, and Testing of a Movable Solar Operated Sprayer for Farming Operation. *International Journal of Mechanical Engineering and Technology (Ijmet)*, *11*(3), 6–14. https://doi.org/10.34218/ijmet.11.3.2020.002
7. Rajput, R.K. (2010) Material Selection In Engineering, Ketaria And Sons Publishing Co.ltd, New Delhi.
8. Vigneshwaran, M., Kannan, A. N., Adhithyan, S., Krishna, S. G., Sakthivel, J. K., & Saran, S. A. (2023). Design and Fabrication of Smart Electric Bike. *AIP Conference Proceedings*, *2914*(1), 609–646. https://doi.org/10.1063/5.0175942
9. Dauter, Z. (2006). Research Papers Research Papers. *Acta Crystallographica Section B*, *356*(4), 867–876.
10. Tahir, T., Khalid, A., Arshad, J., Haider, A., Rasheed, I., Rehman, A. U., & Hussen, S. (2022). Implementation of an IoT-Based Solar-Powered Smart Lawn Mower. *Wireless Communications and Mobile Computing*, *2022*.

    https://doi.org/10.1155/2022/1971902
11. Jabbar, M. W., Noman, M., Muneer, A., Abbas, A., & Mazhar, A. (2022). Solar Powered Grass Cutter for Domestic Utilization †. *Engineering Proceedings*, *12*(1), 8–12. https://doi.org/10.3390/engproc2021012105
12. Sharma, M., & Yadav, D. (2022). Design and Fabrication of Solar Powered Agricultural Pesticide Sprayer. *Advances in Behavioral Based Safety*, 283–291.

    https://doi.org/10.1007/978-981-16-8270-4_21