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# Simple Design of Self-Powered Lawn Mower

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## ABSTRACT

The design objective is to come up with a mower that is portable, durable, easy to operate and maintain. It also aims to design a self-powered mower of electrical source; a cordless electric lawn mower. The heart of the machine is a battery-powered dc electric motor. It comprises of a system of speed multiplication pulleys which drive the cutting blades and the charging unit comprising of a 12V alternator and a lift mechanism meant to alter the height of cut. This is achieved by means of a system of v-belt pulleys with minimal slip effect; collapsible blades to reduce the common problem of wear. The use of collapsible blades and incorporation of an alternator for recharging the battery make the design unique such that no engine is involved. Performance test gave a cutting efficiency of 89.55% with 0.24kN human effort. Thus, the machine is considered highly efficient and is readily adaptable to different cutting conditions.

**Keywords:** *Lawn Mower; Electric-powered; Cordless; Cutting Efficiency; Collapsible blades; Rechargeable.*

## 1. 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 habitat environment. As man evolved intellectually, grass cutting inevitably developed to an art. As technology advanced grass cutting developed, away from use of machetes, hoes and cutlasses to motorized grass cutters. Technology had continued to advance and better techniques of grass cutting has been invented and constantly improved upon. This gave birth to the invention of lawn mower. A lawn mower 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.

The first lawn mower was invented in 1830 by Edwin Beard Budding (www.altavista.com/history). He was said to obtain the idea after watching a machine in a local cloth mill which used a cutting cylinder mounted on a bench to trim clothes for a smooth finish after weaving. Budding realized that a similar concept could be used to cut grass if the mechanism is mounted in a wheel frame to enable the blades rotate close to the lawns surface. These early machines were made of cast iron and featured a large rear roller with a cutting cylinder (reel) in the front. Cast iron gear wheel transmitted power from the rear roller to the cutting cylinder. In 1832, Ransoms of Ipswich (under license) began the making of Budding's mower. This company is today the world's largest manufacturer of lawn care equipment. By mid 1850, Thomas Green developed a mower which used chains to transmit power from the rear roller to the cutting cylinder. It was called 'Silens Messor' meaning silent cutter. The machines were found comparatively lighter and quieter than the gear driven machines that preceded them.
By late 1890, motorized mowers appeared as light weight petrol engines and small steam power units became available. In US, Colonel Edwin George produced the first gasoline powered mower in 1919. Electric powered mowers and rotary cutting machines emerged in the 1920's and 1930's.

By 1960 the introduction of plastic components greatly reduced cost. Today, new technology has brought new improved versions. Low emission gasoline engines with catalytic converters are introduced to help reduce air pollution. Improved muffling devices are also incorporated to reduce noise. Today, the recent innovation is the rotary hover mower (www.ask.com/oldmowersclub).

There are primarily two types of mowers (www.gardenadvice.com), namely (i) the reel mowers, and (ii) the rotary mowers. The reel (cylindrical) mowers seem to be better. Made of blades on a revolving cylinder, they achieve clean cut by scissors action. As the mower moves forward, the rotating blades come in contact with a stationary bar called the bed knife and placed parallel to the ground. Grass is held by the shearing action of the reel blades against the bed knife. The mower is adjusted to various cutting heights. Rotary mowers are often powered either by an internal combustion engine or an electric motor and are generally moved manually, with the engine only spinning the cutting blades. The most common types are fitted with wheels, but a newer innovation is the hover model in which the spinning blade also acts as a fan that provides a lift force, lifting the mower body clear of the ground on the same principle with a hover craft. Rotary mowers generally have opening by the side of the housing through which cut grasses are expelled. Some are attached with a grass collector at the exit point. The blade is seldom sharp enough to give a neat cutting. The blade simply tears the grass resulting in brown tips. However, the horizontal blades are easy to remove and sharpen or replace (www.lawnmowerguide.com).

## 2. DESIGN CONCEPT

Figures 2.1 and 2.2 show the assembly diagram and the orthographic view of the lawn mower respectively. Figure 2.3 shows the circuit diagram of the mower while Table 2.1 gives the component parts.

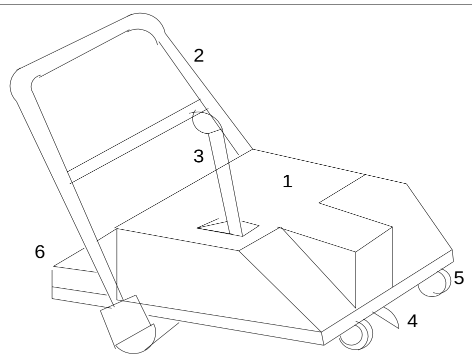


Fig.2.1 Assembly View of the Lawn Mower

**Table 2.1: Component Parts of the Mower**

| S/N | Item | Quantity | Remark |
|---|---|---|---|
| 1 | Casing | 1 | With air vents for cooling the motor and the alternator |
| 2 | Handle Frame | 1 | Strong frame needed (mild steel) |
| 3 | Lift Rod | 1 | Activates the lift mechanism |
| 4 | Collapsible Blades | 2 | High carbon steel to resist wear |
| 5 | Tires | 4 | Rubberized |
| 6 | Collection Bag | 1 | Collects the grasses as mowing progresses |

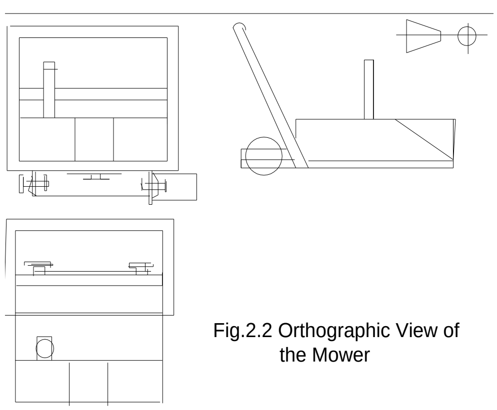

Fig.2.2 Orthographic View of the Mower

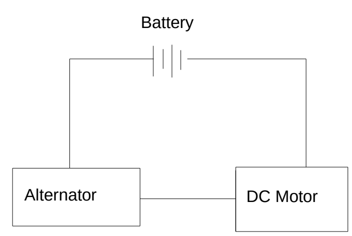


Fig.2.3. Circuit Diagram of the Mower

### 2.1 Description

The lawn mower is made up of an induction motor, a battery, an alternator, two collapsible blades, and a link mechanism. Speed of blade shaft is increased by an arrangement of a speed multiplication pulley system mounted on a steel platform. The power and charging system comprises of an alternator which charges the battery while in operation. The D.C. motor forms the heart of the machine and provides the driving force for the collapsible blades. A collapsible blade design is used to reduce wear and a grass collection box mounted at the rear collects cut grasses. This is achieved by the combined effect of mechanical action of the cutting blades and the forward thrust of the mower. The system is powered by an electrical switch which completes the circuit comprising the induction motor and the battery. The revolving front wheels ensure easy maneuverability whilst a lift system activates the link mechanism with which the height of cut is altered.

### 2.2 Operation 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 channeled 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.

## 3. DESIGN ANALYSIS

### 3.1 Theory

The shearing force of most annual and perennial grasses found on most lawns is usually between 9.2N ~ 11.51N (Yong and Chow, 1991). Force required by cutting blade to shear the grass is given by;

$$F = T/R \quad (1)$$

(Khurmi, 2003)

Where T = Shaft torque; R = Radius of cutting blade

But shaft torque is given by;

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

(Khurmi, 2003)

Where P = Power developed by shaft; T = Torque required; and N = Shaft speed in Rev/min

### 3.2 Selection of Electric Motor

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 a shear force of about 10.5 N is recommended (www.lawnmowerguie.com). 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.

### 3.3 Design of the Pulley System

The mower is made of a speed multiplication v-grooved pulley system shown in Fig.3.1.

$D_1$ = Diameter of motor pulley, 120 mm

$D_2$ = Diameter of blade shaft pulley

$D_4$ = Diameter of alternator shaft pulley; $D_2 = D_3 = D_4$

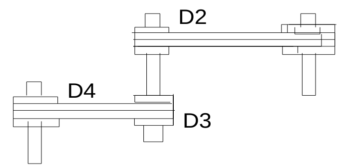


Fig.3.1 The Pulley System

$$\pi D_1 N_1 = \pi D_2 N_2$$

(Khurmi, 1997)

$D_1/D_2 = N_2/ N_1$

Where $N_1$ = Speed of motor pulley = 2,500 rev/min

$N_2$ = Desired blade shaft speed, ≥ 3,000 rev/min

$D_2 = D_1 N_1 / N_2$ = (120 x 2,500) / 3,000 = 100 mm

Thus, let $D_2$ = 80 mm; $N_2$ = (120 x 2,500) / 80 = 3,750 rev/min

$D_2 = D_3 = D_4$ = 80 mm

### 3.4 Length of Drive Belts

$$L_1 = \pi/2\ (D_1 + D_2) + 2C + (D_1 - D_2)^2\ /4C$$

(Khurmi, 2003)

Where $L_1$ = Length of drive belt for pulleys 1 and 2

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C = Centre distance between the two pulleys, 180 mm

Thus, $L_1$ = 3.142/2 (120 – 80) + 2(180) + $(120 – 80)^2$ / 4(80) = 676 bmm

Similarly, $L_2$ = Length of drive belt between pulleys 3 and 4

$L_2$ = 3.142/2 (80 + 80) + 2(180) + $(80 – 80)^2$ /4 x 180 = 611 mm

### 3.5 Power Transmission

Power transmitted from the motor to the blade is given by;

$P = (T_1 - T_2)\ v$ (Khurmi, 2003)

Where $T_1$ = Tension on tight side of belt

$T_2$ = 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.

2.3 log $(T_1/T_2)$ = μθcosecβ (Khurmi, 2003)

Sinα = $(R_1 – R_2)$ /C = (60 – 40) /180 = 0.1111; α = $6.38^o$

Where $R_1$ and $R_2$ are radii of pulleys 1 and 2 respectively.

Angle of contact, θ = $180^o$ - 2α = $180^o$ – 2(6.38) = $167.24^o$

θ = $167.24^o$ (π/180) = 2.92 rad.

2.3 log(T1/T2) = μθcosecβ; where μ = 0.2 and 2β = $34^o$

Thus, $T_1/T_2$ = 7.379; $T_1$ = 7.379$T_2$

P = $(T_1 – T_2)$ v ; where P and v are transmitted power and peripheral velocity respectively.

932.5 = $(T_1 – T_2)$ x 15.71

$T_1 – T_2$ = 59.36 N

7.379T2 – T2 = 59.36; $T_2$ = 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 $15.71^2$ = 26.67N

### 3.6 Cutting Blades and Shaft Design

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.r F = T/r = 2.37/0.21 = 11.29N

**3.6.1 Shaft Design**

Fig.3.2 shows the shaft loading. The horizontal tension acting on pulley B is given by;

$W_B = T_1 + T_2 + 2T_c$ = 68.67 + 9.31 + 2(26.67) = 131.32 N

Horizontal load on pulley C;

$W_C = T_3 + T_4 + 2T_c$ where $T_3$ and $T_4$ are tensions in the tight and slack sides of belt on pulley C respectively.

But torque acting on B; $T_B = (T_1 – T_2) R_B$ = (68.67 – 9.31) x 0.04 = 2.37 N

Since torque on both pulleys (B and C) is the same;

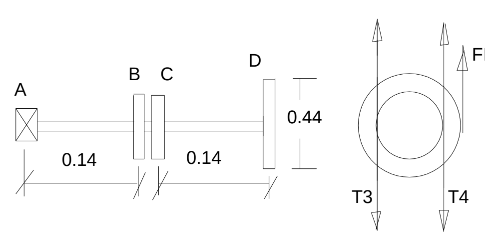


Fig.3.2 Blade Shaft Loading

$(T_3 – T_4) R_C$ = 2.37 N; $T_3 – T_4$ = 2.37/0.04 = 59.36 N

Also, $T_3/T_4 = T_1/T_2$ = 7.38 N; $T_3$ = 7.38 $T_4$

Thus, $T_3 = T_1$ = 68.67 N; $T_4 = T_2$ = 9.31 N

$W_C$ = 68.67 + 9.31 + 2(26.67) = 131.32 N

Horizontal load acting on the shaft at D is given by;

$T_D = F_D.R_D$ ;   $F_D = 2.37/0.22 = 10.77$ N

### 3.7 Bending Moment on Drive Shaft

Taking moment about support A; bending moment at B;

$M_B = 131.32 \times 0.14 = 18.38$ N-m

Bending moment at C;

$M_C = 131.32 \times 0.16 = 21.01$ N-m

Bending moment at D;

$M_D = 10.77 \times 0.3 = 3.23$ N-m

Thus, maximum bending moment occurs at C.

Equivalent twisting moment at C; $M_E = \sqrt{M^2 + T^2}$ (Shigley, 2001)

$M_E = [(21.01)^2 + (2.37)^2]^{½} = 21.14$ N-m

$M_E = (\pi/16) \times \tau \times d^3$

But $\tau = 20$ MPa   (Ashby and Jones, 1993)

$21.14 = (\pi/16) \times 20\times10^6 \times d^3$;     d = 18 mm

Equivalent bending moment is taken as;

$M_{Equ} = ½ (M + M_E)$ (Shigley, 2001)

$M_{Equ} = ½ (21.01 + 21.14 = 21.08$ N-m

$M_{Equ} = (\pi/32) \times \tau_a \times d^3$ ;   Where $\tau_a$= 30 MPa

IS2494, 1974; maximum allowable bending stress for shafts between 15~30 mm is 30 MPa     (Marks, 2004)

$21.08 = (\pi/32) \times 30\times10^6 \times d^3$;   d = 19.27 mm; **Use d = 20 mm**

## 4. PERFORMANCE TEST

Area of grass cut = 2.2 $m^2$

Desired height of cut = 20 mm

Time taken = 2 min

Area of grass cut to desired height = 1.97 $m^2$

Cutting Efficiency of the mower = (1.97/2.20) x 100 = 89.5%

## 5. EFFECT OF ANGLE OF MOWER HANDLE ON MANEUVERABILITY

Fig.5.1 shows the effect of handle angle on maneuverability of the mower.

Force required to move the mower, $P = W \sin\theta$ (Yong and Chow, 1991)

Where W = Weight of mower, 343.35 N

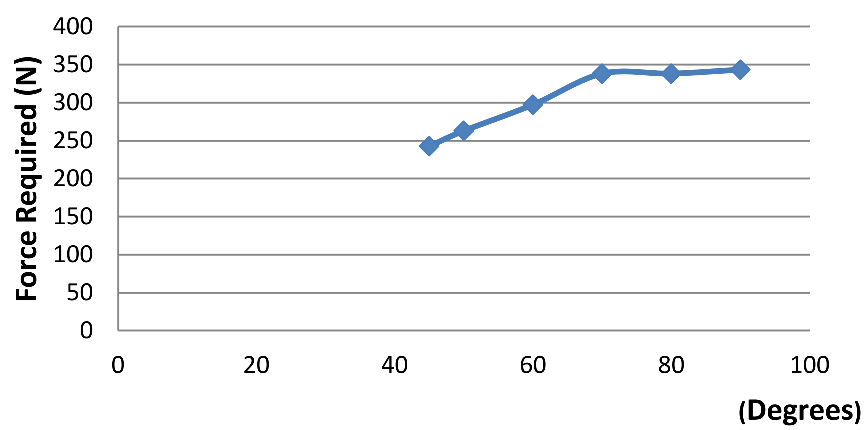


**Fig.5.1 Effect of Mower Handle Angle on Maneuverability**

## 6. DISCUSSION

Below 40 degrees the mower handle becomes very uncomfortable to handle and pushing the mower becomes quite difficult. At an angle of 45 degrees, the handle is found most convenient in terms of freedom in moving the mower.

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