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Design and Fabrication of Battery Operated Grass Cutter

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ABSTRACT
In Agricultural field or in Nursery or even in House hold, growing grass is a commonly found problem. Removal of the grass is also a tedious job involving lot of human efforts. In order to reduce the time and effort in clearing the unwanted grass, the removal of grass need to be mechanised. This machine can be called as grass cutter. Depending on the type of power utilised for the machine, it can be termed differently like solar powered, battery powered electrical and manual etc. In its simple construction a very high speed motor is connected to an end of a holding rod that is hang with a shoulder and held with hand to the free end of this rod a battery pack is attached. Also a solar panel can be attached to charge the batteries there by making the grass cutter run with the help of solar energy. Multi agriculture is the new innovative and effective concept mainly used for agricultural field. The main goal of this project is to design a grass cutting machine for making the cutting operation smooth and with less effort. The main components used in this project are motors, blade, Switch, battery, connecting wires and a robust chassis. The cutter used is sometimes a flexible wire that cuts the grass with high speed rotation. We prefer to go for a solid steel blade as the cutting tool. The switch pad is used to control the cutting machine to ON/OFF the motor containing a grass cutting blade on its shaft. The motors are powered by the battery. The purpose of the project is to design the different components of the grass cutter like electrical motor, battery pack, cutting assembly, base frame and fabricate the same.
In the first phase the components will be designed and in the second phase the grass cutter will be assembled.

I. INTRODUCTION

The aesthetic value of his environment is as important as food and shelter to the modern man. In general, grasses are found to survive in a variety of conditions and thus the need to curtail their growth in order to enhance the beauty of our habit environment. Conventional Grass cutting Machines produces number of unpleasant effects on human as well as environment. Running and maintenance cost of traditional grass cutting machines are high .Looking in to all these problems it was decided to develop a good machine with easy in operation and with low cost. The first actual mower was invented in 1830 by Edwin Beard Budding. Budding was an engineer from England who first discovered the idea of a mower from a cylindrical machine used for cutting in a mill. A lawn is any area of grass; mostly tough grass which is neatly cut like in a private garden or a public park.

The mower that he developed was composed of a large roller which provided power to the cutting cylinder using gears. The cutting cylinder contained several blades connected in series around the cylinder. His innovation opened the door for numerous advancements in lawn cutting. An electrical Grass Cutter is more suitable & easy to use than the Grass Cutter with an engine, so we select an electrical Grass Cutter with an electric motor, which will provide the high speed rotation to the blades. Cordless electric Cutters are powered by 12-volt rechargeable batteries.

Typically, more batteries mean more run time and/or power. Batteries can be in the interior of the Grass Cutter or on the outside. If on the outside, the depleted batteries can be quickly swapped with recharged batteries. Cordless Cutters have better.

II. DEFINITION

A grass cutter is a machine used for cutting grass or lawns. A lawn is any area of grass; mostly tough grass which is neatly cut like in a private garden or a public park. In early years sheep and other animals were used to keep the lawn or yard trimmed. The animals used to gaze the grass however in today's modern time a machine with rotating blades is used for cutting grass of lawns. These machines are called grass cutter and they

can be manual (hand-operated) or motor-driven. Some cutter blades may be push forward and some may cut the grass to an even height with spinning of blade. All the mowers have some similar structure which includes a motor, rotating blade, moving around options and grass clippings dispenser. While searching for a lawn mower, please make sure that paying a high price here wouldn't really mean higher quality results. There are other factors to consider.

III. TYPES OF GRASS CUTTER

There are three types of lawn mower nowadays used in general. They are as fallow:-

I. Walk-Behind Mower
II. Riding Mower
III. Tow-Behind Mower

WALK-BEHIND MOWER

[Figure 1: Walk-Behind Mower]

Types of Walk-Behind Mower

I. Gas powered grass cutter.
II. Electric grass cutter.
III. Manual grass cutter.

ELECTRIC GRASS CUTTER

The electrical powered mowers are suitable for land under 1/3 acres. They offer similar features to that of gas powered mowers including 3-in-1 feature, push or self-propel, wide cutting etc. but they save you fuel and maintenance cost.

Moreover they have relatively quieter operation. These machines are environment- friendly with no carbon emissions. There are corded and cordless electrical mowers available and usually have a motor power between 6-12amp. Cordless mowers operate on battery giving you ease of mowing around. These are most suitable for flat surfaces.

RIDING GRASS CUTTER

As opposed to walk-behind grass cutters, the riding lawn mowers have a seat to ride on for cutting. It includes various controls that enable you to cut your lawn while being seated on this mower.These are suitable for larger lawns and are often termed as small farm tractor. These machines have powerful engines and cutting decks as compared to push cutters.

[Figure 2: Riding Grass Cutter]

TOW-BEHIND MOWER

Tow-behind cutters are used for much larger areas, like massive fields, and are used much more in agriculture and road sides. Tractors or powerful vehicles must tow these devices. Most are mechanical, much like some of the first grass cutters ever invented. They use the rotation and energy from being pulled over ground to rotate and cut grass, sod or whatever needs to be cut.

[Figure 3: Two-Behind Mower]

IV. PARTS OF GRASS CUTTER

The main parts of a Grass Cutter are:-

I. B**lade–**It Consist of 2 to 3 blades that are attached to a rotating shaft. The blades rotate, creating a cutting motion.
II. **Body frame -** The main structural frame of the Cutter onto which the other parts of the Cutter are mounted.
III. **Wheels -** These help propel the Cutter in action. Generally Grass Cutter have four wheels.

IV. **Push Handle -** The "power source" of a manually operated Cutter. This is a sturdy handle that is connected to the frame, wheels and blade chamber.
V. **Motor -** The power source of a Grass Cutter that is powered by Battery & We are using AC motor.
VI. **Bag -** The bag is used to carry grass clippings.
VII. **Battery –** It Provides Power source to the motor.

V. DESIGN OF GRASS CUTTER

- The design of an electrical Grass Cutter consists of a Blades, Body frame, wheels, Push handle, Bag, & Motor. The power systems have many Options, but we will use rechargeable battery powered motor, which is attached to the cutting blades. Sizing the battery will depend on what we are powering, specifically the motors. Like batteries, there is a range of motors to choose from. We suggest 36 volt motor with pulleys.
- It consists of two parts.

I. Housing
a. Blade
b. PushHandle
c. BodyFrame
d. Wheel
II. Power Supply
a. Shaft
b. Pulley
c. Motor
d. Battery

CUTTER DECK HOUSING
This houses the blade and the drive system of the Cutter. It is shaped to effectively eject the grass clippings from the Cutter
BLADE MOUNTING AND DRIVE SYSTEM
The blade of a rotary Cutter is usually mounted directly to the motor shaft or through pulley drive.
CUTTER BLADE
A rotary Cutter generally has two blades that rotate horizontally. The blade features edges that slightly curved up to generate a continuous air flow as the blade rotates, thus creating a sucking and tearing action.

VI. DESIGN AND THEORATICALANALYSIS

6.1 BLADE

- It Consist of blades that are attached to a vertically rotating shaft, to the downward direction. The blades rotate, creating a cutting motion.
- It's important to cut grass, with a sharp blade as blunt blades can rip or tear grass from the roots, damaging our greenery and causing our lawn to become patchy over time.
- Size:-390mm, Metal:-The blade is made of Steel

[Figure 4: Blade]

6.1.1 TYPES OF BLADE

I. Straight Shaped Blade

[Figure 5: Straight Shaped Blade]

II. Taper Shaped Blade

[Figure 6: Taper Shaped Blade]

III. Larger Blade

[Figure 7: Larger Blade]

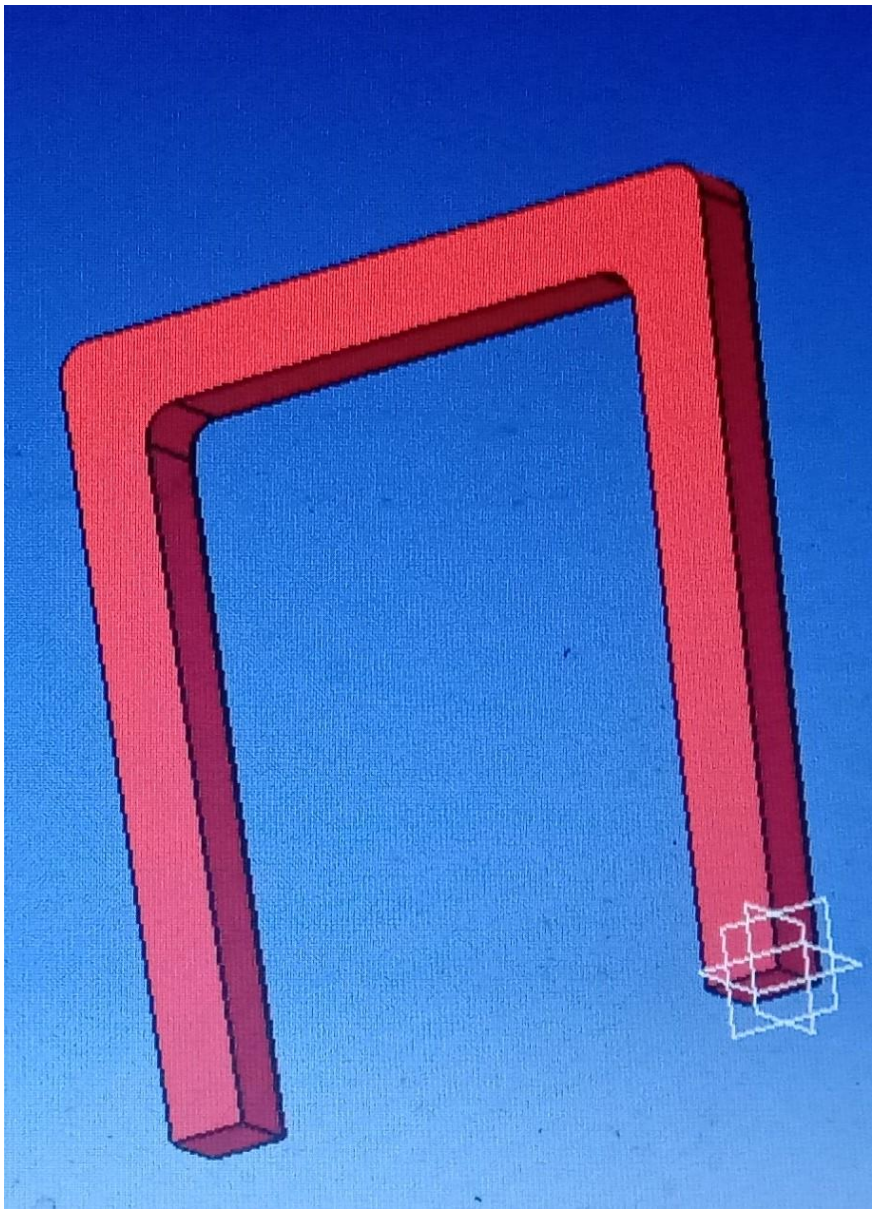
6.1.2FAILURE CHECK OF BLADE

We select blade of 390mm length.
We select C50 as the material for blade
Referring to data hand book
Ultimate Tensile strength=650N
Assuming Variable load we take Factor of safety=8
Allowable stress ($\sigma_{allowable}$) =Tensile strength/Factor of safety =650/8 =81.5N/mm^2
The force required to cut grass is 11.3N.
Force (F) =11.29N
Radius (r) =195mm
Thickness (t) =5mm
Breath (b) =30 mm
Moment (M) =F ×r =11.29× 195 =2201.55 N.mm
Section modulus (Z) = bt2/6 =5 ×302/6 =750mm^3
Stress (σ) =M/Z =2201.55/750 =2.93 N/mm^2
Allowable stress > stress
So, the design is safe.

6.2 PUSH HANDLE

- The "power source" of a manually operated cutter .This is a sturdy U-shaped handle that is connected to the frame, wheels and blade chamber.
- The hollow Iron piped push handle will be designed to provide adequate sectioning for the separate subsystems.

[Figure 8: Push Handle]



[Figure 9: Push Handle Design by CATIA Software]

6.2.1 FAILURE CHECK OF PUSH HANDLE

We take the material as WI

From data hand book

Ultimate Tensile strength =150N

Factor of safety=5

Allowable stress ($\sigma_{allowable}$) =U. Tensile strength/Factor of Safety =150/5=30N/mm^2

Load (w) =400N

Width (b) =500mm

Maximum Moment (M) =200×100=20000Nmm

Outer diameter (do)=35mm

Inner diameter (di)=25mm

Section Modulus (Z) = $\pi(do^4-di^4)\div 32do$

= (354 -254) /32x35

=1077.94 mm^3

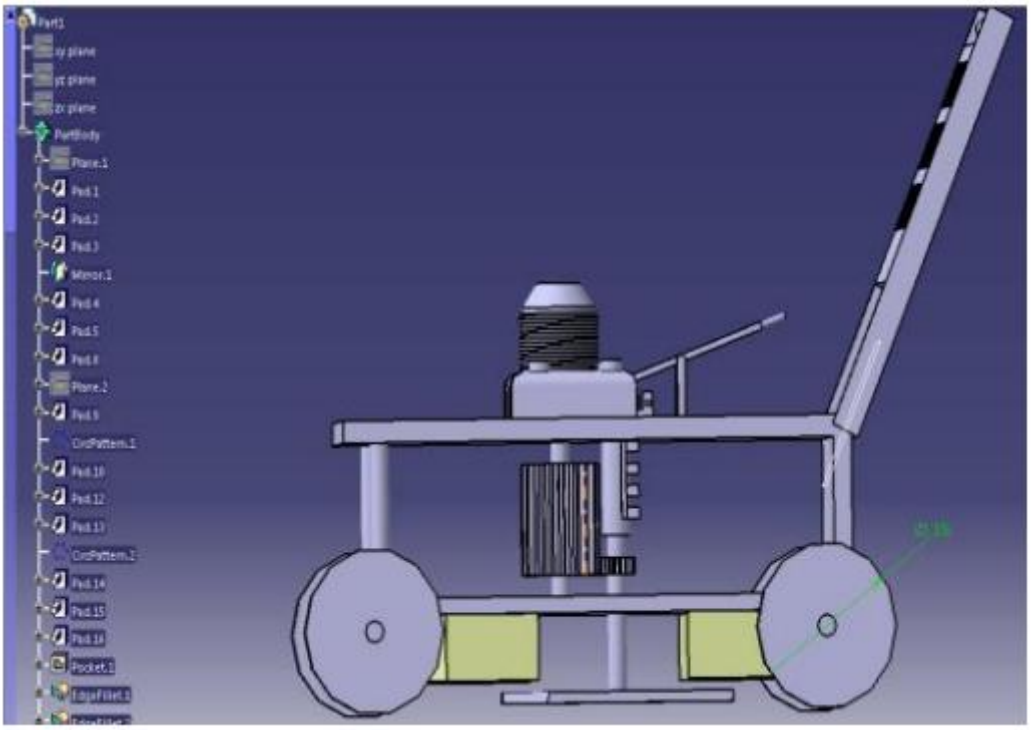
Stress (σ)=M/Z =20000/1077.94 =18.56 N/mm^2

Allowable stress > Actual stress

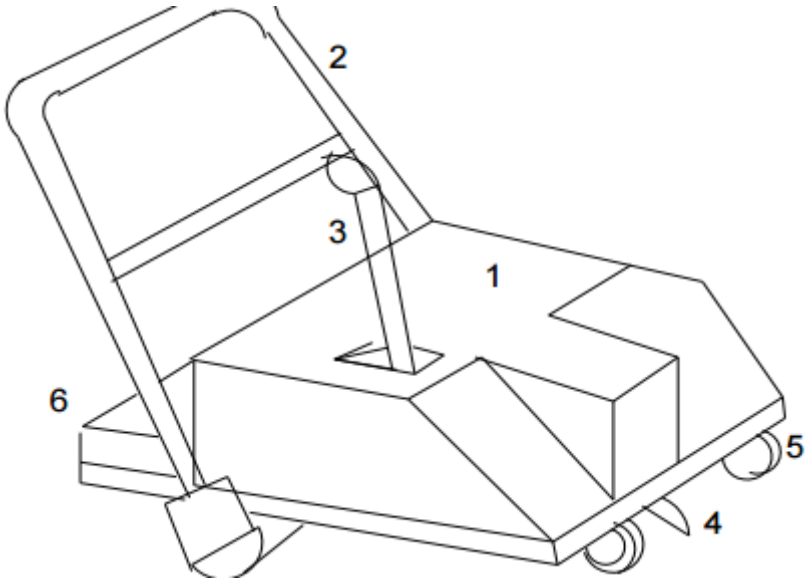
So, the design is safe.

6.3 BODY FRAME

The frame is that provides a base unit that all of the components/subsystems are mounted on. The hollow Iron piped frame will be designed to provide adequate sectioning for the separate subsystems. The rear wheel motors are mounted to the rear exterior section of the frame.The Batteries will have a separate compartment for mounting and secured safely.The Frame is to be composed of 45mmX75mm Hollow Iron pipe was chosen due to its strength and availability.



[Figure 10: Body Frame Design by CATIA Software]



[Figure 11: Body Frame]

6.3.1 FAILURE CHECK OF BODY FRAME

We select hollow WI pipe of 75X45mm dia.

From data hand book

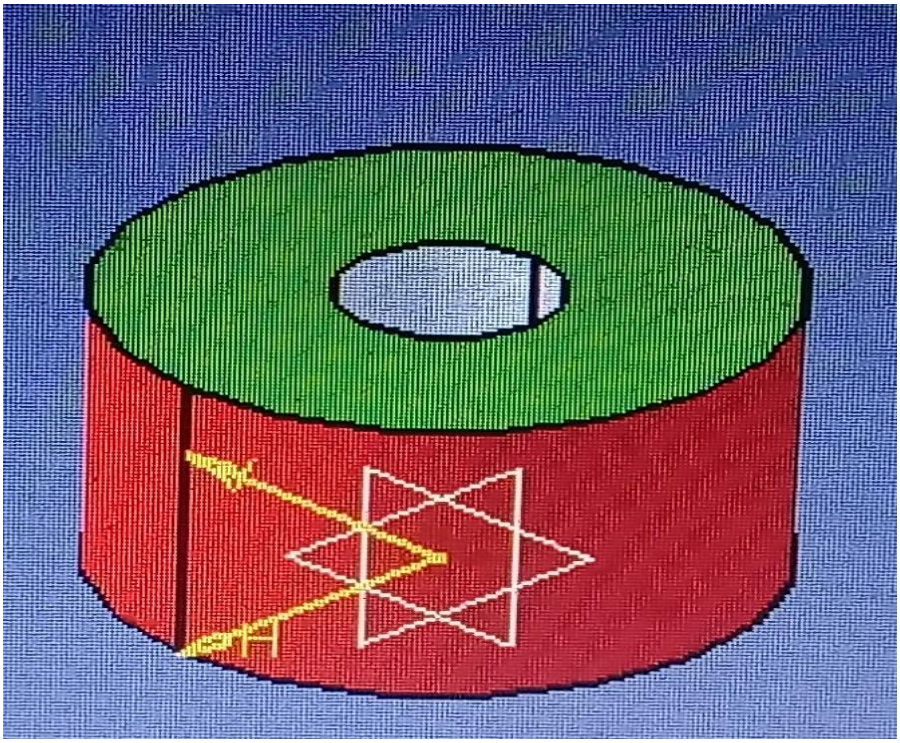
Ultimate Tensile strength =150N

Taking Factor of safety=5

Allowable stress ($\sigma_{allowable}$) =U. Tensile strength/Factor of Safety =150/5=30N/mm^2
Total load=1178N
Load on one wheel(W)=294.5N
Moment(M)=W×L/2=294.5×500/2=73625Nmm
Section Modulus(Z)= π (do^4-di^4)/32do =π (75^4-45^4/32×75) =36049.77mm^3
Stress=M/Z=73625/36049.77=2.04N/mm^2
Allowable stress=Tensile Strength/ FOS =150/5=30
Allowable stress>stress
So, the design is safety.

6.4 WHEEL

These help propel the cutter in action. Generally, our grass cutters have four wheels. The diameter of the wheel is 8 inches.A base frame with Four Wheels of the grass cutter.The wheels having rubber gripped, for better moving on grass.



[Figure 12: Wheel]

6.5 BAG

The bag carries the grass clippings.

[Figure 13: Bag]

VII. OPERATING PRINCIPLE

Electrical energy of the battery is converted to mechanical energy through a set of blades designed to achieve cutting operation. The electric circuit ensures power transfer from the battery to run the D.C. motor, whilst the alternator utilizes the mechanical power to continuously recharge the battery while in operation. The cutting blades tap power from the D.C. motor. When the power switch is on, the electrical energy from the battery powers the motor which in turn actuates both the blades and the alternator shafts. The rotating motion of the alternator shaft generates current to recharge the battery, thereby compensating for the battery discharge. The rotating blades continuously cut the grass as the mower is propelled forward and the cut grass is channelled to the collection box/bag attached at the rear of the machine. Height of cut is adjusted by means of the link mechanism via the lift rod.

VIII. ANALYSIS OF POWER SUPPLY

8.1 THEORY

The shearing force of most annual and perennial grasses found on most lawns is usually between 9.2N ~ 11.51N.

Force required by cutting blade to shear the grass is given by;

$F = T/R$ - - - - - - - - - - - (1)

Where, T = Shaft torque

R = Radius of cutting blade

But shaft torque is given by;

$T = P/2\pi N$ - - - - - - - - - - (2)

Where P = Power developed by shaft

T = Torque required and

N = Shaft speed in Rev/min.

8.2 MOTOR

The power source of a grass cutterthat is powered by electric. The electric motors for grass cutters are typically 24V, 1¼hp (932.5 W) DC motor. The benefits of the electric motors are that they run very quietly and they do not take up too much space on the cutter chassis.

For smooth grass cutting, a motor power of not less than 628.3W (0.84hp) having a rotational speed of not less than 3,000 rev/min and producing ShearForce of about 10.5N is recommended. However, due to non-availability of wide range of DC motors in the market, a 1¼ HP (932.5 W) having a rotational speed of 2,500 rev/min was used. Though this gives a sufficient torque with a high cutting force, using an average blade radius of 210 mm, the speed is still not sufficient enough for easy grass cutting. Hence a speed multiplication pulley system is used.

[Figure 14: Motor]

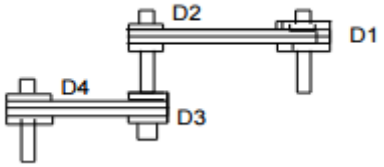
8.3 BATTERY

For this project, batteries will be needed to provide 12V to the electric motors in order to run these systems.
Features:-
Voltage – 12V, 100amp
Weight- 1.05 Kg
Height – 210 mm

[Figure 15: Battery]

8.4ANALYSIS OF PULLEY SYSTEM

The mower is made of a speed multiplication v-grooved pulley system shown in Fig.
D1 = Diameter of motor pulley, 120 mm
D2 = Diameter of blade shaft pulley
D4 = Diameter of alternator shaft pulley; D2 = D3
$\pi D1N1 = \pi D2N2$
D1/D2 = N2/ N1
Where N1 = Speed of motor pulley = 2,500 rev/min
N2 = Desired blade shaft speed, $\geq$ 3,000 rev/min
D2 = D1 N1 / N2 = (120 x 2,500) / 3,000 = 100 mm
Thus, let D2 = 80 mm; N2 = (120 x 2,500) / 80 = 3,750 rev/min D2 = D3 = D4 = 80 mm



[Figure 16: Pulley system]

8.5 LENGTH OF DRIVE BELTS

L1 = π/2 (D1 + D2) + 2C + (D1 – D2) 2 /4C
Where L1 = Length of drive belt
C = Centre distance between the two pulleys, 180 mm
Thus, L1 = 3.142/2 (120 – 80) + 2(180) + (120 – 80)2 / 4(80) = 676 mm
Similarly, L2 = Length of drive belt between pulleys 3 and 4
L2 = 3.142/2 (80 + 80) + 2(180) + (80 – 80)2 /4 x 180 = 611 mm

8.6 POWER TRANSMITION

Power transmitted from the motor to the blade is given by;
P = (T1 – T2) v
Where T1 = Tension on tight side of belt
T2 = Tension on slack side of belt, and P = 932.5 N
Use was made of group A, v-belt design having a power transmission range of 0.7 ~ 3.5 kW.
Log(T1/T2) = μθ cosecβ
Sinα = (R1 – R2) /C = (60 – 40) /180 = 0.1111; α = 6.38o
Where R1 and R2 are radii of pulleys 1 and 2 respectively
Angle of contact, θ = 180o – 2α = 180o – 2(6.38) = 167.24o
θ = 167.24o (π/180) = 2.92 rad
2.3log(T1/T2) = μθ cosecβ
Where, μ = 0.2 and 2β = 34o
Thus, T1/T2 = 7.379; T1 = 7.379T2
P = (T1 – T2) v
Where p and v are transmitted power and peripheral velocity respectively
932.5 = (T1 – T2) x 15.71
T1 – T2 = 59.36 N
7.379T2 – T2 = 59.36
T2 = 9.3N and T1 = 68.66N
Centrifugal tension in the belt is given by;
$T_C = mv^2$
Where, m = mass of belt per meter, and
v = peripheral velocity.
T_C = (1.06/9.81) kg/m x 15.712 = 26.67N

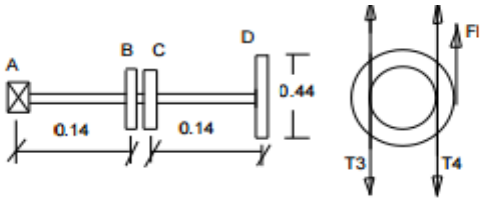
8.7 CUTTING BLADES

Speed of blades and shaft = 3750 rev/min
Power transmitted = 932.5W
Torque transmitted, T = P/2πN = (932.5 x 60) / 2 x 3.142 x 3750 = 2.37N-m
But T = F × x
F = T/r = 2.37/0.21 = 11.29N

8.8SHAFT

The horizontal tension acting on pulley B is given by;
WB = T1 + T2 +2Tc = 68.67 + 9.31 + 2(26.67) = 131.32 N
Horizontal load on pulley C;
WC = T3 + T4 + 2Tc
Where T3 and T4 are tensions in the tight and slack sides of belt on pulley C respectively.
But torque acting on B;
TB = (T1 – T2) RB = (68.67 – 9.31) x 0.04 = 2.37 N
Since torque on both pulleys (B and C) is the same;

(T3 – T4) RC = 2.37 N;
T3 – T4 = 2.37/0.04 = 59.36 N
Also, T3/T4 = T1/T2 = 7.38 N;
T3 = 7.38 T4
Thus, T3 = T1 = 68.67 N;
T4 = T2 = 9.31 N
WC = 68.67 + 9.31 + 2(26.67) = 131.32 N
Horizontal load acting on the shaft at D is given by;
TD = FD× RD ;
FD = 2.37/0.22 = 10.77 N



[Figure 17: Shaft]

8.9BENDING MOMENT ON DRIVE SHAFT
Taking moment about support A
Bending moment
MB = 131.32 x 0.14 = 18.38 N-m
Bending moment at C;
MC = 131.32 x 0.16 = 21.01 N-m
Bending moment at D;
MD = 10.77 x 0.3 = 3.23 N-m
Thus, maximum bending moment occurs at C.
Equivalent twisting moment at C; ME = √M 2 + T2
ME = [(21.01)2 + (2.37)2] ½ = 21.14 N-m
ME = (π/16) x τ x d^3
But τ = 20Mpa
21.14 = (π/16) x 20x106 x d^3
d = 18 mm
Equivalent bending moment is taken as;
M_{equ}= ½ (M + ME)
M_{equ} = ½ (21.01 + 21.14 = 21.08 N-m
Mequ = (π/32) x τa x d^3
WhereƮa= 30 Mpa
Maximum allowable bending stress for shafts between 15~30 mm is 30 Mpa
21.08 = (π/32) x 30x106 x d^3
d = 19.27 mm; (Use d = 20 mm)

8.10PERFORMANCE TEST
Area of grass cut = 2.2 m^2
Desired height of cut= 20 mm
Time taken = 2min
Area of grass cut to desired height= 1.97 m^2
Cutting Efficiency of the mower = (1.97/2.20) x 100 = 89

IX. ASSEMBLY OF GRASS CUTTER

All Components which has used to design electric and battery type lawn mower written below,

Component	Specification
Mild steel rods	To make frame of grass cutter
Blades	Taper shaped Blade 300mm
4 wheels	8" Rubber wheels
4 Iron roller	7" per roller
AC Motor	700 watt

9.1 BASE

First we cut the mild steel rods in four pieces, having length 91.4 mm, breath 609.6mm and thickness is 25.4mm. Then join these rod pieces by the help of Arc welding (using ferrous electrode rod which length is 350mm).

[Figure 18: welding of Base Frame]

After completion of base Frame we cut the sheet metal by gas cutter, having dimensions written as below and fixed above the base by the help of screw. So we have to drill the sheet metal with base frame by using drilling machine.

Length - 914.4mm
Thickness - 5mm
Breath - 609.6mm
Weight – 23kg

[Figure 19: Cutting of Sheet metal]

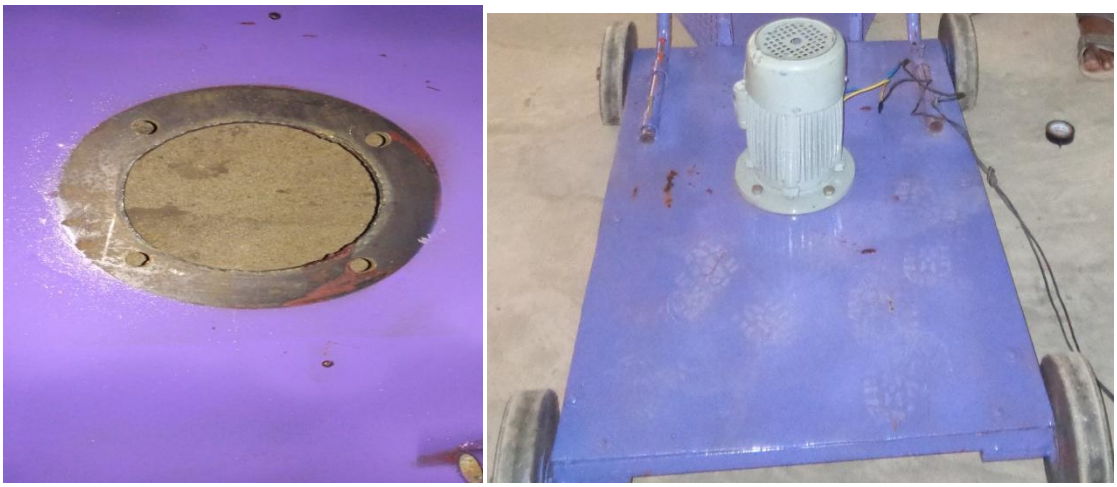
After mounting the sheet metal then we cut the iron rods into four pieces by the help of cutting machine because as we take four wheels, it is required four shafts. At last make a hole on the iron shaft by the help of drilling machine and fixed below the base frame by welding.

[Figure 20: Cutting & Drilling the wheel shaft]

[Figure 21: Completion of Base Frame]

9.2 MOUNTING THE MOTOR

When mounting the motor to the mower deck the most important thing was to make sure it was centered and properly secured. I made sure it was centered by measuring an equal distance from the sides of the motor to the outside diameter of the mower. I secured the motor to the deck with screw joint on specific height from the surface. It is mounted above the frame. For safety Purpose of motor we covered it's by thin steel plate.



[Figure 22: Mounting of motor]

9.3MOUNTING THE BLADE

Mounting the blade is very difficult task for us but we tried so many ways. We choose one way to mount blade on motor shaft. We mount blade on motor with screw.

[Figure 23:Blade fixed with motor Shaft]

X. ADVANTAGE AND DISADVANTAGE

ADVANTAGES

- It is easy to use, because it is cordless.
- With Battery powered grass Cutter, there is no more messy oil & smelly gasoline.
- Now we are safety with no pollutants emitted.
- There are also no air filters & spark plugs to bother it.
- The cost of electricity to recharge the battery is minimal compared to the high cost of gasoline, oil, air filters, & sparkplugs.

DISADVANTAGES

- It is Costly,An electric Cutter is more expensive.
- The eventual disposal of worn-out batteries is problematic & the motors in cordless Cutter tend to be less powerful than gasoline motors of the same total weight (including batteries).
- Recharging of Grass Cutter batteries can take from 8 to 16 hours with only an hour of operation. We need to replace the batteries after so many hours of operation.
- As a result of incorrect use, fluid can leak from the rechargeable battery. Avoid contact with the fluid.

XI. CONCLUSION

Easiest operation is obtained by the control unit in the "LAWN MOWER". The comparative gain that can be accomplished because of the utilization of motor in control unit.This will reduce the labor required to cut the grass.This project "GRASS CUTTER" is designed with the hope that it is very much economical and helpfull to many agricultural areas. This project helped us to know the periodic steps in completing a project work. Thus we have completed the project successfully.

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