DESIGN AND CONSTRUCTION OF A HYBRID (SOLAR-ELECTRIC) FLEXIBLE GRASS CUTTER USING LOCALLY AVAILABLE MATERIALS

M.A. ISLAM[1] and M.H. ALI[2]
[1]Scientific Officer, [2]Chief Scientific Officer
Agricultural Engineering Division, Bangladesh Institute of Nuclear Agriculture

Abstract

Solar energy is the renewable source of energy which can meet the demands of agricultural activity. An initiative was taken to develop a low-cost solar power operated lawn mower from locally available materials which can use solar energy for mowing grass of lawn. The developed mower consists of solar panel (80W), D.C. motor (24V, 14A and 900 rpm), rechargeable battery (24 volt), charge controller, frame, cutting blades and transport wheel. The fabrication and assembling of the mechanical parts of the machine was done by welding machine. The electronics parts of the mower like battery, solar panel and wires were fitted manually. The battery of the machine can also be charged by AC plug-in as a secondary power source at unfavorable weather condition. We tested the machine in the playground of BINA residential area. According to the field test, the theoretical field capacity of 0.0307 ha/hr and effective field capacity of 0.0257 ha/hr were found. The field efficiency of the machine was 83.7%. The local manufacturing cost is around BDT 25000 (USD 250$) which is much lower that of other available mower in the market. The performance of the developed lawn mower was satisfactory during field operation for cutting lawn grasses.

Keywords: Renewable energy, grass cutter, solar operated mower, and Photovoltaic effect

1 INTRODUCTION

1.1 Lawnmower and Photovoltaics

Grass is a narrow leave (herbaceous and monocotyledon plants) that grows from the base and covers the ground in a lawn and other places. There are many different types of grasses in nature, on lawns, in the area around houses, and in agricultural fields. Although most members of the grass family are small, some can get quite tall. If not kept up with, these grasses can seriously hinder other beneficial plants and cause environmental problems. Grass maintenance essentially entails trimming and maintaining the grass at a manageable height. For cutting grass in the past, people used scythes, hand shears, and cutlasses. Modern techniques for cutting grass, however, have emerged as a result of expanding technical breakthroughs. Use of a lawnmower or grass-cutter is one of these strategies.

Mowers are widely employed in gardening, agriculture, sports, and public use. Mowers with revolving cutters that are powered by an electric source first became popular in the early 1990s. In 1830, Edwin Beard Budding created the first type of lawn, which was based on a neighborhood textile mill that was used for trimming fabric. The cast iron cutting wheel mounted to the shaft was used to trim the grass in the same way. By 1832, Ransoms of Ipswich, the world's largest manufacturer of lawn mowers, had begun producing the Budding's lawn mower. Thomas Green created a novel type of lawn that used a chain drive and was known as a "silensmessor" due to its low noise output.By the turn of the 20th century, heavy powered mowers dominated the market. By using gasoline, Colonel Edwin George created the first motor in 1919. The latest technology are now utilized, and the mower is lifted to different locations

using the hover concept and catalytic converters to lessen air pollution. The RC-SOLAR type of mower is currently being used in lawn mowers in order to stop all the issues.

Using a typical motor-powered lawn mower to trim the grass or mow the lawn is inconvenient. Grass cutting is not a task that the old, young, or crippled can readily perform. Push lawn mowers and riding lawn mowers with motors emit local air pollution from engine combustion as well as noise pollution from the loud engine. A motor-powered engine also needs routine maintenance, including changing the oil. Electric lawn mowers may often be a hassle, despite the fact that they are ecologically beneficial. Electric lawn mowers are dangerous as well as motor-powered lawn mowers and are difficult for everyone to use. Additionally, if the electric lawn mower is corded, mowing may be difficult and dangerous.

Lawnmower as defined by Ogiemudia (2015) is a machine that uses a revolving blade to cut grasses at equal heights. According to Manpreet et al. (2016), a lawnmower is a device with a rotor, a motor, and blades that is used to cut grass up to a specified height that can be adjusted based on the mower blades' design specifications. There are many various varieties of lawnmowers, including the hand-held, walk-behind, riding, tow-behind, automatic, and solar-powered lawnmowers, each with its own distinct peculiarities in terms of use, performance, upkeep, cost, etc.

The source of the machine's power supply is a crucial design consideration for any equipment, especially in developing nations like Bangladesh. The energy utilized by the earth's atmospheric system for a variety of uses comes from the sun in sustainable amounts. The sun emits approximately 5.68 1026 calories per minute, yet the earth only absorbs 2.55 1018 of those

calories.(NRF, 2010). Only one millionth of all solar energy transmitted into space is represented by this. The idea of solar energy is not new, but its applications are, and this is because of the unpopularity of its applications as compared to the previously developed energy like wood fuels and fossil fuels. (Tanimola et al., 2015). The usage of the plentiful solar energy from the sun as a source of power is growing as a result of the continual growth in fuel costs (and also availability uncertainties) and the effect of emissions of gases from the burned fuel into the atmosphere.

According to an estimates (Mgbemu, 2005), the solar energy is 30,000 times more powerful than the world's yearly energy output. The solar-powered lawnmower operates on the same fundamental concept as other early lawnmower technologies. Only the manner in which the energy source is employed differs. The photovoltaic panel is used to produce the electricity required to run the mower. It is anticipated that a lawn mower powered by solar energy will address a number of concerns that conventional lawn mowers powered by internal combustion engines and electric motors do not. A solar-powered lawnmower will be easier to use, minimize downtime from frequent visits at gas stations for refills, and lower the danger of fuel leaks. There are no longer any harmful emissions into the atmosphere from internal combustion engines or gasoline spills. By using a solar-powered lawnmower, one may lessen the noise and air pollution that are both caused by conventional lawnmowers.

Direct light-to-electricity conversion at the atomic level is known as photovoltaic. Free electrons can be caught to create an electric current that can be used to generate power (Knier, 2010). The electrical configurations used in series and parallel to provide any needed voltage. Direct-current

(DC) power and current combinations are generated by photovoltaic modules and arrays. Solar photovoltaic cells are essentially semi-conductors, which have insulating qualities similar to rubber and electrical transmission capabilities similar to metal or salt water. Doped silicon, the main component of beach sand, is combined with impurities like phosphorus to create panels that allow electrons to flow. An electron flow that can be pulled off by two wires to produce direct current begins when the protons from solar energy strike a photovoltaic cell. A photovoltaic module is a group of solar cells that are electrically coupled to one another and fixed in a frame or support structure. A photovoltaic module is a group of solar cells that are electrically coupled to one another and fixed in a frame or support structure. A specified voltage of power can be supplied through modules. The amount of light that strikes the module directly affects the current that is produced.

A lawn or field is mowed using a solar-powered lawn mower, which works by using solar energy to drive an electric motor, which in turn moves a blade. Designs have been created in a variety of ways, each to meet a certain requirement or convenience. Over the years, a lot of people have contributed modifications to the speed, efficiency, and power of a mowing machine, making the task of cutting grass easier. The cordless electric lawn mower has been improved by the solar-powered model.

There are several different types of lawn mowers in use around the world, including rotary, riding, hover, and reel mowers. The majority of these are powered by an engine or batteries. Mowers powered by diesel, gasoline, and petrol engines are quite expensive, challenging to use and maintain, and may prove to be very problematic as they age. The cost of an engine-powered mower is likewise extremely high. Compared to gasoline lawn mowers, which are louder and

produce 95 decibels, electric lawn mowers are comparatively quiet at 75 decibels. (Hessayon 2007).

1.2 Environmental issues of gasoline machine

In the modern world, pollution is a serious problem. As with ordinary internal combustion engine lawn mowers, which emit greenhouse gases from their engine exhaust, man-made pollution may be seen in the environment and is mostly caused by the burning of fossil fuels. This leads to global warming. Additionally, the price of fuel (petroleum products) is rising, making it less cost-effective to use as a source of energy. The battery can be charged using sustainable energy sources like solar energy from solar panels.

The advantages of direct current electric lawn mowers over gasoline-powered ones are discovered through research. Health risks, noise pollution, and vibration are all produced by gasoline-powered machinery. Furthermore, it has an irreversible impact on human health. Because a typical lawn mower operates for 8 to 9 hours, it is a major worry for the general population. Authorities take care of workplaces and work sites, but for the general public, it is a worrying issue because the mower's annoying noise level is higher than 85 decibels.

The use of solar energy to drive an electric motor, which in turn moves a blade, is what is referred to as a solar-powered lawn mower. Solar energy is an excellent source of renewable energy. A renewable resource is one that can be replenished or replaced by either human activity or the natural processes of the earth. Nearly every place on earth has access to solar energy in some form. Unlike energy sources based on fossil fuels, it cannot be depleted. A "clean" energy

source is solar energy. It does not entail the release of greenhouse gases, which are thought to be the primary cause of Earth's escalating global warming.

The development of the solar lawn mower aims to solve a variety of problems with traditional mowers powered by internal combustion engines. It will stop an internal combustion mower's emissions of greenhouse gases, which are mostly to blame for environmental pollution and the effect of green gases. Designs have been created in a variety of ways, each to meet a certain requirement or convenience. A lead screw is used in the solar-powered lawnmower's design to regulate the height of the cut grass.

Any agricultural machine that runs successfully on solar power has the potential to save gasoline. The overall goal of the current research was to transform a hand-held gasoline disk mower into an electric solar-powered mower by swapping out the gasoline engine for an electric DC motor that runs off a 12 volt battery; this battery will be charged using a photovoltaic solar panel, or electricity. This conversion also aimed to reduce greenhouse gases and their detrimental environmental impact.

Purpose of the study

In this study, a hybrid (solar plus DC battery powered) grass-cutter/lawn-mower was designed, constructed and the performance was evaluated.

1.3 Literature review

Basir (2013) designed a straightforward, portable, and user-friendly self-powered lawn mower. He created an alternator in his design to recharge the D. C. battery that drives the electric motor.

The system's blades are propelled by a number of pulleys attached to the motor. Overall, it has a cutting efficiency of 89.55% and is a cordless electric power mower.

Okokpuje et al. (2017) designed and constructed a manually operated cylindrical lawn mower. Using an internal gear system, the mower transmits torque to the blade. The machine's performance was assessed on a sporting field, and the cutting efficiency was determined to be 91% with 0.244KN of human effort.

Talimola et al. (2014) developed a solar mower. The mower's blades are driven by a direct current (D.C.) motor that is connected to the battery, and the energy needed to drive it is produced by a photovoltaic panel. A field capacity of 1.1110-4 ha/hr nm was used to evaluate the design's performance, and an efficiency of 93% was found. Vivek et al. (2016) designed and examined a rotational lawn mower. A new, reasonably priced product with a straightforward design was proposed. Utilizing ANSYS Workbench, the frame and adjustable module were analyzed. The frame was confirmed to be safe and reliable under loading conditions, according to the results.

Ogiemudia (2015) developed a simulation of an improved solar lawn mower machine. In Nigeria, emphasis was placed on enhancing solar-powered lawnmowers utilizing resources that were readily available. According to one theory, the lawn mower's effectiveness depends on the software's capacity to foresee the conditions that will most likely lead to failure. The intended model was simulated using the finite element method (FEM) and SOLIDWORKS 2014 version.

Manpreet et al. (2016) researched and assessed three distinct types of lawnmowers (solar, electric, and gasoline) and came to the conclusion that solar powered lawnmowers have a cutting

efficiency of over 90% and cause no noise or air pollution in comparison to lawnmowers powered by internal combustion engines. Additionally, they came to the conclusion that how the system is charged can vary depending on the angle of sunlight hitting the solar panel.

In the study of McCoy (1988), In order to draw the desired amount of current and voltage, the solar cell combination was combined in an array and set up in parallel or series connection. It was asserted that connecting the group of cells in parallel would allow for the generation of the greatest possible current without increasing the voltage across the terminal. There were groupings of three to four cells each in the array. Due to the electrical separation established by the diode, which stopped the current from flowing from the battery to the solar cells, this arrangement was utilized to charge the batteries quickly. Each solar panel group has its own diode. Each group of solar panels was divided from the other groups by this diode.

According to Paytas' (1991) study, an electric motor-powered lawnmower was constructed. Either an electric power source or solar energy was used to recharge the lawnmower batteries by placing them in direct sunlight. The solar panel pairs were raised above the electric motor in the design and connected by a ridge. The solar panels were made up of several solar cells that generated the necessary current and voltage. To manage current flow with each battery, a voltage regulator was connected to the charging outlet. As more voltage or current could be extracted from the solar cell, a voltage regulator was needed to maintain the safe charging. As more voltage or current could be extracted from the solar cell, a voltage regulator was needed to maintain the safe charging.

In the study of Lucas et al. (2010), The hybrid lawnmower, which could run on either alternating current (AC) or direct current (DC) power, was introduced. A hybrid AC/DC controller that served as a step down controller or power inverter supplied the motor with a 60 volt DC feed from the battery pack. The current was converted from AC to DC using the complete bridge rectifier. There are two operating modes for the lawnmower, including conserve and turbo. The hybrid AC/DC controller received an additional 6 volt battery, which, when activated in boost mode, doubled the speed of the blade motor. Additionally, the battery life was increased when the mower was in the conserve mode.

In the study of Thomas et al. (1982), a lawnmower with AC and DC engines was developed. The gear and clutch arrangement that connected the two motors allowed them to be used either jointly or independently. The clutch assembly mechanism allowed DC to the free wheel when the AC motor was energized. The AC and DC motors were both running while the grass was thick. The gear was moved by both AC and DC motors thanks to their connection to the clutch assembly. Three gears were employed in the design, and they were positioned so that they were constantly in touch with one another and moving relative to the driven clutch plates. The AC and DC motors were positioned side by side.

2 MATERIALS AND METHODS

The components of a practical solar-powered lawn mower include an electric motor, a battery, a frame, a deck, a charge controller, a solar panel, a cutter, and the wheels. These components all work as a single unit to effectively cut grass. An adjustable wheel system was added into the

design to allow the machine to cut grass at various heights according to the user's preferences. The battery is fueled by two charging sources (solar and AC plug-in).

2.1 Design concept

In order to cut grass effectively, a functioning solar lawn mower has an electric motor, a battery, a frame, a deck, a charge controller, a solar panel, a cutter, and wheels. **Fig. 1** shows the various views (side, front and top view) of the solar lawnmower. The design will have an adjustable wheel system that will allow the machine to cut grass at various heights according on the user's preference. The machine batteries will be fueled by two charging sources (solar and AC plug-in).

The lawnmower batteries were either charged by electric power source or by solar energy by exposing it to the sunlight. In the design, the pairs of solar panels joined by the ridge of the panels was raised above the electric motor. The solar panels consisted of plurality of solar cells that produced required voltage and current. The voltage regulator at the charging outlet was connected to control current flow with respective battery. Voltage regulator was required to maintain the safe charging as additional voltage or current could be drawn from the solar cell. The electric clutch was used as electric brake which provided the opposite polarity when the safety bar was released.

In the study, the hybrid lawnmower was introduced which could be run by either direct current (DC) or alternating current (AC) power supply. A 60 volts DC supply was provided from the battery pack to the motor with a hybrid AC/DC controller which acted as step down controller or power inverter.

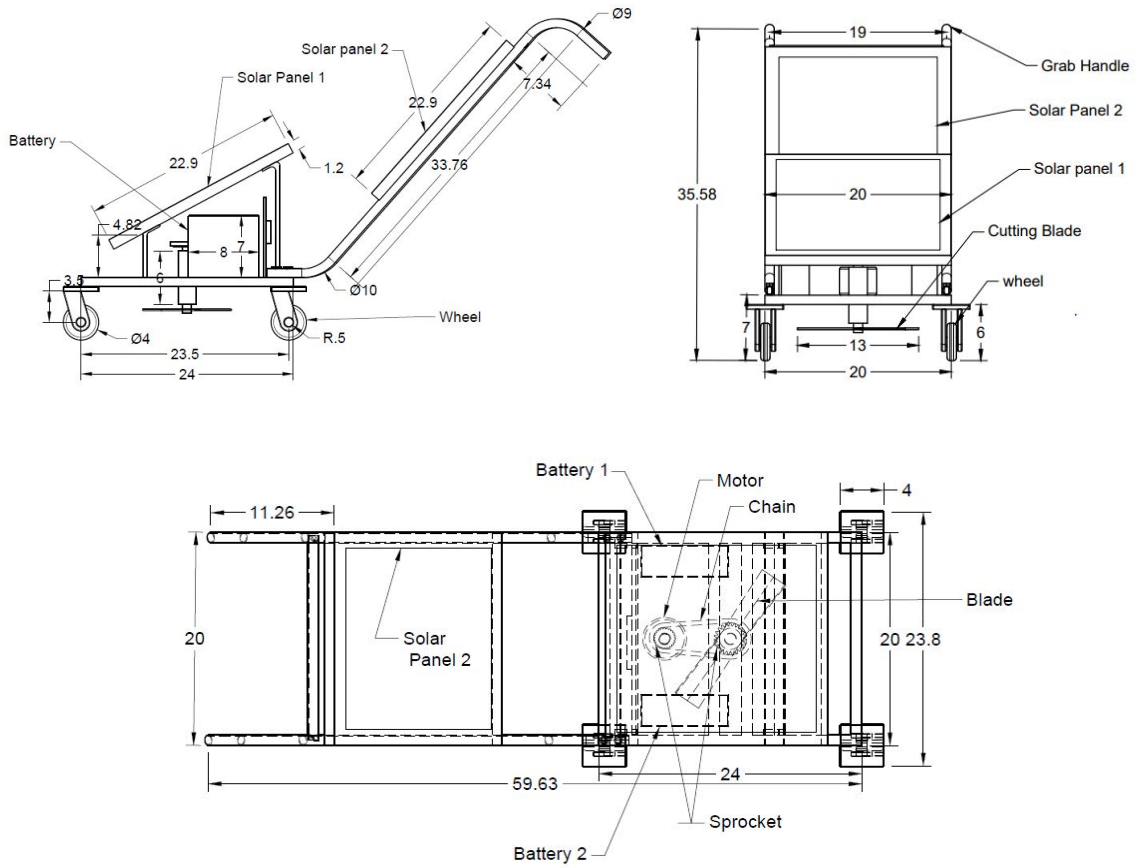

Fig.1. Design elements of solar mower

2.2 Different components

Different parts/components of prepared solar mower are shown in Fig.2.

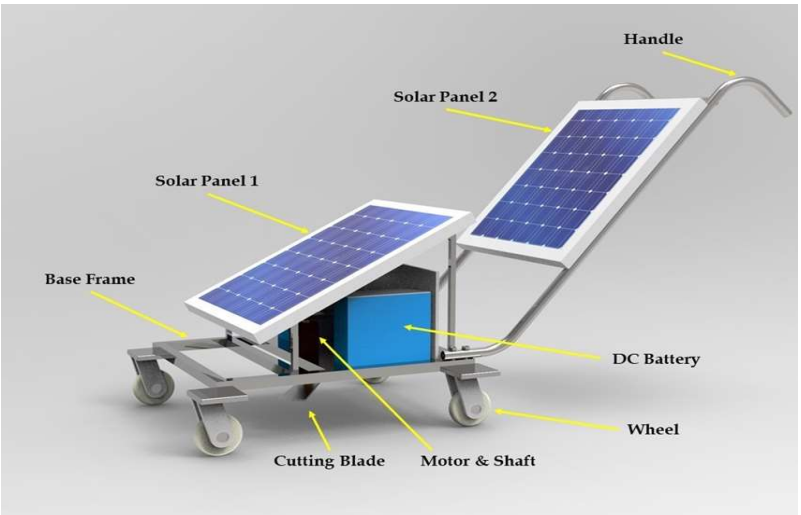

Fig.2. Components of prepared solar mower

2.3 Materials used

A functional solar powered lawn mower consists of an electric motor, battery, frame, deck, charge controller, solar panel, cutter, and the wheels, all working together as a unit to efficiently cut grass. An adjustable wheel system was added into the design to allow the machine to cut grass at various heights according to the user's preferences. The battery is fueled by two charging sources (solar and AC plug-in). Dimension of different components are summarized in Table 1.

Table.1. Dimension of different components

Component/Element	Side	Dimension (cm)
Whole dimension	L	150
	B	60
	h	92
Solar	L	58
	B	52
	ht	1
Battery	L	19
	B	8

	h	18
Blade	L	33
	B	4
	h	3
Frame	L	62
	B	52
	h	4
Total machine wt.	W	50 Kg

i. Solar Panel

A solar panel is a collection of electrically linked solar photovoltaic modules that are installed on a base. A photovoltaic module is a packaged, connected assembly of solar cells. A solar panel is a collection of electrically connected solar photovoltaic modules that are installed on a base. A bundled, connected assembly of solar cells is known as a photovoltaic module. The solar panel can produce and supply power for use in home and commercial applications as part of a larger photovoltaic system. Each module's rating, which normally runs from 20 to 320 watts, is based on its DC output power under standard test conditions (STC). For a given rated output, a module's size is determined by its efficiency. Since a solar module can only provide a limited electricity, most installations employ many modules. A panel or array of solar modules, an inverter, and occasionally a battery, solar tracker, and interconnecting cables make up a photovoltaic system. Two of the 40W solar panels used in the mower were employed in this application.

ii. The Battery:

Solar cell modules can only generate electricity while the sun is out. Since they cannot store energy, it is required to store some of the energy generated in order to ensure the flow of power when the sun is not shining. Utilizing batteries, which chemically store electric energy, is the

most straightforward method. Batteries are series-connected collections of electrochemical cells, or "devices that convert chemical energy into electrical energy." Two electrodes dipped in an electrolyte solution make up battery cells, which generate an electric current when a circuit is created between them. Reversible chemical reactions between the electrodes and the electrolyte inside the cell provide the current. Rechargeable batteries are referred to as secondary or accumulator batteries. Electric energy is converted to chemical energy in the battery's cells when it is being charged. When a battery is discharged, the chemical energy that has been stored there is taken out and transformed into electrical energy. Here we used two pieces of 12V batteries for storing energy for the lawn mower.

iii. DC Motors

A direct current (DC) motor is a form of electric motor, and it is mechanically commutated. By definition, the stator and its current are immobile in space. The commentator changes the current in the rotor such that it is also stationary in space. This maintains the maximum torque at an angle between the stator and rotor magnetic flux that is close to 90 degrees. DC motors have a non-spinning armature magnetic field, a static field winding (winding that produces the principal magnetic flux), and a permanent magnet in addition to a rotating armature winding (winding in which a voltage is induced). Different field and armature winding connections offer various intrinsic speed/torque regulation properties. A DC motor's speed may be adjusted by varying the voltage provided to the armature or the field current. Speed control was made possible by the addition of variable resistance to the field or armature circuit. Modern power electronics devices known as DC drives are frequently used to control DC motors.

iv. Blades

The blade is the portion of a tool, weapon, or machine that has an edge and is designed to pierce, cut, slice, push, or scrape surfaces or materials. Rarely is the blade sharp enough to allow for precise cutting. Brown tips result from the blade's simple tearing of the grass. The horizontal blades, however, are simple to remove, sharpen, or replace. The drawbacks of current engine trimmers include high startup costs, loud engines, excessive fuel consumption, and long-term operator fatigue. Lawn mowers' cutting parts are called mower blades. They are frequently constructed of durable metals since they must be able to endure high-speed contact with a range of items in addition to grass. The materials used (as well as size, thickness, and design of the blades) vary by manufacturer. A flaking stone, like flint, metal (often steel), ceramic, or other substance can be used to create a blade. We utilized two metal blades in this instance.

2.4 Power transmission system of the machine

The batteries can be charged from the solar panel which can convert solar energy into electrical energy by photovoltaic effect. The batteries can also be charged through the AC current by through a converter which convert AC to DC current. Then batteries transmit the power to the D.C. motor. The cutting blade is connected to output shaft of the D.C through a coupler.

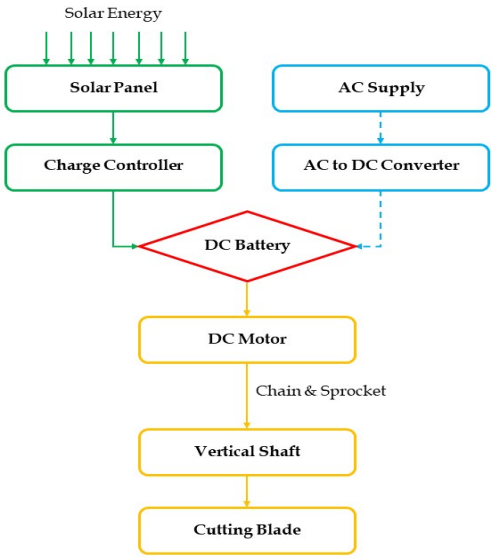

Fig. 3. Mechanical power transmission system

2.5 Design calculation

Useful mechanical engineering design texts were examined while calculating and choosing the right materials for the manufacturing and selection of various parts needed for the design of the machine. In this study, the selection of the different materials and components needed for the design took into account criteria like price, availability, strength, weight, etc.

Power Selection

- Mass of the blade 0.32 kg
- Angular velocity of 104.7 rad/s
- Radius of gyration 0.0825 m
- Centrifugal force at blade = $0.32 \times (104.7)^2 \times 0.0825 = 289.4$ N
- Torque of the blade 0.264 Nm
- Power at blade = $0.264 \times 104.7 = 27.64$ W $\approx$ 28 W

Charging Capacity:

Voltage of solar panel 24V

Capacity of solar panel 80W

Power input 80W/24V=3.33A

Capacity of battery= 60Ah

Charging time= 60/3.33= 18 hrs

i. Time taken for the battery to reach full charge = 18 hours

ii. Time taken for the battery to discharge = 4.2 hours

2.6 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 (Fig.4). 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.

Fig.4. The developed machine

2.7 Working principal of the machine

The solar panel convertssolar 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 and toggle switch is also provided to control the direction of blade (clockwise & anti clockwise). The rotating blade will continuously cut the grass and mower is propelled forward by the operator (Fig.5).

Fig.5. Field activity of Solar operated garden mower

2.8 Cost comparison

Solar operated mower is made from the locally available material, as a result the cost is very low, and the cost varies from 200-250USD.On the other side, the purchase price of engine operated lawn mower is comparatively high. The price of hand-push type engine-operated mower is more than double to thatof present developed mower.

3 RESULTS AND DISCUSSION

3.1. Performance Evaluation

The developed mower was tested in lawn with different blades and different height of cut to evaluate its performance. The results of performance evaluation are presented in **Table 2**. In conclusion, the functional performance of lawn mower was satisfactory during field. Lawn mower can be successfully used for lawn grasses and forage crops. The lawn mower takes little more time for covering area because of its less working width. Lawn mower gives fairly uniform height of cutting. The performance of lawn mower was also satisfactory in economical point of view.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.The result of the field tests is presented in following table:

Table2. Performance of lawn mower

Sl. No.	**Sample plot**	**Coverage area (m^2)**	**Grass Type**	**Average height before mowing (mm)**	**Expected grass height (mm)**	**Average height after mowing (mm)**
1	BINA residential park	47.2	Spare grass	120	60	58
2	BINA residential park	48.4	Stubborn grass	200	60	58
3	BINA residential playground	49.6	Carpet grass	70	50	53

Forward distance traveled = 6.5 m

Theoretical width of cutting blade = 0.33 m

$\boldsymbol{TheoreticalFieldCapacity}$ $(\boldsymbol{TFC}) = ForwardSpeedxTheoreticalwidthofblade$

To calculate theoretical field capacity,following data table was prepared(**Table 3**):

Table 3. Theoretical field capacityof lawn mower

Sl. No.	Forward distance traveled (m)	Time taken (s)	Forward speed (m/s)	Forward speed (km/hr)	Theoretical width (m)	Theoretical field capacity (ha/hr)	Average T.F.C. (ha/hr)
1	6.5	24.5	.265	0.954	0.33	0.0315	0.0307
2	6.5	25	.26	0.936	0.33	0.0309	
3	6.5	26	.25	0.9	0.33	0.0297	

Average theoretical field capacity was found approximately 0.0307 ha/hr.

$\boldsymbol{Effective\ Field\ Capacity}$ $(\boldsymbol{EFC}) = TotalAreaCovered\ /\ TotalTime$

To calculate effective field capacity, following data table was prepared(**Table 4**):

Table 4. Effective field capacity of lawn mower

Sl. No.	Area covered (m^2)	Time taken (s)	Effective field capacity (m^2/s)	Effective field capacity (ha/hr)	Average E.F.C (ha/hr)
1	47.2	682	0.0692	0.0249	0.0257
2	48.4	663	0.073	0.0263	
3	49.6	687	0.0722	0.026	

Average effective field capacity was found approximately 0.0257 ha/hr.

Average T.F.C. = 0.0307 ha/hr

Average E.F.C. = 0.0257 ha/hr

So, field efficiency = (E.F.C./T.F.C.) x 100%

= (0.0257/0.0307) x 100%

= 83.7%

The field efficiency of the solar powered lawn mower designed and developed is calculated to be 83.7% which is very efficient as it is able to perform the operation for which it was designed excellently.

4. Advantages

• Compact size and portable

• Easy to move from one place to another place

• Operating principle is simple.

• Non-skilled personnel can also operate this machine

5. Limitations

•Manually operated

•Large time required to remove the grass

• Difficult to operate in rainy seasons

6. Conclusion

Machines have been developed over the past few decades with the goal of lowering or eliminating greenhouse gas emissions, which are the primary contributor to climate change brought on by global warming. The upgraded solar-powered lawn mower will address the issue of environmental pollution and provide low operating costs because there are no fuel costs, which is what this project aims to do. For usage in homes and businesses with lawns where tractor-driven mowers couldn't be used, the solar-powered lawnmower was created. The machine has enough capacity to serve this need. The machine's field efficiency was 83.7%, which is a comparatively high figure. It was also tested on various grass samples. To achieve the anticipated height of grass after mowing, the average height of cut for each grass sample was modified. The features of the grass, such as its roughness and density, affected how long it took to cut each sample of grass. The functional performance of the solar-powered lawn mower was quite satisfactory in well prepared fields and lawns, according to the findings of field operations carried out by the device. The machine's handle may be adjusted, making it simple for both men and women of different heights to use. Its field efficiency was excellent, and its field capacity is extremely high. The cost of machine was reasonably low as compared to engine operated lawn mower.

REFERENCES

Basil, O. (2013). Simple Design of Self-Powered Lawn Mower. International Journal of Engineering and Technology, 3(10): 933-938.

Hessayon, D.G. (2007).The lawn expert. Transworld publishers, London. http://en.wikipedia.org/history_of_the_lawn_mower. Accessed on 25-02-2020.

Knier, G (2010). How do Photovoltaics Work? https://science.nasa.gov/science-news/science-at-nasa/2002/solarcells**.** Accessed on 25-02-2020.

Lucas, D.R., Justin Lucas, and Lucas, R. J. (2010). "Hybrid electric lawn mower", US Patent, Patent no. US20080120955A1.

Manpreet, S., Ashutosh, P., Suman, S., Kurman, P., Maushan, R., & and Tekelllapati, N. (2016). A Review and Comparative Analysis of Solar, Electric and Gasoline Lawn.

Mgbemu, E.N. (2005). Modern Physics, First Edition. Spectrum Limited, Ibadan. pp.72

Akinyemi, A.O., Ayobami D.O.H.R. and Damilare A.S. (2020). Design and Fabrication of a Solar Operated Lawnmower. International Journal of Innovative Science and Research Technology, 5(10): 1161-1197

Manpreet, S., Ashutosh, P., Suman, S., Kurman, P., Maushan, R., & and Tekelllapati, N. (2016). A Review and Comparative Analysis of Solar, Electric and Gasoline Lawnmowers: An Extensive Study. Internetional Journal of Innovative Science, Engineering and Technology.

National Research Foundation (NRF) (2010). Communication Astronomy101 in School. Astronomy Activities/Demostrations, Cape Town, South Africa.

Ogiemudia, O. (2015). Design and improvement of a solar powered lawn mower from locally sourced material. Asia pacific journal of mechanical engineering research.

Okokpujie, I., and Olaseyi, O. K. (2017). Design, Construction of a Cylinder Lawn Mower. Journal of Engineering and Applied Science.

Paytas, A. R.,(1991). "Solar powered mower", US Patent, Patent No. US4987729A.

Tanimola, O. A., Diabana, P. D., and and Bankole, Y. O. (2014). Design and Development of a Solar Powered Lawn Mower. International Journal of Scientific & Engineering Research, 5(6): 215-228

Thomas R. McCoy (4988). "Solar powered golf kart", US Patent, Patent No., US4744430A, 1988.

Thomas, R., and Donald H. Smith, (1982). "Combined A.C./D.C. electric lawn mower", US Patent, Patent No.US4333302A, 1982.

Vivek, P. R., Vishnu, N. V., Akhil, K. A., Kevin, R., and P, A. R. (2016). Design and Analysis of Rotary Lawn Mower. Vol. 5 (04). DOI : http://dx.doi.org/10.17577/IJERTV5IS040152