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Design and Construction of Automated Lawn Mower

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***Abstract*— Existing lawn cutting machines suffer from more than one of the following; high initial cost, high levels of engine noise, high running cost due to high fuel consumption rates, need for perimeter wires around the field to be trimmed and high operator's fatigue in long-run due to vibration, noise and other characteristics caused by different types of lawn. Hence the need for a system that can achieve the same cutting effect has the existing lawn mowers with little or no operator's fatigue, minimized noise pollution and running cost. In this paper we describe the design and construction of an automated lawn mower, a device that cut grass automatically with little human intervention using a linear blade driven by a robotic car which is powered by a battery that uses dual charging system, namely solar energy and AC supply. Ackermann steering is used for the robotic car in this device; it has proximity/sensor which it uses to detect and avoid objects while mowing. It can be operated in semi-autonomous and full autonomous mode with minimized running cost, no health hazard on the operator and it does not have any effect on the environment. The prototype was tested and it shows lawns can be cut whilst eliminating exposure of users to unhealthy conditions.**

***Index Terms*—** lawn cutting machine, semi-autonomous mode, Ackermann steering, operator's fatigue

I. Introduction

LAWN mowers designed by Edwin Beard have been in existence since the early 1800s [1]. Machines for grass cutting is popular amongst workers in agriculture, gardening, landscaping, horticulture, etc. There are conceptually two types of mowers: the reel/cylindrical and the rotary mowers. The cylindrical mowers are made up of blades mounted on a rotating cylinder that produces clean trim by scissors action.

For its operation, a stationary metal bar known as bed knife is placed on the ground, Grass is cut by the shearing action of the blade(s) against the bed knife. Rotary mowers are usually powered either by an electric motor or an internal combustion engine and are generally moved manually, leaving the engine or motor to rotate cutting blades [2]. Despite the obvious advantages of lawn mower, noise and vibration are two of the associated health hazards while using manually propelled type, which may have irreversible impairment on human health. In workplaces there are health and safety requirements for those affected by noise and vibration, but for public or occasional users there is no legislation mitigating against the potential health hazards for vibration.

Lawn maintenance workers generally spend about nine (9) hours exposed to sound levels above 85 dB, and only a few employees wear hearing protection [1]. Some of the works done on health hazards resulting from lawn mowers and possible improvements are briefly discussed. [3] investigated noise produced from cutting blades, noise levels at different frequencies and possible solutions for damping the vibration of cutting blades and made comparisons on the risk factor associated with workers working on different lawn maintenance machines. These health challenges are overcome by the use of autonomous lawn cutters. It reduces human intervention to remote control mechanism, completely expunging a user from the hazardous noise, vibrations and possible fumes that manual machines produce. A further improvement is the predominant use of DC motors and batteries as against internal combustion engines. [4] developed a lawn mower that needs no human interaction except when its being placed in the work area. The machine uses sensors to provide a microcontroller within cutting area, and the machine determines the path to take, evaluate its position and stops once the task is accomplished. [5] produced a survey on robotic lawn mowers and enumerated their comparative advantages over one another.

Although existing lawn mowers perform the task of trimming lawns, their operations are accompanied by health hazards. However, the invention of automated lawn cutter helps reduce high-level noise and operator's fatigue experienced by use of pre-existing lawn cutting machines. There are different models produced commercially and they are available for purchase, but these lawnmowers require a boundary wire to be installed around the perimeter of the lawn area. [6] came up with a concept that eradicates the use of perimeter wire for a robot car with the use of sensors for obstacle detection and avoidance. [7] developed an automatic lawn cutter that employs the use of different sensors to detect and avoid objects and humans while working. The user specifies the area to be mown and the desired lawn height through the use of a keypad. [8] developed an autonomous lawn mower but retains the ability to be used manually where users specify how the lawn should be mowed. This is done using Dual-tone multi-frequency signaling (DTMF) over the GSM network. The mower was equipped with GSM module. When in the automatic mode, it requires no perimeter wires to keep the

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robot within the lawn, and requires very little human effort for operation. [9] developed an automatic mower with four different sensors, giving the mower greater flexibility. [10] investigated and modeled a lawn cutter that will also gather the cut grass, rather than have human workers clean the lawn after mowing. [11] built a lawn mower that uses two (2) mobile phones, one in the mower, and the other with the user. The mower is controlled via the tone from the user's mobile phone using DTMF. [12] developed a prototype that uses a camera rather than sensors in obstacle detection and avoidance. [1, 13, 14, 15, 16] all developed autonomous lawn mowers with differing peripheral apparatus, but all based on the same concept.

II. Methodology And Materials

The components used in the work are: diodes, resistors, relays, LM7805, PIC16F876A, resistors, SIM 800 GSM module, transistors, IFR3205, relays, 4Mhz Crystal oscillator, 9w DC motor, 2 units of18W DC motor, plastic casing, mild steel blade, 1/4" bolts and nuts, 16 x 2 LCD display, push buttons, transistors, MOSFET, 2 units of 18Ah batteries, solar panel, ultrasonic sensor, wheel encoder.

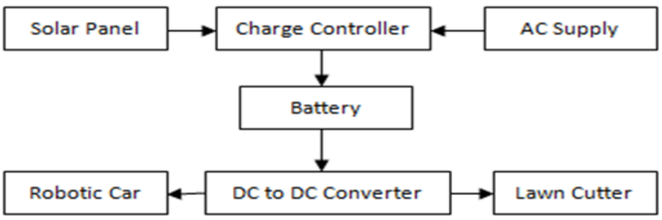

Fig 1: System's Block diagram

These components were combined according to the block diagram Figure 1. The circuit in Figure 2 was designed and simulated using Proteus®software. It provides both driving force and control for the system.

The automated lawn mower in this study is made up of a robotic car and a lawn cutter. It is powered by a battery which can be recharged using both solar and mains power supply. The robotic lawn cutter has a solar panel mounted on it so that it can receive rays with high intensity from the sun.

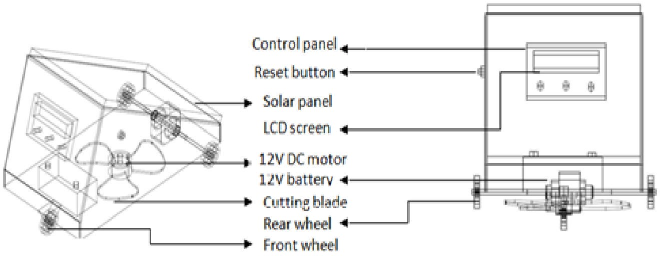

Fig 3: Isometric and front view of the automated lawn cutter

The storage of electrical energy in batteries is engendered by solar charger, the charger raises the current from the panels to speed up the charging process. It also disconnects the solar panel from the batteries when the battery is fully charged. Direct current from the battery is regulated to 5V as required by the microcontroller and relays, and 12V for the DC motors. The microcontroller receives input either from an operator remotely, push buttons, ultrasonic sensors and the battery and its action is based on the data received. Energy from the battery is converted to mechanical energy by the rear DC motor to propel the robotic car, the front DC to steer the robotic car and through a set of mild steel blades designed to achieve cutting operation. The batteries power a set of blades mounted under the robotic car to cut the lawn. The cutting blades tap power from the D.C. motor. 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. The rotating blades continuously cut the grass as the mower is propelled

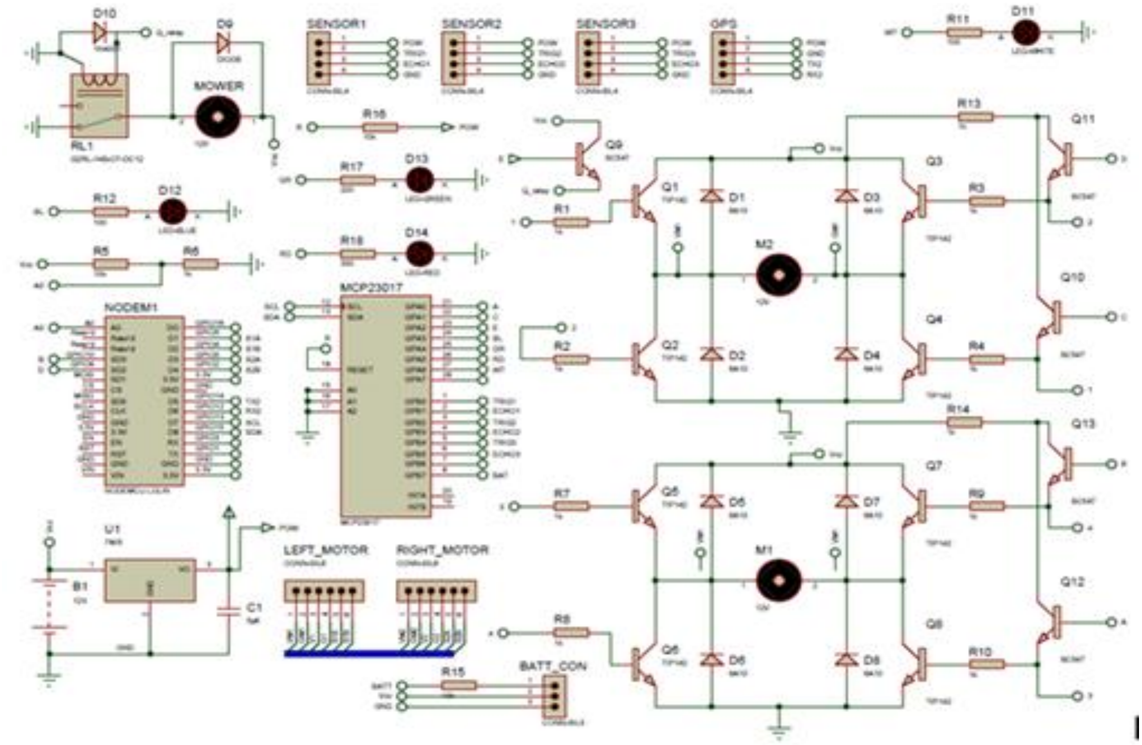
Fig 2: Circuit Diagram (bus design)

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forward. The operator is requested to enter the dimension (length and breadth) of the field to be mown. This can be done remotely or on the device using the push button. After which a run button is selected for the device to starts its operation.

The shearing force of most annual and perennial grasses found on most lawns is usually between 9.2N - 11.51N [1]. Let F be the force required to cut grass by the cutting blade.

$$F = \frac{T}{R} = \frac{T}{d/2} \quad (1)$$

where T = the shaft torque, R = radius of the rotating cutting blade and d = diameter of the cutting blade. But shaft torque is given by:

$$T = \frac{P}{\omega} \quad (2)$$

where ω is the angular velocity.

$$\rightarrow \quad T = \frac{P \times 60}{2\Pi N} \quad (3)$$

where P is the power developed by shaft, T is torque required to turn the blade and N is its shaft speed in rev/min. The selected properties of the DC motor used in the project are 18W, 12V with 30 RPM speed. This gives a torque of $5.73 \times 10^3 Nmm$. The shaft is made of mild steel with allowable shear stress of 42MPa. Therefore, using:

$$T = 42 \times 3.142 \times \frac{d^3}{16} \quad (4)$$

Then according to Equation (4), the required diameter is 8.85 or 9mm. The solar panel charging time is determined by solar panel power rating of 30W and the two batteries with rating of 12V, 8AH each connected in series. But actual power output of the solar panel (A_P) used is the product of peak power rating and the operation factor, hence A_P = *25.5W*. and the current supplied by solar panel is $25.5W / 12V = 2.125A$. Thus, the time required to charge the battery is $16Ah / 2.125 = 7.5h$.

Figure 4 shows the unlabeled aerodynamic design of the device revealing the positions of its key components and its conceived direction of operation.

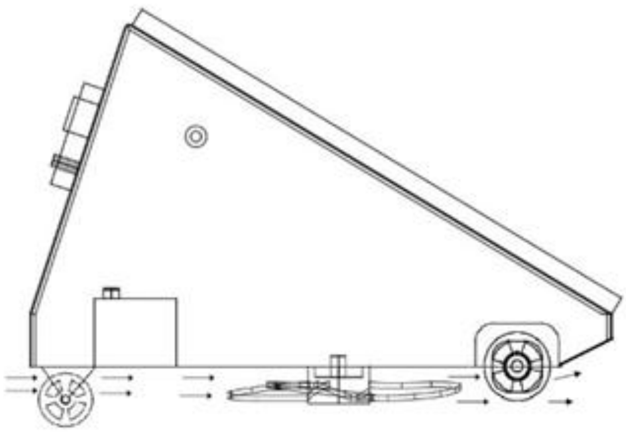

Fig 4: Aerodynamic consideration in design

The 3-D design of the automated lawn mower is as shown in Figure 5. It shows the detailed peripheral features of the mower. The Figure revealed the preconception of the detailed structure of the grass cutting machine.

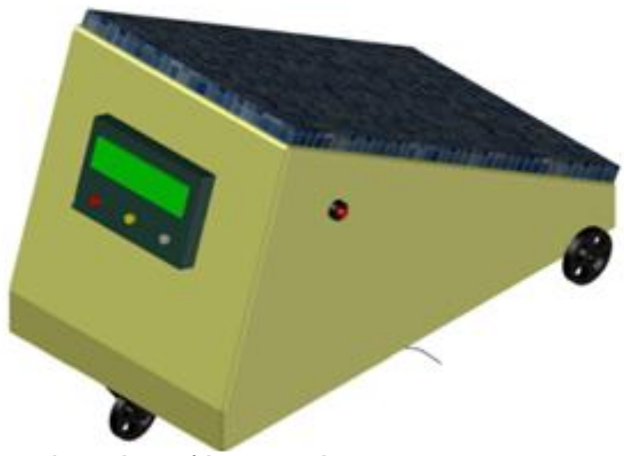

Fig 5: The 3-D design of the Automated Lawn Mower

The device is so shaped in order to reduce the effect of drag force (F_D) given by Equation (5), viz:

$$F_D = \frac{1}{2} \rho v^2 C_d A \quad (5)$$

where ρ = density of the medium the automated lawn cutter is travelling, in this case air. Density of air is a function of the atmospheric temperature, if the temperature is $30^o c$, then from engineering toolbox, ρ at $30^o c$ is $1.165 kg/m^3$. Given that C_d is the drag coefficient, then C_d contains all the complex dependencies and its usually determine by experiment. Suppose A (= 0.44 x 0.02 = $0.0088m^2$) is the reference area, then, A is the area perpendicular to the direction of motion of the vehicle. But

$$F_D \propto v^2 A \quad (6)$$

Thus, according to Equation (6), a reduction in reference area translates to reduced drag. Hence the reason for the shape and slant front surface

Down force is the same force as the lift, only it acts to press down instead of lifting up. The underside of the automated lawn cutter is its designed down force. In accordance with Bernoulli's principle, if the device front end is lower than the rear end, then the front end restricts the air flow under the device and the widening gap between the underside and the field creates a low pressure area. If there is a neutral or a higher air pressure above the device, then down force is recovered due to the difference in the pressure above and below the car.

III. Results And Discussion

In this work, we design and constructed an Automated Lawn Cutter that can cut lawns without the need of building an obstacle or boundary wire round the field to be mowed. It has a little running cost with no harmful effect on the environment. Figure 6 below shows the aerial view of the constructed automated lawn cutter revealing the placement of the solar panel used to collect rays of light from the sun. Figure 7 is the side view of the constructed Automated Lawn Mower clearly gave an exposition of the aerodynamic features of the system.

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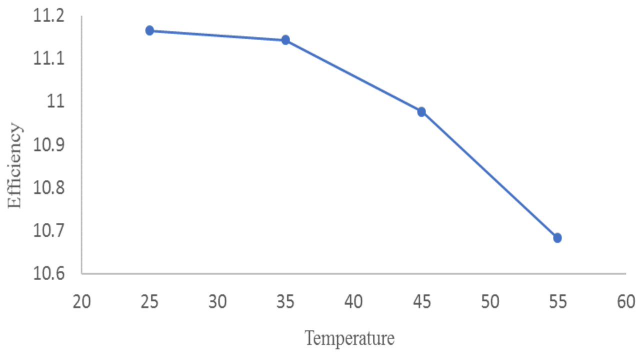
Fig 6: Aerial view of the constructed Automated Lawn Mower

Fig 7: Side view of the constructed Automated Lawn Mower

For the energy consideration, the automated lawn cutter is powered by solar energy captured by a solar panel. The panel powers the device and stores the excess energy in a battery which is used to power the system when sun energy seizes. The battery can also be charged with alternating current (AC) from the grid via an adaptor (a rectifier). The rectifier is a transducer which converts electrical energy from AC to direct current (DC).

Figure 8 summarizes the relationship between the rates of charging of the battery of the automated lawn cutter and the angle of incidence of the sun rays. The result was achieved by employing solar cell simulator with cell temperature in the range 25–55 °C at constant light intensity. The results from Figure 8 clearly show that the cell temperature has a significant impact on photovoltaic parameters and it controls the quality and performance of solar cell. This is achieved by varying the angle of inclination of the solar panel. The solar panel charges optimally when it is placed at right angle to the direction of the sun rays. The charging rate decreases as the angle of inclination deviates from right angle.



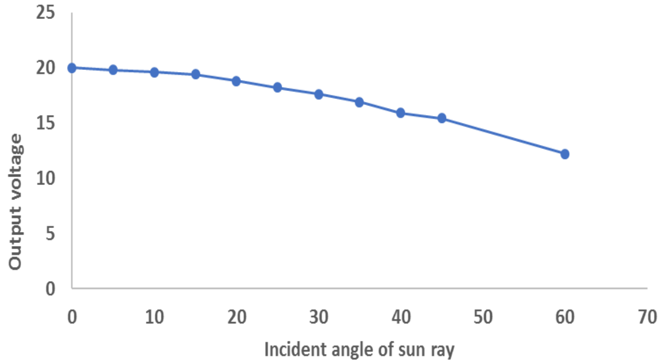


Fig 8: Relationship between the Efficiency of solar cell and Temperature

The solar panel is mounted in a way to reduce the temperature. Thus:

$$\eta = \frac{Pm}{Pin} = \frac{Vm \text{ x } Im}{I(t) \text{ x } A} = \frac{Ff \text{ x } Voc \text{ x } Ioc}{I(t) \text{ x } A}$$

where *Pin* is input power, *I*(*t*) is the light intensity [the light intensity may be defined as irradiance (*E*)], *A* is the surface area of silicon solar cell, *Ff* is the filling factor, *Pm* is the maximum power, *Vm* is the maximum voltage attainable while *Im* is the maximum current

The relationship between the angle of incidence of sun ray and output voltage of the solar panel is summarized in Figure 9 above. The panel charges optimally when the panel is at right angle to the direction of the sun rays and the angle of incident is zero. The efficiency of the solar panel decreases as the angle of incident increases. In summary Efficiency is inversely proportional to increasing angle of incidence of solar panel.

From Figures 8 and 9 above, it is clear that the efficiency of the charging system (solar) depends largely on the positioning and mounting of the solar panel. Hence, the solar panel is mounted in a way to prevent heating up of the panel

IV. Conclusion

This work involved complete development of an automated lawn cutter which is an eco-friendly device that cut lawns without the need to build boundary wire as a fence around the field to be mowed. It has a minimal noise level and does not have any known negative effect on either the environment or the operator. It has no harmful effect on the operator. It can be operated with minimal human supervision and it is cost effective. The only imperfection observed during testing was the device’s inability to achieve

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fine cut in a region where grass population is very high. However, the imperfection can be corrected by making the cutting blade adjustable. In the nearest future, a deformable robotic car can be design so that the vehicle can be used on any type of field

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BIOGRAPHY

Ajibola Olawale Olaniyi Emmanuel received BSc (Hons) in Mathematics from University of Ibadan, Nigeria in 1990, both MSc in Engineering Analysis and PhD in Systems Engineering in 1995 and 2009 respectively from University of Lagos also in Nigeria. He is the Dean of the Faculty of Engineering and Technology, First Technical University, Ibadan, Oyo State, Nigeria; immediate past Chair of Department of Biomedical Engineering at the College of Medicine of the University of Lagos and, Senior Lecturer and immediate past Coordinator of Postgraduate Programmes at the Department of Systems Engineering, Faculty of Engineering, University of Lagos, Lagos, Nigeria. His research interest spans Bioinspired Modelling and Simulations, Development of portable but cost effective biomedical devices; Rehabilitation Medicine, Engineering Education and Energy Engineering. He has published widely both in National and International Journals. He is a member of Biomedical Engineering Society (BMES) in the USA, and International Association of Engineers (IAENG), Hong Kong, and he is a registered member of the Council for the Regulation of Engineering in Nigeria (COREN).

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