# DEVELOPMENT OF AN IMPROVED SOLAR POWERED LAWN MOWER

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**Abstract:**

As a result of the continuous hike in the cost of gasoline and the adverse effect caused by the emission of greenhouse gases from the burnt fuel into the atmosphere, this necessitated the use of the abundant solar energy from the sun as a source of power to drive a lawn mower. A solar powered lawn mower of 0.109 $m^2/s$ field capacity was designed and developed for operational convenience. It is made of a solar panel of 75A/100W capacity which charges the battery of the mower. The solar panel is connected to a charge controller that prevents complete discharge or overcharge of the battery. The designed solar powered lawnmower comprises of a DC electric motor, a charge controller, a rechargeable battery (12V, 100Ah), solar panel (100W), a stainless steel blade and control switch. Mowing is achieved by the DC motor (3500rpm) which provides the required torque needed to drive the stainless steel blade which is directly coupled to the shaft of the motor. The solar powered lawnmower is operated by the switch on the board which closes the circuit and allows the flow of current to the motor which in turn drive the blade used for mowing. The battery recharges through the solar charging controller. Performance evaluation of the developed machine was carried out with different types of grasses. The machine was found to have a field efficiency of 96.7% which demonstrated ease of use as well as neat mowing of the grasses as blade height was adjusted for the desired height of cut.

**Keywords:** Solar energy, lawnmower, field efficiency, DC motor

## 1. Introduction

Lawn maintenance and landscaping remain one of the most important constraints from keeping clean and fresh looking gardens and yards (Ogiemudia et al., 2016). Man is constantly trying to adapt to his environment/surrounding by creating a habitat suitable for his survival. The natural environment which modern man reside, is usually covered with vegetation which includes forest trees or grassland (Atkins 1984). As man evolved intellectually, much effort has and will continue to be expended to improve the state/condition of his habitat for various purposes (security or aesthetic value).

A lawn mower is a machine that uses one or more revolving blades to cut a grass surface to an even height (Ahmad 2009). The blades are powered by pushing the mower forward to operate the mechanical blades, by an electric motor, or a standard internal combustion engine to spin the blades. Some mowers also include other functions, such as mulching the cut grass or collecting their clippings in a bag. Different styles of blades are used in lawn mowers. There are several types of mowers, each suited to a particular scale and purpose.

Nowadays, pollution is a major issue for whole world. Pollution is manmade and can be seen in the environment mainly resulting from the burning of fossil fuels as in the case of standard internal combustion engine lawn mowers due to the emission of the greenhouse gases from its engine exhaust and thereby resulting in global warming. Also the cost of the fuel (petroleum products) is increasing making it less economical to make use of as a source of energy. Hence, the solar powered lawn mower is to be introduced as a substitute for the common standard internal combustion engine lawn mower. Solar powered lawn mower can be described as the application of solar energy to power an electric motor which in turn rotates a blade which does the mowing of a lawn.

Solar energy is a renewable resource. A renewable resource is a resource that is able to be replaced or replenished, either by the earth's natural processes or by human action. Solar energy is available at varying proportions almost everywhere on earth. It cannot be depleted unlike the fossil fuel based energy resources. Solar energy is a “clean” energy resource. It does not involve the emission of greenhouse gases that are believed to be responsible for the worsening global warming of our planet, Earth.

The solar powered lawn mower is developed to address a number of issues that standard internal combustion engine mowers has. It will eliminate the emission of greenhouse gases of an internal combustion mower which is mostly responsible for environmental pollution and causes the green gases effect. Different designs have been made, each to suit a particular need or convenience. The solar powered lawn mower is designed to control the height of the cut-grass making use of a leadscrew.



## 1.1 Purpose of Study

In this research, a solar powered lawnmower was designed, fabricated and the performance evaluated.

## 1.2 Literature Review

Basil Okafor (2013) designed a lawn mower is made up of an induction motor, a battery, an alternator, two collapsible blades, and a link mechanism. Speed of blade shaft is increased by an arrangement of a speed multiplication pulley system mounted on a steel platform. The power and charging system comprises of an alternator which charges the battery while in operation. The use of collapsible blades and incorporation of an alternator for recharging the battery make the design unique such that no engine is involved. The major weakness of the machine is that the battery discharges easily due to the power drawn by the motor and there is need for a more efficient means of charging it other than the alternator.

Tanimola et al. (2014) designed a solar powered lawnmower which comprises of a DC motor, a rechargeable battery, solar panel, a stainless steel blade and control switch. Mowing is achieved by the D.C motor which provides the required torque needed to drive the stainless steel blade which is directly coupled to the shaft of the D.C motor. The battery recharges through the solar charging controller. The machine was found to be highly efficient because of the components used with an efficiency of about 93%. The weakness of the machine is such that the operational time of the machine at battery full charge is low.

Ramalingeswara and Satwik (2015) developed a lever operated solar lawnmower which has a spur gear displacement mechanism in which rotor blade height can be adjusted. Arduino board is used to control the speed of the motor manually and an anti-collision sensor is also placed in front of the machine to prevent collision. The weakness of the machine is such that the battery charging time is too long.

## 2. Methodology

### 2.1 Design Concept

In carrying out the design, several considerations were made which include the shape of the blade, material of the blade, the speed of rotation of the electric motor, the size of the frame, the power rating of the solar panel and the output capacity of the battery. Solidworks software was used for the CAD design and also for the structural analysis of the frame. The conceptual design, exploded view and sectional views of the machine are shown in figures 1–3. The components of the machine are mounted on the metal frame which serves as the support of the machine. The blade is attached to the shaft of the motor and the motor is connected to the battery. The solar panel is mounted on the frame and it is also connected to the battery and charge controller.



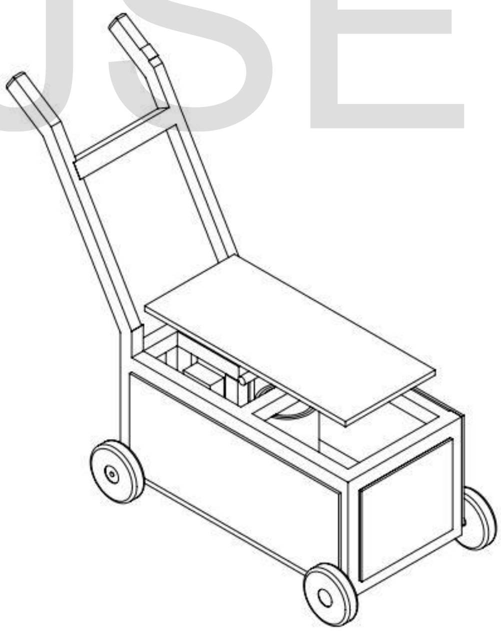


**Figure 1: Isometric View**

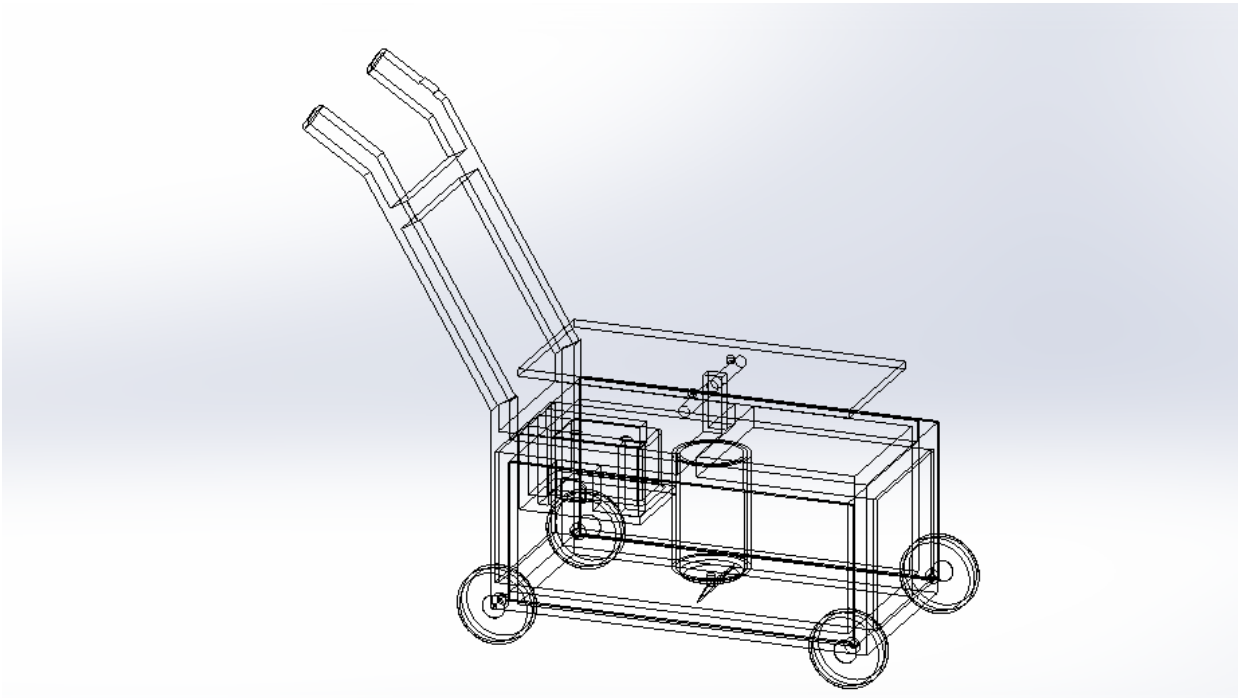
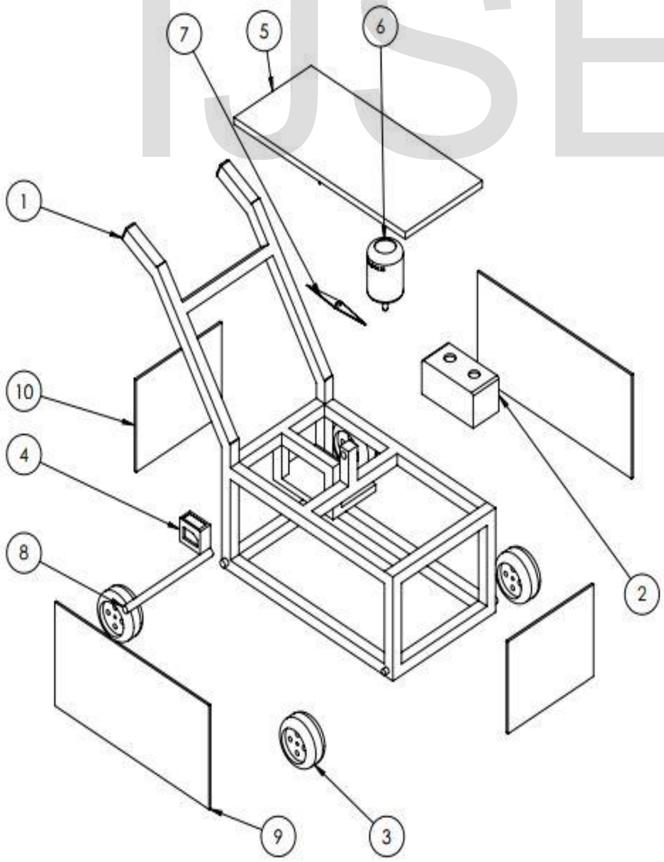


**Figure 2: Wireframe design of the machine**






| ITEM NO. | PART NUMBER | QTY. |
|---|---|---|
| 1 | projframe | 1 |
| 2 | projbattery | 1 |
| 3 | projtyre | 4 |
| 4 | projcontroller | 1 |
| 5 | projsolar | 1 |
| 6 | projdcmotor | 1 |
| 7 | projblade | 1 |
| 8 | projrod | 1 |
| 9 | projplate2 | 2 |
| 10 | projplate | 2 |

**Figure 3: Exploded view and machine part list**

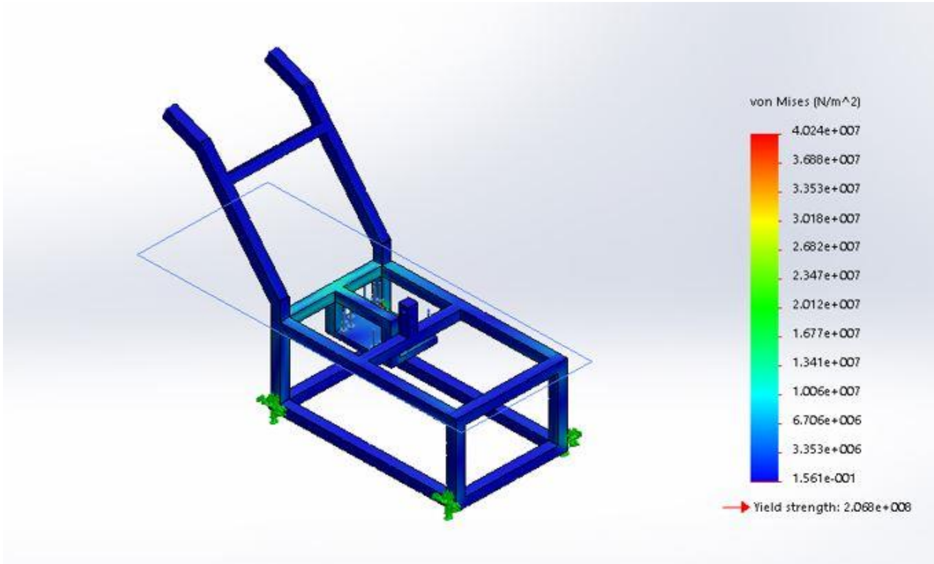



**Figure 5: Stress analysis of the frame**

## 2.2 Design Analysis

### Power selection

The force required to cut grass by a sharp object should not be less than 10Newtons, this is subjected by factors such as: the height of the grass, type as well as grass density in the area. However a slightly bigger force will be required (or selected) for high efficiency. Therefore, the force required to cut grass should be greater than 10Newtons.

**Length of blade** = 0.450m

**Breadth of blade** = 0.050m

**Thickness of blade** = 0.003m

**Speed of motor, N** = 3500 rpm

**Density** = 7850 kg/$m^3$

**Acceleraation due to gravity g** = 9.81$ms^{-2}$

1) **To Determine the area of the blade:**

$$Area = Length \; x \; Breadth \quad ...1$$

$$Area = 0.450 \; x \; 0.050$$

$$= \mathbf{0.0225 \; m^2}$$

2) **To determine the volume of blade**

$$Volume = Area \; x \; Thickness \quad ...2$$

$$= 0.0225 \; x \; 0.003$$

$$= \mathbf{6.75 \; x \; 10 - 5 \; m^3}$$

3) **To determine the mass of the blade**

ISSN 2229-5518

$$Mass = density\ x\ volume \quad ...3$$
$$= 7850\ x\ 6.75\ x\ \mathbf{10^{-5}}$$
$$= \mathbf{0.53\ kg}$$

**4) To determine the Force the blade will produce**

$$Force = mass\ x\ acceleration\ due\ to\ gravity \quad ...4$$
$$= 0.53\ x\ 9.81$$
$$= \mathbf{5.20N}$$

**5) To determine the torque**

$$Radius\ of\ the\ blade = \frac{diameter}{2} \quad ...5$$
$$= \frac{0.450}{2}$$
$$= 0.225m$$

$$Torque = Force\ x\ Radius \quad ...6$$
$$= 5.20\ x\ 0.225$$
$$= \mathbf{1.17Nm}$$

**6) To determine the angular velocity**

$$w = \frac{2\pi N}{60} \quad ...7$$
$$where\ N = 3500rpm$$
$$\pi = 3.142$$
$$w = \frac{2\ x\ 3.142\ x\ 3500}{60}$$
$$= \mathbf{366.57rad/s}$$

**7) To determine the power generated at the blade**

$$Power = Torque\ x\ angular\ velocity \quad ...8$$
$$= 1.17\ x\ 366.57$$
$$= 428.89w$$
$$= \mathbf{0.43kw}$$
$$Since\ 1kw = 1.3596\ hp$$
$$0.43kw = \mathbf{0.583hp}$$

**8) To determine the battery capacity:**

$$Power\ factor = 0.8$$
$$Design\ power = \frac{Current\ x\ Voltage}{power\ factor\ of\ machine} \quad ...9$$
$$Current1\ (I_1) = \frac{Power\ selected\ x\ Power\ factor}{12v}$$
$$Current2\ \ (I_2) = \frac{Power\ selected\ x\ Power\ factor}{24v}$$

$$I_1 = 2100\ x\ 0.8\ /\ 24$$
$$= 70A$$

$$I_2 = 2100\,x\,0.8 / 12$$
$$= 140A$$

Available battery to be used is **100Ah**

$The\ battery\ is\ therefore\ expected\ to\ discharge\ after\ 100 / 70 = 1.43hrs$

$$= \mathbf{1hr\ 26mins}$$

$$OR\ \frac{100}{140} = 0.71hrs = \mathbf{43mins}$$

**9) To determine the time the battery will fully charge**

$Average\ sunshine\ \ time\ is\ 7.43hrs$

$Average\ charge\ per\ day = 7.5A\,x\,7.43hr$

$= 55.74Ah$

$For\ two\ days = 2\,x\,55.74 = 111.496Ah$

$Thus, the\ battery\ will\ be\ fully\ charged\ in\ 2\,x\,100 / 111.496\ (days)$

$= 1.79\ days$

$For\ a\ 100Ah\ battery, it\ will\ be\ fully\ charged\ in\ \mathbf{1.79\ days}$

**Design of the frame**

A mild steel plate will be used in the construction of the frame of the lawn mower due to its strength, workability, availability and cost effectiveness. The frame provides support for the solar panel, electric motor, battery as well as the handle frame. The length of the frame is 1200mm, the breath is 500mm and height 400mm. The frame also has a lead screw which is used to control the height of the motor compartment so as to adjust the height of cut and it has a spin hook. The middle section of the frame will transmit the load of 25kg to the wheel equally through the length of the frame.

From Bansal (2009),

The reactions at the support will be equal to $\frac{W}{2}$ as the load is acting at the middle point of the beam.

Hence $\boldsymbol{R_A} = \boldsymbol{R_B} = \frac{\boldsymbol{W}}{\mathbf{2}}$ ...10

$$\boldsymbol{W = mg = 25kg\,x\,9.81m/s^2 = 235.44kN}$$

$$\boldsymbol{R_A = R_B = \frac{235.44kN}{2} = 117.72kN}$$

Taking a section X at a distance x from A between A and C

Let $\boldsymbol{F_x}$ = shear force at X

$\boldsymbol{M_x}$ = bending moment at X

Here we consider the left portion of the section but the resultant on the left portion is $\frac{W}{2}$acting upwards. The resultant force on the left portion acting upwards. The resultant force on the left portion acting upwards is considered positive. Hence shear force at X is positive and the magnitude is $\frac{W}{2}$.

$$F_x = \frac{W}{2} = 117.72kN$$

Hence the shear force between A and C is constant and equal to $\frac{W}{2}$.

Now considering any section between C and B at distance x from end A, the resultant force on the left portion will be

$$\left(\frac{W}{2} - W\right) = -\frac{W}{2} = -117.72kN$$

The force will also remain constant between C and B. Hence shear force between C and B is equal to $-\frac{W}{2}$. At section C, the shear force changes from $\frac{W}{2}$ to $-\frac{W}{2}$ as shown in figure 3.5.

**Design of the battery compartment**

The battery compartment is located towards the rear of the frame and the length is 350mm, the breath is 200mm and the height is 300mm. The battery compartment transmits a load of 32kg on the frame and the load is uniformly distributed on the rear of the frame.

From Bansal (2009),

Taking a section at a distance of x from the free end B

Let $F_x$ = shear force at X and

$M_x$ = bending moment at X

Here we have considered the right portion of the section. The shear force at the section X will be equal to the resultant force acting on the right portion of the section.

But,

$The\ resultant\ force\ on\ the\ right\ portion\ =\ W\ x\ length\ of\ right\ portion\ =\ Wx$ ...11

$$W = mg = 32kg\ x\ 9.81m/s2 = 313.92kN$$

$$Resultant\ force = 313.92x\ kN/mm$$

This resultant force is acting downwards. But the resultant force on the right portion acting downwards is considered positive. Hence shear force at X is positive.

Therefore, $F_x = M_x$

The above equation shows that the shear force follows a straight line law.

$$At\ B, x = 0\ and\ hence\ F_x = 0$$

$$At\ A, x = L\ and\ hence\ F_x = WL$$

$$F_x = WL = 313.92kN\ x\ 200mm = 62784kN/mm$$

**Bending moment diagram**

Uniformly distributed load over a section is converted into a point load acting at the center of gravity of the section.

The bending moment at the section X is given by

**$M_x$ = - (total load on right portion x distance of center of gravity of right portion from x)**

$$M_x = -\frac{(W.x).x}{2} = -\frac{(W.x).x}{2} = -\frac{Wx^2}{2} \quad \ldots 13$$

The bending moment will be negative as for the right portion of the section, the moment of the load x is clockwise. Also the bending of cantilever will take place in such a manner that convexity will be at the top of the cantilever.

From the equation (iii) above, it is clear that bending moment at any section is proportional to the square of the distance of the section from the free end. This follows a parabolic law.

**At B, x = 0 hence $M_x$ = 0**

**At A, x = L hence $M_x = -\frac{WL^2}{2}$**

$$M_x = -\frac{WL^2}{2} = \frac{(313.92kN\ x\ 2002)}{2} = 3139200kN/mm2$$

**2.3 Materials**

| S/N | COMPONENT | MATERIAL SELECTED | CRITERIA FOR SELECTION | REASONS OF SELECTION |
|---|---|---|---|---|
| 1 | Blade | Stainless steel. | Strength, resistance against corrosion. | Easily accessible, durable and long life span. |
| 2 | Motor | DC motor | Speed, cost | Easily accessible and economical. |
| 3 | Battery | 12V 100Ah battery | Durability, long life span, rechargeable. | Economical |
| 4 | Charge controller | 5/10A | | Easily accessible |
| 5 | Solar panel | 100W | Size and efficiency. | Economical, easily accessible, functionality. |
| 6 | Frame | Mild steel square pipe | Strength, Rigidity. | Easily accessible, durable and long life span. |
| 7 | Wheels | Adjustable wheels | Durability, | Economical, |

| | | | | |
|---|---|---|---|---|
| | | | maneuverability, height control | Functionality |
| 8 | Lead screw | Stainless steel. | High wear resistance and non-corrosive. | Economical and easily accessible. |
| 9 | Sheet metal | Steel | High wear resistance. | Easily accessible and economical. |

The total cost of production of the machine is **₦157,000** which include the material cost and also other miscellaneous expenses.

## 3. Results

### 3.1 Construction process

The machine comprises of both the mechanical and electrical parts. The fabrication of the mechanical part was done by assembling the various parts of the machine together with the aid of the welding machine. The various compartments of the machine include the frame, the handle, the battery compartment and the motor mechanism. Square pipes were used for the frame structure while sheet metal was used for the covering of the machine.

The motor mechanism include a lead screw which is attached to the top of the motor to ensure that the height of the motor during operation is adjustable. The battery compartment is to house the battery and the charge controller and the solar panel is attached to the top of the frame at an angle.



Figure 4: The developed machine

## 4. Performance Evaluation

The development of the solar powered lawnmower was done and the performance evaluation of the machine was carried out. The following parameters were determined: field efficiency, time taken for the battery to reach full charge and operational time of the machine at full charge.

Table 4.1 shows the experimental result for mowing different types of grass.

Coverage area of each test sample = $10m^2$

Area of the four samples = 10 x 4 = $40m^2$

**Table 1 Results from mowing different types of grass**

| **S/N** | **Sample Plot** | **Coverage Area ($m^2$)** | **Time (s)** | **Average height before mowing (mm)** | **Expected Lawn Height (mm)** | **Average height after mowing(mm)** |
|---|---|---|---|---|---|---|
| 1 | Carpet Grass | 10 | 85 | 80 | 50 | 55 |
| 2 | Stubborn Grass | 10 | 90 | 234 | 70 | 60 |
| 3 | Soft Grass | 10 | 87 | 280 | 100 | 84 |
| 4 | Elephant Grass | 10 | 105 | 300 | 100 | 90 |
| **Total** | | | 367 | | | |

**i. To obtain the field efficiency,**

**Forward velocity/speed**

$$Forward\ distance\ covered\ =\ 15m$$

$$Time\ taken\ =\ 60\ sec$$

$$Average\ forward\ velocity\ =\ 15\ /\ 60\ =\ \mathbf{0.25m/s}$$

**Field Efficiency**

$$\boldsymbol{Theoretical\ Field\ Capacity\ (TFC)}\ =\ Forward\ Speed\ x\ Theoretical\ width\ of\ blade$$

$$But\ theoretical\ width\ of\ blade\ =\ 0.450m$$

$$\therefore\ TFC\ =\ 0.25\ x\ 0.450\ =\ \mathbf{0.1125\ m^2/s}$$

$$\boldsymbol{Effective\ Field\ Capacity\ (EFC)}\ =\ Total\ Area\ Covered\ /\ Total\ Time$$

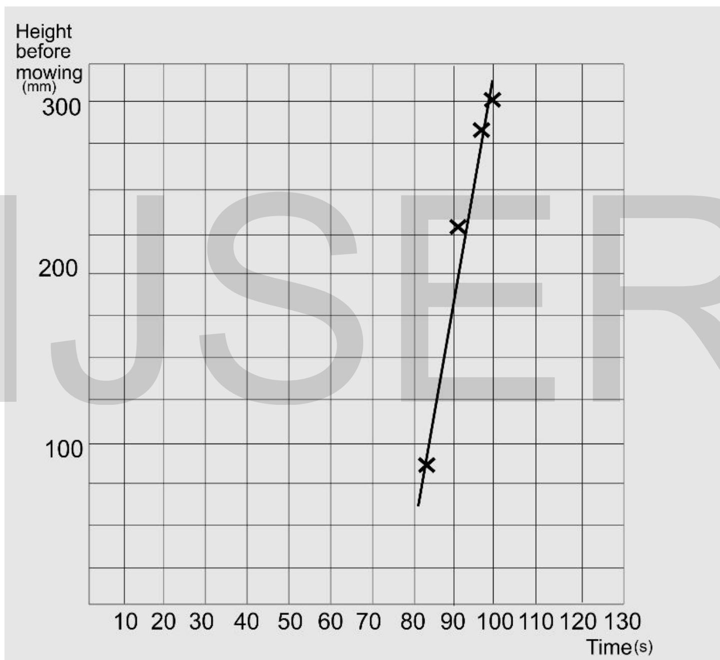
$$=\ 40m^2/367sec$$

$$= \mathbf{0.10899}\ \boldsymbol{m^2/sec}$$

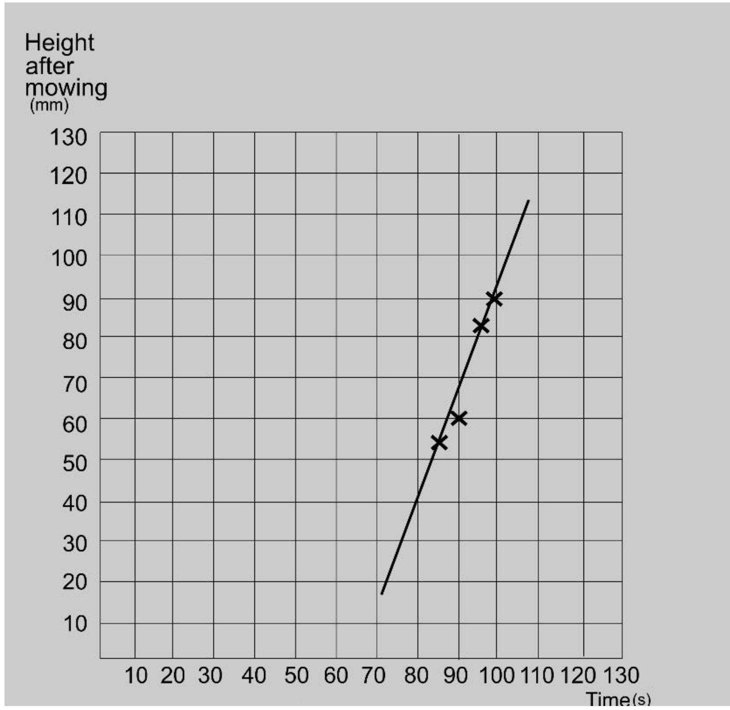
$$\boldsymbol{Field\ Efficiency} = \frac{EFC}{TFC}\ x\ 100\% = \frac{0.1089}{0.1125}\ x\ 100\% = \mathbf{96.7}\%$$

ii. Time taken for the battery to reach full charge = **1.25days**
iii. Time taken for the battery to discharge = **45mins**

From table 1, it can be deduced that the time taken to cut each of the grass samples varied due to the characteristics of the grass samples in terms of toughness and density. The carpet grass and soft grass have the least time for the mowing operation while the elephant grass had the highest time for the mowing operation. The height of cut for each grass sample also varied as the expected height for each sample differs.




**Graph of Height before mowing and time**




**Graph of Height before mowing and time**



The height of blade for each sample was adjusted via the lead screw and after cutting the height of each sample was measured and compared with the expected height. The average height of the grasses after mowing was lesser than the expected. It can be deduced that the reduction in the height of cut grass occurred in the case of stubborn grass. The initial height being 234mm and the final height being 60mm giving a difference of 174mm. For elephant grass, the initial height being 300mm and the final height being 90mm, a difference of 210mm. for the soft grass, the initial height was 280mm and the final height was 84mm, a difference of 196mm. For the carpet grass, the initial height was 80mm and the final height was 55mm giving a difference of 25mm. From these figures, it shows that the machine performed best on stubborn grass followed by the elephant grass. The machine was able to reduce the height of the carpet to 55mm could be due to the very soft nature of this type of grass. The field efficiency of the solar powered lawn mower designed and developed is calculated to be 96.7% which is very efficient as it is able to perform the operation for which it was designed excellently.

## 5. Conclusion

Over the last few decades, machines are designed with the aim of reducing or eliminating greenhouse gas emissions which is the major cause of climate change due to global warming. The improved solar powered lawn mower will meet the challenge of environmental pollution and also low cost of operation since there is no cost for fueling which is the goal of this project. The solar powered lawn mower was 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 this purpose. The field efficiency of the machine was 96.7% which is relatively high and the machine was also tested on different grass samples. The average height of cut for each grass sample adjusted so as to obtain the expected height of grass after mowing. The time required to cut each grass sample varied due to the characteristics of the grass in terms of toughness and grass density.

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