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Performance evaluation of the developed solar powered lawn mower

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Abstract
The continuous increase in the value of gasoline and the effect of emission of gases from the burnt fuel into the environment, this necessitated the usage of the considerable sun power from the solar as a source of electricity to power a garden mower. A solar powered lawn mower become designed and evolved, based on the overall precept of mowing. The designed sun powered lawnmower contains of direct cutting-edge (D.C) motor, a rechargeable battery, sun panel, a chrome steel blade and manage switch. Mowing is done by means of the D.C motor which affords the desired torque had to force the stainless-steel blade that's directly coupled to the shaft of the D.C motor. The sun powered lawnmower is operated by way of activate the board which closes the circuit and lets in the waft of modern-day to the motor which in turn drive the blade used for mowing. The battery recharges via the solar charging controller. Performance evaluation of the developed system changed into performed with different styles of grasses. The machine was discovered to have an efficiency of 90% and a discipline capacity of 1.15×10^{-4} ha/hr. No tremendous distinction was discovered with the peak of grasses at 4% self-belief level.

Keywords: Solar power, battery, lawn, mower, dc motor, mowing, emission

Introduction
Solar powered garden mower may be defined as the utility of solar energy to electricity an electric powered motor which in turn rotates a blade which does the mowing of a lawn. Different designs were made; each to in shape a particular need or convenience. Making the procedure of reducing grass easier through the years, many individuals have brought change to the authentic layout velocity, efficiency and strength of a mowing device. The sun powered lawnmower is a development on cordless electric powered lawn mower. The solar present's sustainable amount of the power used for diverse purposes in the world for atmospheric gadget. Every minute the sun radiates approximately 568×10^{26} energy of energy and the earth intercepts handiest 2.55×10^{18} energy (NRF, 2010) [12]. This represents best 2000 millionth of the entire solar strength sent into the distance. The total sun energy is anticipated to be 30,000 instances greater than the full annual energy of the sector (Mgbemu, 2005) [11]. The solar powered lawnmower is primarily based on the same principle that different early innovations of lawn mowers works on. The difference is simply the software of the energy supply. It uses the photovoltaic panel to generate the electricity had to strength the mower. It is thought that a lawnmower the usage of sun because the strength source will cope with a number of issues that the usual internal combustion engine and electric powered vehicles garden mowers do not. A lawnmower with sun power may be less complicated to apply, it removes down time with the aid of common trips to the gasoline station for fill-united states of America and hazard related to gasoline spillage. The risky emissions generated by means of the fuel spillage and that of the internal combustion engine into the surroundings are eliminated. The solar powered lawnmower will help to reduce air pollutants in addition to noise pollution produced by means of other sorts of lawnmowers. In addition, it's going to assist to reduce the running fee of the use of and preserving a lawnmower. NYSDEC (2012) [13] were of the opinion that lawnmowers need to be designed to reduce pollutions generated than at present. This became similarly buttress by the ARB (2011) [2] presenting the ease of energy to power lawnmower. However, maximum electric powered mowers available at gift are very inconvenient in that they require the use of an extension wire which continually receives within the way of mowing the garden. Rotary mowers are based totally on the usage of small but powerful engine that offers enough torque to spin a very sharp horizontal blade that cuts the grass upon contact.

The blade is placed within the deck that stops grass from flying all over the location when struck. In most instances, the motor is situated on the pinnacle of the deck, that's commonly set up on 4 wheels. There is likewise a bag connected to the deck this is used to collect reduce grasses (Jain and Rai, 1995) [7]. Traditionally used lawnmowers do now not use fuel or electric electricity wire. Pushing it turns some of curved blades (Omoniyi, 2010) [14]. They have no engines, quite cheaper, highly secure and it calls for little blade adjustment and sprucing. Some fashions have battery powered motor to spin the blade at the same time as pushing the mower. Cutting tends to be choppy and some couldn't reduce grasses taller than 1.5 inches or trim nearer than 3 inches round obstacles, even as the electrically operated mower uses an electric powered mechanism (motor) to spin a blade in a rotary form. Cords are capability issues on lawns with timber and other boundaries. Today's cordless models run longer according to charge than preceding models sorts. This requires little renovation past blade sprucing. Most offers a side or rear bag and mulching mode that cut clipping finely enough they settle in the garden and fertilizes it as they decompose. The great electric powered mowers carry out as well as some gas mowers. Electric mowers commonly cut an 18-20 inches swath (Hollis, 1991) [5]. Tractor drawn (semi-mounted or hooked up type) mowers are operated with the aid of energy take-off shaft (Jagdishwar, 2008) [6]. A shaft is connected with power take-off shaft which drives a pulley on the crank shaft of the system and the reciprocating motion is transmitted to the cutter bar. Solar electricity is a time established and intermittent electricity supply. There is need for the storage of energy for later use whilst there's no further deliver of the sun power. An optimally designed solar electric system will collect and convert whilst the isolation is available during the day. Photovoltaic is the direct conversion of light into energy at atomic degree. When free electrons are captured, an electric cutting-edge is produced and can be used as strength (Knier, 2010) [10]. The solar photovoltaic cells are essentially semi-conductors, which have electric transmission properties like metallic or salt water and insulators like rubber. Panels are built with sheets of doped silicon, number one detail in beach sand with impurities brought like phosphorus that allows electrons to waft. When the protons from the solar electricity hit a photovoltaic cellular, a float of electrons begins which may be drawn off by a couple of wires, thereby creating direct current. A number of solar cells electrically related to every different and hooked up in a guide shape or body is called a photovoltaic module. Modules are designed to deliver power at a sure voltage. The current produced is immediately dependent on how plenty light strikes the module. They can be linked in each series and parallel electrical preparations to supply any required voltage. Photovoltaic modules and arrays produce direct-contemporary (DC) energy and contemporary mixture.

Materials and Methods

In designing the reducing blade, the pressure required to cut the lawn as well as the force acting on the blade become considered. The force required by any sharp object to have effect on the grass is less than 10 Newton. It is likewise dependent on the height, density and the vicinity blanketed by means of the object (Atkins, 1984) [4]. Therefore, in designing the blade of the sun powered lawn mower, the pressure required for effective mowing should be more than 10 Newton. A stainless steel changed into used in the creation of the cutting blade because of its strength and weight which can transmit same speed as that of the DC motor or a touch much less motive of friction.

Mass of Blade

The area of the blade = length × width
= 450 × 40
= 18000mm^2
Volume = area × thickness
= 18000 × 0.1 = 1800mm^3
Mass of the blade = density × volume
The density of a stainless steel (Singh, 2005) is 7922kg/m
= 7922 × 1800 × 10^{-9}
= 0.014kg.

Weight and Torque on the Cutting Blade

The weight of the blade, W = Mg
Where, M = mass of the blade = 0.014kg
g = acceleration due to gravity = 9.8 m/s^2
Therefore, W = Mg
= 0.014 × 9.81
= 0.14N
Hence, the torque (T) produce by the blade is given by
T = Wr
Where, W is the weight
r is the radius of the blade
r = 450/2 = 255mm
Therefore, T = Wr
= 0.14 × 225 = 31.5Nm

Angular velocity and force produce by the blade

Universally known that angular velocity (ω) is given as
$\omega = 2\pi N/60$
Where, ω is the angular velocity
N is the rotational speed of the motor = 1450 rev per minute
π = 3.142
ω = 2 × 3.142 × 1450/60
ω = 151.86 rad/s.

Power developed

The Power (P) developed is be the product of torque and angular velocity
P = Tω
Where T is the torque = 0.0315N
ω is angular velocity = 151.86 rad/s
P = 0.0315 × 151.86
P = 4.78W

Motor size

The Power (P) required by the blade was used in the selection of the electric motor.
From the power developed, = 4.78W = 0.00478KW
Converting the determined power to horsepower = 0.26 HP.
For design purpose 1.5 HP D.C motor was used, so that it provides the required torque in other to cut all type of lawns and also it increases the efficiency of the machine.
The force produced by the blade with the speed of the motor is the centrifugal force (F_c). Hence, the centrifugal force according to Khurmi and Gupta (2000) [9]

$F_c = m\omega^2 r$

Hence, F_c = 0.014 × 151.86 × 0.225 = 72.47N

Charging station

In practice, the maximum voltage is in the range of 0.6 volt and this occurs in open circuit, when no power is produced. The maximum power of a silicon cell occurs at an output voltage of approximately 0.45 volts when there is bright sunlight, the current from a commercial cell is then roughly 270 amperes per sq.m of exposed surface. The power is thus about 0.45 × 270 = 120 watts. The rate at which solar energy reaches the top of the atmosphere is 1.353kW/sq.m (Kalyan, 2013) [8]. Part of this energy is reflected back to the space and part is absorbed by the atmosphere (Nelson, 2012) [17]. In bright sunlight, Amos (2013) [3] asserted that the solar energy may reach the ground at the rate of roughly 1kW/sq.m.

Calculating the estimation of average solar radiation monthly is given by Agbo (2010) [1] as

$H_{av} = H_o (a^i + b^i (n/N))$

Where, H_{av} is the average solar radiation available for conversion.

H_o is the monthly average horizontal solar radiation for a clear day.

a^i and b^i are arbitrary constants 0.35 and 0.61 respectively.

n is the average hours of bright sunlight for same period.

N is the maximum daily hours of bright sunlight for same period

The solar panel that was used in the construction of the solar powered lawnmower is rated 50watts, 12 volts, consisting of 24 cells. Hence, according to Khurmi and Gupta (2000) [9]

Power = IV

Where, I is the current

V is the voltage

I = P/V

I = 50/12

I = 4.17A

The solar panel is connected to the battery via a solar charging controller and from the battery to the motor. Also, an electric switch is connected to the circuit to control the flow of current.

Battery

Batteries are to be had in various volts and ampere hour variety. To decide the only to apply, consideration turned into given to the voltage and the ampere hour rating. Since the motor is 1.5hp, then a 12V battery was selected. The ampere hour measures the period of time the battery will discharge even as in use and is not charging. A 17 ampere hour battery will provide a 17 amp of current for one hour and the current required with the aid of the motor is less than that.

Design for the frame

A slight metal plate became used within the construction of the frame due to its electricity, workability, availability and value effectiveness. The body provides support for the electrical motor, battery in addition to the cope with frame. The diameter of the deck is 500mm and top 100mm. The deck is likewise made of 4 hand lever adjusters which can be used to elevate and lower the deck to the favored height of cut. Each is product of flat metallic with five spin hooks to useful resource the operation. They transmit the burden of 20kg to the wheel similarly and period of each is 700mm.

The bending moment M = PL/4

Where P is the load = 20 × 10 = 200N

But the load is equally shared, hence for each it will be 200/4 = 50N

Therefore M = PL/4

= (50 × 700)/4 = 8.75KNmm

Yield stress = 200N/mm^2

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) [9]

Sectional modulus, z = bending moment/ shear stress = 8.75 × 10^3/ 106 = 82.55mm^3

Design of the handle frame

The solar panel is located on the peripheral of the handle, and the weight of the solar panel is 10kg. In order to accommodate the length of the solar panel, a length of 1200mm tilted at an angle of 60^o was chosen. From Khurmi and Gupta (2000) [9]

$$M_{max} = \frac{\sigma I}{y}$$

Where, σ is the stress

I is the moment of inertia

y is the resolved length of pipe at an angle.

σ = 0.53y_s Yield stress, y_s = 200N/mm^2.

Ultimate bending stress = 0.53y_s

σ = 0.53y_s

= 0.53 × 200

= 106N/mm^2

I = π (D^4 – d^4)/64

Where D = 200mm

d = 180mm

π = 3.142

Hence I = 3.142 (200^4 - 180^4)/64

I = 27 × 10^6

Also y = x cos Θ

y = 1200 cos 60^o

y = 600mm

Therefore, $M = \frac{\sigma I}{y}$

M = (106 × 27 ×10^6)/600

M = 4.8 × 10^{6}Nmm

Sectional modulus, z = bending moment/shear stress

Z = 4.8 × 10^6/106

Z = 45 × 10^{3}mm^3

Figures 1 and 2 respectively show the isometric view and the exploded view of the solar powered lawn mower.

Experimental test procedure

The solar powered lawnmower was tested on four different species of elephant grass, stubborn grass; spare grass and carpet grass of 4500mm by 4500mm field noting the time spent cutting the field. Ten replicates of the test were carried out and the Performance Efficiency of the machine was then determined.

The field capacity was also determined by using

$$C = \frac{WSE}{10}$$

Where,

W = Width of cut (m)

S = Speed (km/hr)

E = Efficiency. (%)

Results and Discussion

The solar powered lawnmower turned into designed and advanced. Test was performed using 4 species of grass and the result obtained is summarized as presented in Table 1. From Table 1, it is able to be deduced that the reduction in the height of reduce grass came about inside the case of cussed grass. The initial top being 234mm and the final height being 92mm giving a distinction of 142mm. For elephant grass, the initial height being 224mm and the final height being 90mm, a difference of 134mm. For the spare grass, the preliminary top turned into 111mm and the very last height changed into 70mm, a difference of 41mm. For the carpet grass, the initial peak turned into 70.5mm and the very last peak changed into fifty six.5mm giving a difference of 14mm. From those figures, it suggests that the machine carried out high-quality on stubborn grass followed by means of the elephant grass. The machine became able to lessen the height of the carpet to 56.5mm could be due to the very tender nature of this form of grass. In all, the system has accomplished creditably nicely.

Fig 1: Design of solar powered lawn mower

Table 1: Average height of grass before and after mowing of each sample plot

Sample plot	Average height of the grass before mowing (mm)	Average height of the grass after mowing (mm)	Expected height of the grass after mowing (mm)
Elephant grass	224	90	100
Stubborn grass	234	92	100
Spare grass	111	70	80
Carpet grass	70.5	56.5	50

Table 2: Chi-Square Statistical Table $x^2 = (O - E)^2/E$

Average height of the grass after mowing (mm).O	Expected height of the grass after mowing (mm).E	O - E	$(O - E)^2$	$x^2 = (O - E)^2/E$	Time (s)
90	100	-10	100	1	490
92	100	-10	100	1	470
70	80	-10	100	0.8	450
56.6	50	6.5	42.25	1.18	430

Fig 2: Developed solar powered lawn mower

Conclusion

In the sector these days, all machines are designed with the intention of decreasing or removing greenhouse fuel emissions which is the predominant causes of weather trade. This solar powered lawn mower will meet the undertaking of environmental manufacturing and coffee value of operation considering that there's no value for fueling. A solar powered garden mower has been developed for the use of residences and establishments that have lawns in which tractor pushed mowers couldn't be used. The gadget's ability is ok for its cause. The gadget has proved to be a possible substitute for the gasoline powered garden mowers.

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