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Design of Solar Grass Cutter

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Abstract - *Due to the continuous increase in the cost of fuel and the effect of emission of gases from the burnt fuel into the atmosphere, these necessitate 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 was designed and developed, based on the general principle of mowing. The designed solar powered lawnmower comprises of direct current (D.C) motor, a rechargeable battery, solar panel, a stainless steel blade and control switch. 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. The system will have some automation work for guidance and other obstacle detection.*

Key Words: **Solar grass cutter, Design, 3-D modelling, SolidWorks, Solar Panel, Solar array design, Atmega 328-p.**

1. INTRODUCTION

Now-a-day's pollution is a major issue for whole world. Pollution is manmade and can be seen in own homes. In case Gas powered lawn mowers due to the emission of gases it is responsible for pollution. Also the cost of fuel is increasing hence it is not efficient. So the Solar powered grass cutters are introduced. 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. But the cost of those grass cutters is high. This design is alternative for environmentally hazardous gas powered grass cutter. Solar energy is the form of renewable energy source and this source is characterized as either passive solar or active solar depending on how they capture and distribute solar energy or convert it into solar power. Basically solar energy is the free energy source which can be used easily. Then by using this free solar energy, solar based grass cutter machine will be operating automatically. There are four motors are used which are controlled by the Atmega328 microcontroller. Where the two motors are used for the moving action and the other motor is used for grass cutting purpose. For avoiding the obstacles during the operation the ultrasonic sensor is used for avoiding action. There is no need of fuel and any wire extension for the power supply therefore it is pollution less and eco-friendly project. All the assumptions and considerations made in this project design are taken according to the conditions in India[1].

1.1 Problem statement

The solar lawn mower is the taken into consideration after the efficiency of others felt lacking, which was because of the following factors[1]:

- Pollution is there due to the use of grass cutter working on IC engine.
- Grass cutters working on electricity are efficient but it also increases electricity consumption.
- More time is required to accomplish the work.
- Human effort required is more.
- There are many safety issues regarding grass cutters such as obstruction in the way of the cutter can cause damage to the blades of the cutter or it can cause the obstructions such as stones to fly and cause harm to the operator.
- There is a probability that it could not be used during rain or in wet conditions.

1.2 Objectives

The objectives of this lawn mower are created to solve the problems which existing lawn mowers have, with this objective we can aim to build a very efficient lawn mower. The following are the objectives of this project[1]:

- To design a lawn mower operating on solar energy.
- To reduce operating cost.
- To avoid any damage to operator and the lawn mower itself.
- To keep the environment clean and healthy.

- To reduce human efforts.
- To cut various type of grasses with precision.

The current technology available in the market are too expensive, they can't be used in domestic applications, so the end product need to be economic in price for it to be used on a large scale.

In India the type of grass usually found are the "Ravenna Grass (Saccharum Ravennae)" our main objective is also to cut the grass properly, therefore proper blade design is also necessary for the lawn mower. Elephant grass is also one of the most found grasses in India, they are big in length but have a thin structure, so they must be taken in consideration while designing the lawn mower[2].

1.3 Methodology

Solar powered grass cutter has solar panels mounted on it in such a way that we can utilize the solar radiation coming from the sun with high intensity. This solar energy is then converted into electrical energy which is then stored in rechargeable battery. This battery is connected to the ATMEGA328 which is a micro-controller and also the main processing unit of our lawn mower. Further the micro-controller is connected to the four wheel motor which is going to move and make travelling possible for our mower. The micro-controller is also connected to the main rotor motor which will in turn control its speed and other parameters[1].

Ultrasonic sensors are used to detect any obstructions such as rocks which might damage the lawn mower; this sensor will be controlled by using ARDUINO (ATMEGA328). The sensor will also be connected to the micro-controller. The micro-controller which we are using was selected considering the above mentioned factors, because it will have to perform various tasks at the same time. If we would have used ARDUINO UNO we couldn't perform variety of tasks at same time as this micro-processor has low specifications compared to ATMEGA328p[1].

Proper material selection is required for the design of the frame and the housing of the rotor and its supports by following standard calculations of bending and shearing and torsion.

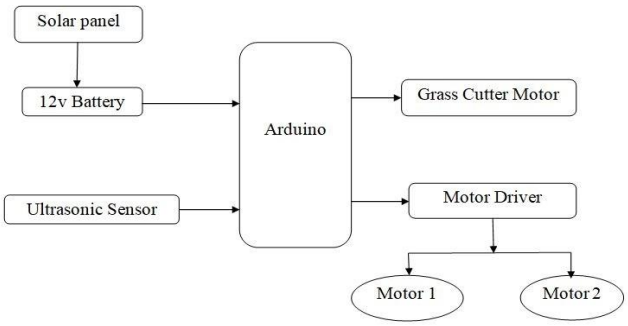

Fig -1: Block diagram of the system

1.4 Accessories

- Micro-controller (ATMEGA328p)
- Battery
- Grass cutting Blade
- Motor operating the Wheels
- Motor operating the Cutting Blades
- Solar Panel
- Frame of the Assembly

2. Design of Solar Grass Cutter

Solar powered grass cutter has solar panels mounted on it in such a way that we can utilize the solar radiation coming from the sun with high intensity. This solar energy is then converted into electrical energy which is then stored in rechargeable battery. This battery is connected to the ATMEGA328 which is a micro-controller and also the main processing unit of our lawn mower. Further the micro-controller is connected to the four wheel motor which is going to move and make travelling possible for our mower. The micro-controller is also connected to the main rotor motor which will in turn control its speed and other parameters. Ultrasonic sensors are used to detect any obstructions such as rocks which might damage the lawn mower; this sensor will be controlled by using ARDUINO (ATMEGA328). The sensor will also be connected to the micro-controller[1].

2.1 Microcontroller (Atmega328p)

ATMEGA328P is high performance, low power controller. ATMEGA328P is an 8-bit microcontroller based on AVR RISC architecture. It is the most popular of all AVR controller as it is used in ARDUINO boards. This micro-controller is

preferred in this project as it has ability for high multitasking and with fast processing speed compare to ARDUINO UNO which can only perform designated task one at a time[11].

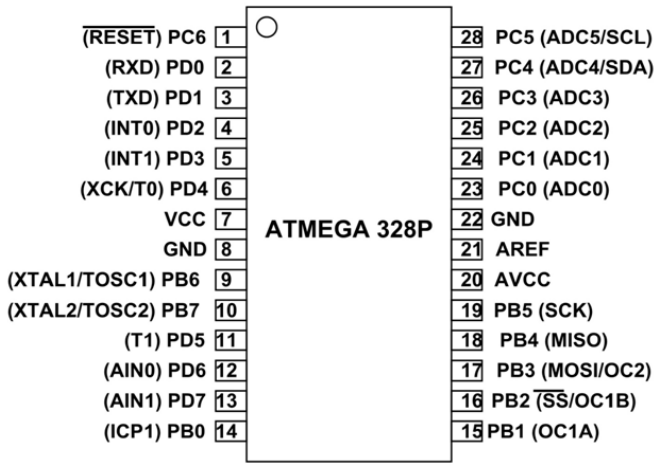

Fig -2: ATMEGA 328P[11]

Table -1: Parameters of ATMEGA 328P[5]

Parameters	Value
Flash	32 kbytes
Pin count	28
CPU	8-bit AVR
Max I/O pins	23
Ext Interrupts	24

2.2 Battery

A rechargeable battery, storage battery, or secondary cell, (or archaically accumulator) is a type of electrical battery which can be charged, discharged into a load, and recharged many times, as opposed to a disposable or primary battery, which is supplied fully charged and discarded after use. It is composed of one or more electrochemical cells. The term "accumulator" is used as it accumulates and stores energy through a reversible electrochemical reaction. Rechargeable batteries are produced in many different shapes and sizes, ranging from button cells to megawatt systems connected to stabilize an electrical distribution network. Several different combinations of electrode materials and electrolytes are used, including lead–acid, zinc–air, nickel–cadmium (NiCd), nickel–metal hydride (NiMH), lithium-ion (Li-ion), lithium iron phosphate (LiFePO4), and lithium-ion polymer (Li-ion polymer)[9].

Rechargeable batteries typically initially cost more than disposable batteries, but have a much lower total cost of ownership and environmental impact, as they can be recharged inexpensively many times before they need replacing. Some rechargeable battery types are available in the same sizes and voltages as disposable types, and can be used interchangeably with them[5][9].

2.3 Grass Cutting Blade

For smooth grass cutting a motor power of minimum 628.3 watts is necessary having a rotational speed of 2000-3000 rpm and producing a shear force of about10.5N[4].

A rotary Mower has shown minimum power requirement at a blade angle of 25◦ - 30◦ with cutting edge of about 0.05 mm. The length of the blade was taken as 500mm with 30◦ cutting angle[3].

2.4 Motor Operating the Cutting Blade

A DC motor is used for the cutting blade. A DC motor is defined as a class of electrical motors that convert direct current electrical energy into mechanical energy. When kept in a magnetic field, a current-carrying conductor gains torque and develops a tendency to move. In short, when electric fields and magnetic fields interact, a mechanical force arises. This is the principle on which the DC motors work[7].

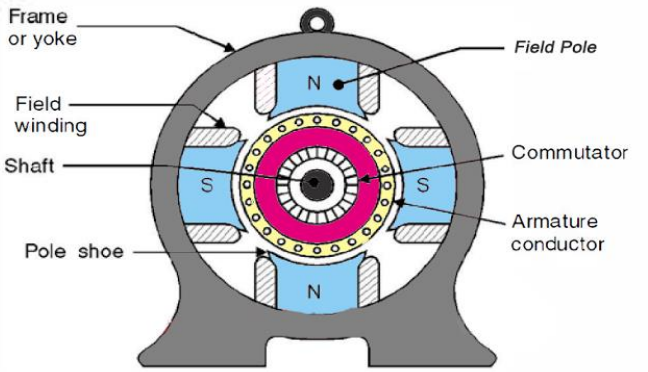

Fig -3: Construction of DC motor[7]

24V 775 DC Motor:

This motor runs at 5000-12000 rpm, this is more preferable compared to 24v DC motor whose rpm goes above 20000 rpm. Current required by the motor is 2.3 amps and weight is 150.00g. This motor has high torque and high power which is required for this project.

Power developed by the motor:

P = V*I = 24*2.3

P = 55.2 watts

Torque developed by the Motor:

P = 2∏NT/60

55.2 = 2*∏*10000*T/60

So, T = 18.97 N-M.

2.5 Motor Operating the Wheels

This application requires high torque low speed 12v DC motor. This motor has a rpm of 300.Current required is 0.3amp. Number of motor used are 4 and each motor is for separate wheel, a total of 1.2 amp current will be used[7].

Power developed by 4 motors:

P = V*I = 12*1.2

P = 14.4 watts

Torque developed by 4 motors:

P = 2∏NT/60

14.4 = 2*∏*300*T/60

So, T = 0.45 N-M.

2.6 Solar Panel

Fig -4: 100w mono-crystalline solar panel[12]

Solar PV panels are comprised of many small photovoltaic cells – photovoltaic meaning they can convert sunlight into electricity. These cells are made of semi-conductive materials, most often silicon, a material that can conduct electricity while maintaining the electrical imbalance needed to create an electric field.

When sunlight hits the semiconductor in the solar PV cell, the energy from the light, in the form of photons, is absorbed, knocking loose a number of electrons, which then drift freely in the cell. The solar cell is specifically designed with positively and negatively charged semiconductors sandwiched together to create an electric field. This electric field forces the drifting electrons to flow in a certain direction- towards the conductive metal plates that line the cell. This flow is known as an energy current, and the strength of the current determines how much electricity each cell can produce. Once the loose electrons hit metal plates, the current is then directed into wires, allowing the electrons to flow like they would in any other source of electric generation[6].

12v 100 watts mono-crystalline solar panel is preferred for this project. This solar panel is selected by considering the required power input for the motor which are required for running the blades as well as the mower itself.

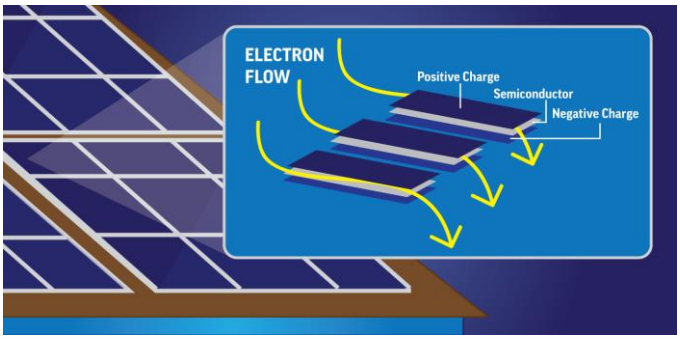

Fig -5: Working of Solar Panel[6]

Features of Mono-Crystalline Cells:

- These cells in the panel have a pyramid pattern which offers a larger surface area to collect more energy from the sun's rays.
- The top surface is diffused with phosphorous which helps to create an orientation that is electrically negative as compared to the bottom which has a positive electrical orientation, which in turn helps to create the electric field.
- To reduce reflection and thereby increase absorption, the cells are coated with silicon nitride.
- The produced electricity is collected through metal conductors printed onto the cells.
- These panels have longevity up to 30 years.
- It has the efficiency of 20%.

Power required by rotor = 55.2 watts

Power required by 4-wheels = 14.4 watts

Total power required = 55.2+14.4 = 69.6 ≈ 70 watts

- Assuming the lawn mower takes 1 hr for the cutting operation either in Day/Night:

Day_{load} = Wh_{day} = Power required * Working hours

Wh_{day} = 70 *1 = 70 Wh

$Night_{load}$ = Wh_{night} = Power * Working hours

Wh_{night} = 70*1 = 70Wh

- Watt-hour of photovoltic cell is derived by equation:

$Wh_{pv} = (wh_{day}+(wh_{night}/\eta_B))+ (wh_{day}+(wh_{night}/\eta_B))*N_a/N_r$

Where,

ηB = Battery efficiency

Na = No. of autonomous days

Nr = No. of rechargeable days

- If the mower is working in the day time:

$Wh_{pvday} = wh_{day}$ = 70 wh

- If the mower is used at night when there's no solar power available:

$Wh_{pvnight} = wh_{night}/\eta_B$ = 70/0.7 = 100 Wh

- Autonomous operation means the operations in which solar energy is not available for a certain period of days :

$Wh_{auto} = (wh_{night}/\eta_B)*N_a/N_r$

- Since, grass cutting operations are not used daily so we can assume to have sunlight everytime.

Therefore, N_a = 0 & N_r = 0

- As grass cutting opertions in India are mostly done in commercial or educational or entertainment parks we can assume it to be done once in week in daytime.

Therefore, Wh_{night} = 0

- Watt-hour for Photovoltic cell is now:

$Wh_{pv} = Wh_{pvday}$ = 70 Wh

- Array per watt, Pm ≥ Wh_{pv}/H_{atmin}

Where,

H_{atmin} = hours of equivalent standard of insulation or average sunlight hours[8]

For Pune H_{atmin} is 8.055 ≈ 8 hrs

Pm = 70/8 = 8.75 watts at peak

- Area of the panel is calculated by the following formula:

$A_{intrinsic} = Pm/\eta_{pv} * 1000\ m^2$

$A_{intrinsic}$ = 8.75/0.2*1000 = 0.00043 m^2

Therefore, the PV panel area designed for the required power is 0.0043 m^2 = 437.5 cm^2

2.7 Bar Housing the Cutter Rotor

The bar housing the rotor of the Blade will have forces acting on it due to the weight of the DC motor. This force may cause bending of the bar and it can lead to damage to the cutter and operator or nearby entities. To check whether the bar size is safe or not we need to calculate the shear force acting on it and its bending moment and also the max stress and normal stress acting on it.

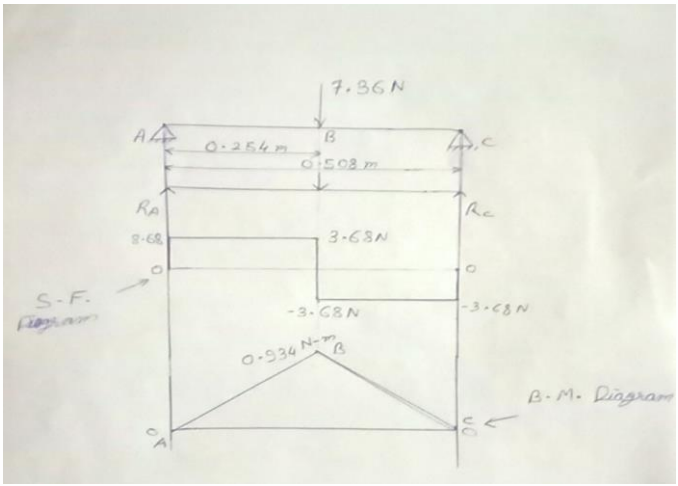

Fig -6: SFD and BMD

Available data:

Length of the Rod = 508mm = 0.508m

Force acting on the Bar = weight of the bar*acceleration due to gravity

Force acting on the Bar = 0.75kg*9.81 = 7.36N

Calculation:

∑F = 0

Ra -7.36+Rc = 0

Ra + Rc = 7.36N

∑M@A = 0

(Rc*0.508)-(7.36*0.254) = 0

Rc = 3.68N

So, Ra = 3.68N

- Shear Force Calculations:

Ra = 3.68N

B = 3.68-7.36 = -3.68N

Rc = -3.68N

Rc = 0

- Bending Moment Calculations

M@C = 0

M@B = (3.68*0.254) = 0.934 N-M

M@A = (3.68*0.508)-(7.36*0.254) = 0

Therefore, the shear force acting on point B is 3.68N and the bending moment acting on point B is 0.934N-M.

- For Rectangular Bar

Max Shearing Stress due to Bending is:

∂max = 3F/2A

Where, F = Shearing force, A = Cross-sectional area

∂max = 3*7.36/2*508*20 = 0.0010 N/mm2

Shearing force = ∂ = F/A = 7.36/508*20

∂ = 0.00072 N/mm2

Since, ∂max ≥ ∂

Therefore, this bar is safe to use.

3. Material Selection of Solar Grass Cutter

Material selection is done on the basis of:

- Availablity of material.
- Required properties of the material.
- Weldable material.
- Cost efficient material.

3.1 Material Selection of Blades:

The blades of the Lawn Mower is to be made by using Stainless Steel, as the grass which blade will be cutting will not always be dry, so as we cut the wet grass there are chances for corrosion. Stainless Steel is the alloy of iron and carbon with 2% C which has non-corrosive properties. The stainless steel considered for this project is of grade X14CrMoS17, this steel is also known as "ASTM A276 / AISI 430F".

3.2 Material Selection of Frame:

The frame of the Lawn mower will be made of grey cast iron and will be welded at the joints. Grey cast iron is the alloy of iron and composes of 2-4% carbon with the presence of silicon and manganese. Grey cast iron used in the frame is of grade ASTM A48 CLASS 20. It is more effective because it can be easily machined and manufactured and it is easily available. MIG welding will be preferred for joining all the joints of the Lawn Mower.

3.3 Material selection of the Bar Housing the Rotor

Bar which will be housing the rotor, will have shear force acting on it. The approximate value we have will calculate the forces acting on it by shear force and bending moment diagram calculations. By the calculations performed and presented in calculation section we select Cast iron as the material which will be used to make the frame. Cast iron considered for the project is of grade ASTM A48 CLASS 30.

4. 3-D and 2-D Model of Solar Grass Cutter

The solar grass cutter was designed by the means of analytical calculations of the sizes considered or assumed but just the calculations can't alone give us the exact idea of what the model might actually look like. To make the project more valuable 3-D model is introduced. The 3-D model is made by using SOLIDWORKS 2019 software, SOLIDWORKS is used to develop mechatronics systems from beginning to end. At the initial stage, the software is used for planning, visual ideation, modeling, feasibility assessment, prototyping, and project management. The software is then used for design and building of mechanical, electrical, and software elements.

The 2-D model of solar grass cutter is made using SOLIDWORKS 2019 software, the 2-D or orthographic

model helps in understanding the dimensions of the 3-D model created. In this each part is given smart dimensions.

4.1 3-D Model of Solar Grass Cutter

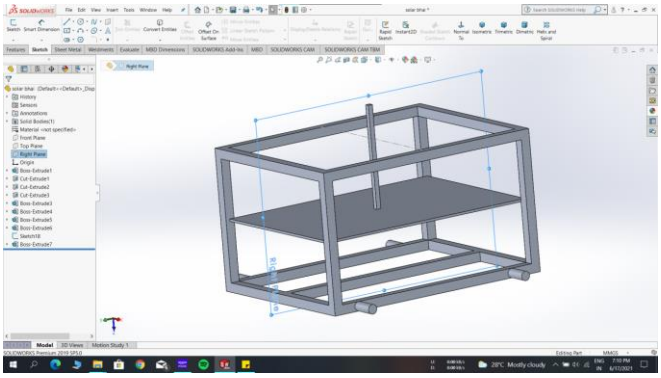

Fig -7: 3-D model of the frame

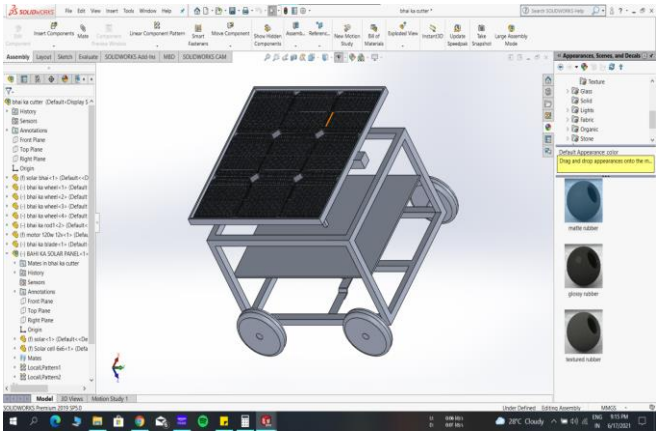

Fig -8: Left corner view of Grass Cutter

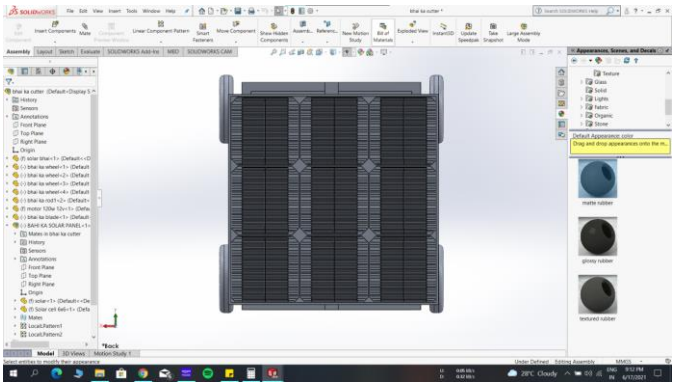

Fig -9: Top view of the Grass Cutter

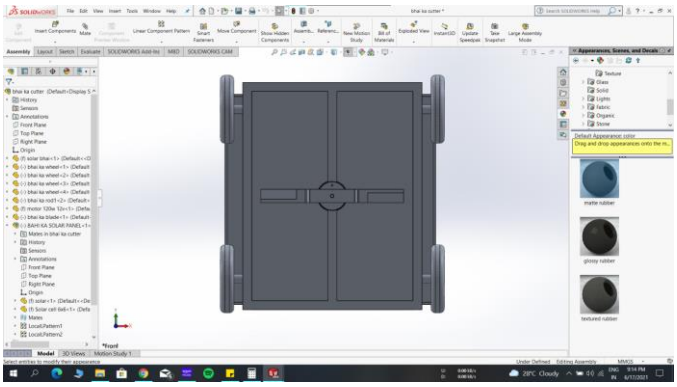

Fig -10: Bottom view of the Grass Cutter

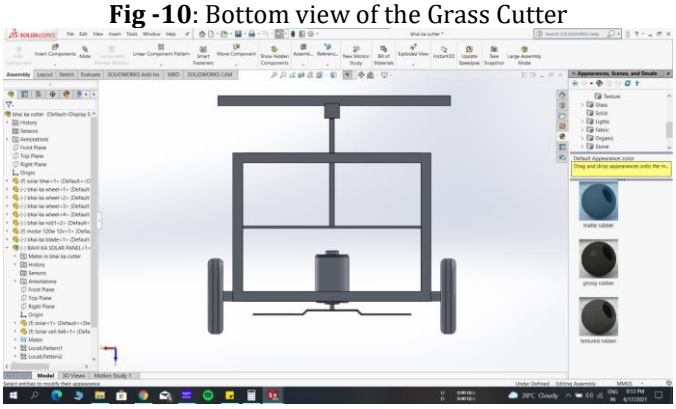

Fig -11: Front view of the Grass Cutter

4.2 2-D Model of the Solar Grass Cutter

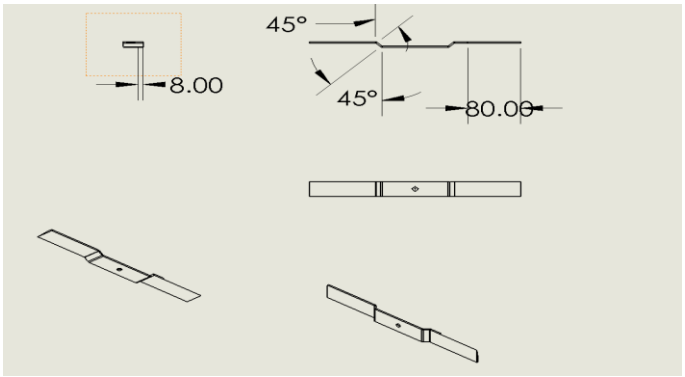

Fig -12: 2-D view of Cutting Blade

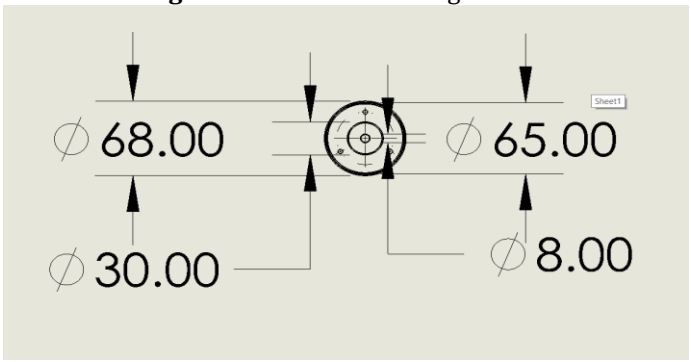

Fig -13: 2-D view of the DC Motor

5. CONCLUSIONS

Solar Grass Cutter is a device which is mostly used at big theme parks and gardens, so to make it more appealing to grow on domestic scale we performed this project. We designed the Solar Mower and came to conclusion considering all the entities which affects it, the mower has very high efficiency more than 90%, as it uses solar radiation as input and gives its work on the output.

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