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Development of an Improved Solar Powered Lawnmower

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Abstract

The need to develop, a user friendly, environment friendly, less noisy, less weighty lawnmower, led to this research on the development of a solar powered lawnmower. It was aimed at developing a solar powered lawnmower, which was achieved by designing, fabricating and testing the solar powered lawnmower system. The frame of the mower was made up of mild steel and the blade of the mower was made up of stainless steel, because of its strength and transmits a relatively high mass and speed form the motor. The motor used for transmitting enough speed to cut grass, was a 12V, 1hp, 3,500rev/min motor. Von-misses stress analysis was carried out on the blade to ascertain its strength during operation, using creo-parametric software. The performance evaluation on the machine showed that the mower battery lasted longer, charged fast, and had a low weight compared to the conventional ones.

Keywords: - Creo-Parametric, Design, Fabrication, Lawnmower, Solar, Von-Misses.

Citation
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Introduction

Grass is a leave, which might either be herbaceous plants or monocotyledon plants that grows from the ground in various areas of our environment (Pratik, 2014). There are different types of grasses that exist in nature; depending on the grass family, may be short or tall. They also serve as food source to some certain organisms and creatures, and furthermore serve as a source of oxygen to man and other living things for breathing. However, if not well maintained those grasses might cause obstruction and some issues in nature. Maintaining grasses could be in form of cutting or reducing the grass to a worthy level. Previously, sickle, hand shear and cutlass were used for grass cutting. Nowadays, with evolving mechanical technologies, innovations of cutting grasses has been adopted. One of such techniques is the utilization of rotary lawnmower. Lawnmowers have been in use over a long time, with its first development dating as far back as 1830 (khurmi, 2005). A rotary lawnmower is defined as a machine that utilizes a spinning sharp edge to cut grasses at equivalent statures, (Mabesh, 2014)additionally defined a rotary lawnmower as a machine that comprises of rotor, engine and cutting edges used to slice grass up to some measurable heights that can be changed by the plan measures of the cutter edges

Methodology

Design Consideration

In order to ascertain the effective and efficient development of the solar powered lawn mower, design considerations were put in place. The blade geometry, blade material, r.p.m considerations, the power rating of the solar panel are essential in obtaining a good fabrication process of the machine. Considering the geometry of the machine, and in order to have a smooth operation, the blade to be used is a flat shaped blade. Flat shaped blade is preferred, because in the designed, to provides enough lift to cut the grass

adequately and evacuates the deck area conveniently. There are other blade shapes like tapered blade and sickle bar blade which are good for operation, but flat blade is preferred for this development process because of its mass which is suitable considering the size and weight of the machine and speed of the motor. Compared to flat blades, tapered and sickle bar blades have better cutting pressure but although, have relatively low mass. In order to prevent the blade from wobbling during operation, the shaft rotating the blade has a high mass so the blade has to have a relative high mass. Stainless steel material was chosen for the flat blade. It transmit relatively the same speed as that of the electric motor, which is required for smooth evacuation of grass from the deck area. Mild steel, stainless steel and angle bar iron are also suitable for this development. But stainless steel has higher resistance to corrosion and has high strength.

Selection of Electric Motor

In-order to have a smooth grass cutting, a motor power of not less than 628.3W (0.84hp) having 3,000 rev/min rotational speed and cutting force of 10.5N was recommended (Tanimola, 2014).

Cutting Blade and Motor Design

In designing the cutting blade, the force required to cut most annual and perennial grasses was considered to be in the range of 9.2N – 11.5N (Yong and Chow, 1991) and is also dependent on the height, density and the area covered by the object.

For the selection of material for the blade, stainless steel was used. Based on its strength and weight which can transmit speed as that of the DC motor or little less due to friction. Stress analysis was done on the mower blade using Creo Parametric 5.0 in order to ascertain the strength of the material under loading. The stress analysis done on the mower blade, wasto understudy its behavior during operation. The figure 1 shows the deformation on the blade towards the edge of blade, during cutting operation.

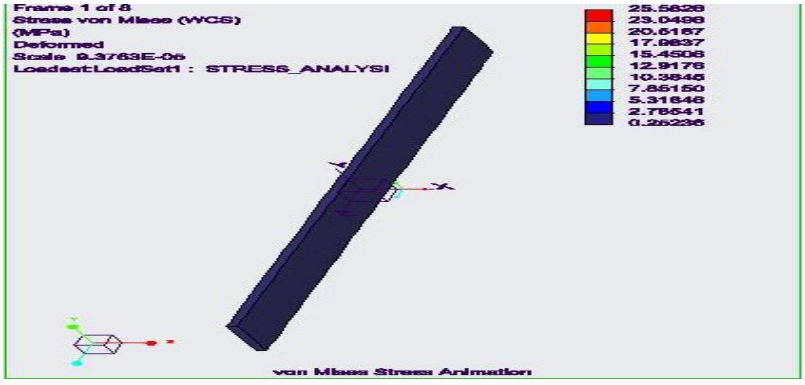

Figure 1: Von_Misses Stress Analysis

Design Calculation

Dimensions for the Blade
Blade Length = L = 480 mm = 0.48m
Blade Breadth = 55mm = 0.055m
Blade Thickness = T =4.9mm = 0.0049m
The Electric Motor Speed = N = 3000 rpm
Stainless Steel Material Density = ρ = 7850 kg/m^3
Acceleration due to gravity = g = 9.81 ms^{-2}

Mass of Blade

Area of blade =Width × Length(1)
Blade Mass = Volume × Density(2)
Stainless steel density,(Singh, 2005) is 7850kg/m³.
From equation (1); Area of blade = 0.48m × 0.055m = 0.0264m²

Volume of blade = Area of blade × Thickness (3)

Volume of blade = $0.0264m^2 \times 0.0049m = 0.00013m^3$
From equation (2); Mass of blade = 7850×0.00013
= 1.021 kg

Weight and torque on the cutting blade

Blade weight, W = Blade Mass × Acceleration due to gravity (4)
Where, M = Blade Mass = 1.021Kg
Acceleration due to gravity = 9.8 m/s^2
Therefore, W = Mg = 1.021 × 9.81 = 10.02 N
Hence, the blade torque (T) produce by the blade is given T = W × r (5)

Where, W is the radius of the blade r = $\frac{480}{2}$ =

240mm = 0.24m
Therefore, T = W × r = 10.02 × 0.24 = 2.4Nm

Angular Velocity

Angular Velocity (ω) = $\frac{2\pi N}{60}$ (6)

Where recommended motor speed should not be lower than 3000rpm (Tanimola, 2014).

Angular Velocity (ω) = $\frac{2 \times 3.142 \times 3000}{60}$ =

314.20 rads/sec
Motor Power Required
Power = Torque of Cutting Blade × Angular Velocity = $T \times \omega$ (7)
Power = 2.4 × 314.20 = 754.08 W = 1.01hp
Therefore, 1hp rating of motor is required, since 1hp is 746W.

Battery Selection

The voltage and current required for the electric motor to function properly, has to be considered in the selection of battery, in order to have a good performance of the machine. 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 200Ah battery was selected

A 12V, 200 Ah battery was selected for greater efficiency.

Design Power = $\frac{current \times voltage}{PowerFactor}$ [2]. (8)

Current = $\frac{Power \times PowerFactor}{Voltage} = \frac{746 \times 0.8}{12}$

= 49.73A (9)

Solar Panel Selection

Essential factors are to be considered when selecting a solar panel like; the battery capacity, the average sun hours, the current drawn, the mower operation duration. The solar panel used for the solar lawn mower was a 12V, 60Watts panel because of its functionality and the battery also used was 12V battery which has higher efficiency provided. There are three basic types of solar panel; polycrystalline, monocrystalline ,and amorphous solar cells. Monocrystalline was used for this development, because it has lesser silicon crystals and provides adequate spacing(Adubika, 2020).

Considering the required power and voltage of the solar panel;
Power = 60W, Voltage = 12V

Required current = $\frac{Power}{Voltage}$ (10) = $\frac{60}{12}$ = 5Ah

Hence, solar panel requires 5amps.

Design of the Frame

Considering the strength, workability, availability and cost effectiveness, mild steel plate was used in the construction of the frame. The frame made-up of mild steel weighing 15kg, in which an electric motor of 2.9kg weight is attached on the deck area for adequate support and smooth operation. The diameter of the deck was 510mm and height 110mm. The deck was designed to be adjusted at four different heights, for

convenience during operation. They transmitted a load of 17.9kg to the wheel equally and length of each was 690mm.

Design of Handle Frame

The required tilt angle of a mower should not be less than 45 ° (Basil, 2013). The tilt angle of handle frame was 55 ° for convenience of the operator. It has a height of 859mm from the ground level for convenience according to (Akene, 2020) and the a pipe bending machine was used to bend the mild steel material of 2mm thickness to form a diameter of 19mm. The solar panel was located on the peripheral of the handle, and the weight of the solar panel was 6kg. In order to couple the solar panel with the frame for convenience of the operator, a length of 911mm tilted at an angle of 55° was chosen.

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	MOWER HOUSING	
2	2	TIRE (BACK)	
3	2	TIRE (FRONT)	
4	1	MOWER HANDLE	
5	1	MOWER MOTOR	
6	1	MOWER BLADE	
7	1	MOWER BATTERY	
8	1	MOWER BATTERTY COVER	
9	1	MOWER SOLAR GUIDE	
10	1	SOLAR PANEL	

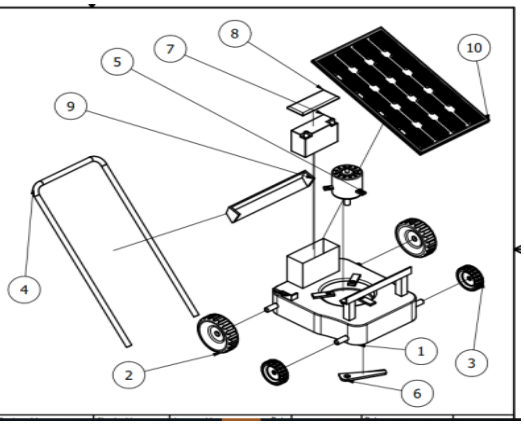

Figure 2: Exploded View of Solar Powered Mower

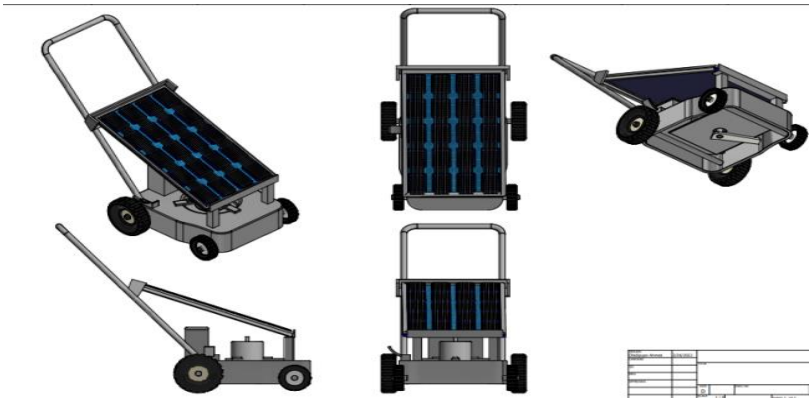

Figure 3: 3-D View of Solar Powered Lawnmower

Result Analysis and Discussion

The figures 4, 5, and 6 shows the pictorial view of the fabricated solar powered lawnmower. The machine was subjected to testing based on stubborn and soft grasses, with respect to time. The performance evaluation was carried out by marking the areas to be cut, with meter rule and also timing the machine movement with a stop watch.

Figure 4: Pictorial View 1 of Solar Powered Lawnmower

Figure 5: Pictorial View 2 of Solar Powered Lawnmower

Figure 6: Pictorial View 3 of Solar Powered Lawnmower

Result Analysis

The charts in figures 7,8,9, and 10 shows the analysis of the effect of area cut and time on the performance of the machine using the stubborn and soft grasses. The result showed increase and decrease at different area cut and time on both stubborn and soft grasses.

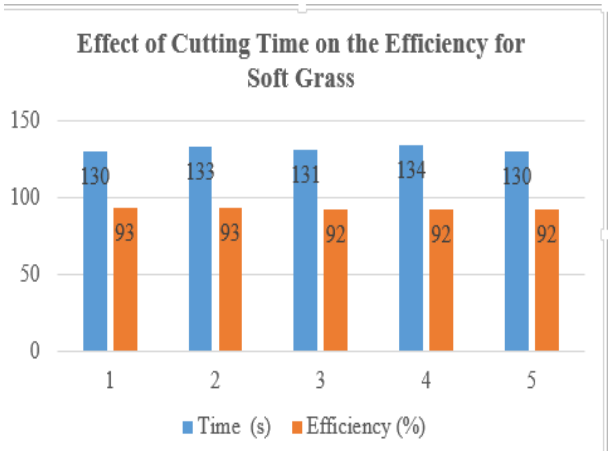

Figure 7: Effect of Cutting Time on the Efficiency for Soft Grass

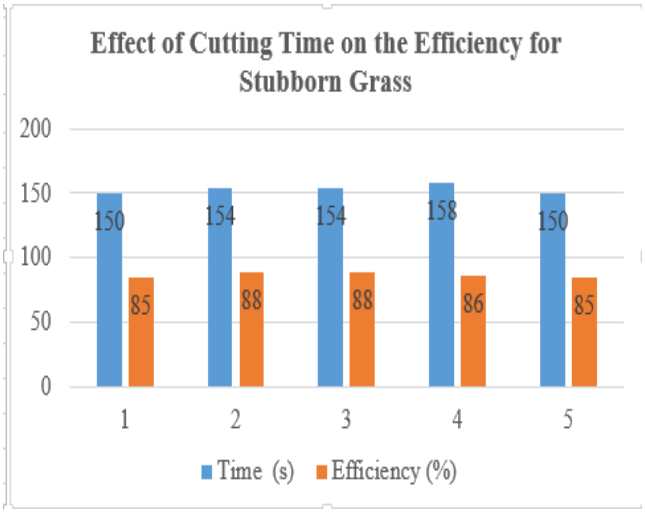

Figure 8: Effect of Cutting Time on the Efficiency for Stubborn Grass

Discussion

The charts showed the effect of time and portion cut on the efficiency of the machine at different conditions of cutting stubborn and soft grasses. It showed that there was corresponding increase in the efficiency of the machine, with corresponding increase in area cut for both stubborn and soft grasses. Also, there was an increase in the efficiency of the machine, with decrease in cutting time of both stubborn and soft grasses. Therefore, an increase in the area cut, increases the efficiency of the system. While a decrease in cutting time of the machine increases its efficiency. The total weight of the machine is 23.60kg which shows that it has a lesser weight than the conventional gasoline powered lawnmowers which has weight of 39kg and above. Hence requires lesser

effort of the operator to push, thereby enabling the operator push for longer duration and covering more distance with lesser time. Therefore, producing a better efficiency.

Conclusion

The frame work of the rotary Lawnmower was designed with mild steel for support and balancing of the system. The lawnmower 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 had a maximum efficiency of 88% cutting stubborn grasses and a maximum efficiency of 93.33% cutting soft grasses. The test carried out also showed that the battery charges for 30minutes and discharges for 70minutes. The total weight of the machine is 23.60kg.

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