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Design of a Hand-held Grass Mower

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Abstract : The hand-held grass mowing machine is a petrol-powered machine with rotary blades for cutting grass on lawn. The machine was designed with locally available materials, putting into consideration factors such as strength, durability, light weight, ease of assembly and disassembling. This machine saves both energy and time, which is not so with the manual and pushable mowing methods, thereby providing greater and flexible mobility. A detailed design of the machine was done and performance test result shows that proper grass trimming is achieved in a comparatively shorter time with 67 percent process efficiency.

Keywords: Design, hand-held, Grass mowing, Rotary blades

1. 1.0 Introduction

In the past and even until now, cutting of grasses in the schools, sports tracks, fields, industries, hotels, public centres, etc. was done with a cutlass. This method of manual cutting is time consuming because human effort is needed for the cutting. Also inaccuracy in cutting level was observed using the manual cutting method.

This work deals with the cutting of verdant (shrubs, stubborn grass, flowers, leaves of trees), and also with the design of the machine, its efficiency, rigidity, mode of operation and the selection of materials. The design gives a greater degree of flexible mobility and interchangeability.

The aims of this work include, but not limited to the following: (i) to reduce labour input in the cutting of not only weeds or grass but also in the trimming of flowers and trees. (ii) to reduce cost, time of cutting and also to beautify the environment.

The first lawn mower was invented by Edwin Budding in 1830 in Gloucestershire, England. This first grass mower was fabricated with wrought iron and manually driven [1]. In 1914, the first gasoline powered grass mower was invented by Ideal Power Company in the United States [2]. All the early designs of the mowers were either animal driven or steam powered while the later models were either petrol or electric powered.

The petrol- powered hand-held grass mower works on the principle that a blade that is turned fast enough is held out from its housing (the rotating reel) very stiffly by centrifugal force. The hand-held mower is powered by an internal combustion engine which is located on the opposite end of the shaft from the cutting head.

2.0 Design Concept

Figures 1.0 and 2.0 show the exploded assembly drawing and the orthographic views of the hand-held grass mowing machine respectively. Table 1.0 gives the component parts of the machine or the parts list.

Fig 1.0 Exploded assembly drawing of hand-held grass mowing machine

Table 1.0 Parts List of Hand-held Grass Mowing Machine

S/N	Item	No off
1	Blade	1
2	Blade base	1
3	Gear case	1
4	Safety guard	1
5	Inner pipe with thread	1
6	Outer pipe	1
7	Handle holder	1
8	Hale bracket	2
9	Throttle lever	1
10	Throttle	1
11	Spindle housing	1
12	Gasoline engine	1
13	Throttle cable	1
14	Left handle	1

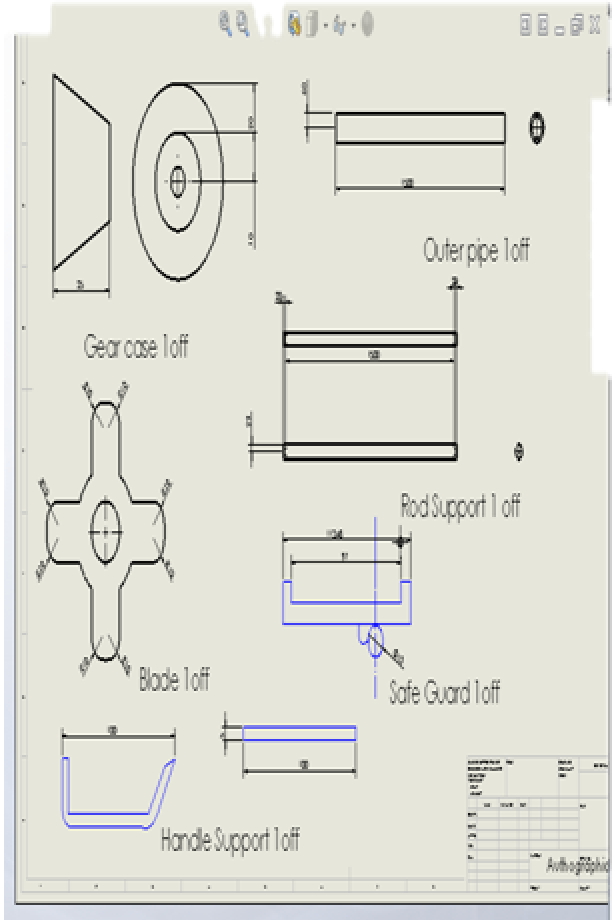

Fig 2.0 Orthographic views of the Hand-held Grass Mower

3.0 Design Analysis

3.1 Blade Design

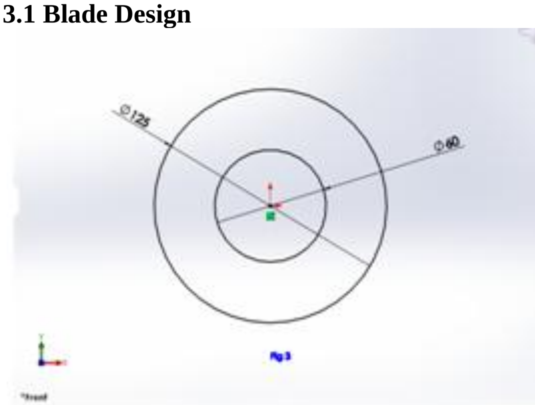

Fig. 3

From Fig 3 above,
Large circle diameter = 250mm
Hence R_2 = 125mm
Small circle diameter = 120mm
Hence R_1= 60mm

3.2 Ratio of the Blade

$$\left[\frac{r2}{r1}\right]^2 = \left[\frac{125}{60}\right]^2 = 0.2304\text{mm}$$

3.3 Area of Blade

$$\pi (R_2 - R_1)^2 = 3.142(125- 60)^2$$
$$= 13275\text{mm}^2$$

3.4 Circumference of the Blade

$$2\pi (R_2 - R_1) = 2x3.142\ (125- 60) = 408.5\text{mm}$$

3.5 Speed Required (N)

$$N = \frac{Large\ diameter\ of\ the\ blade}{Ratio\ of\ the\ Blade}$$
$$= \frac{250}{0.2304} = 1085 \text{ rpm}$$
$$\simeq 1100 \text{ rpm}$$

Therefore estimating the maximum shear stress, τ_{max} using Tresca's criterion theory which describes failure ''as taking place when the maximum shear stress exceeds the shear strength associated with yielding in the uniaxial tension test'' [3].

$$\tau_{max} = \sigma_1 - \sigma_2 \leq \tau_y/2FS \quad \text{---} \quad (1)$$

From equation (1)

$$\tau_{max} = \tau_y / 2FS$$

Where $\tau_y$is the shear stress at yield point from simple tension test and FS is the factor of safety. Then the shear strength of grass is: τ_{max} =112N/mm^2 (from plant and polymer test by Intertek, Fibre analysis by Orkwiszewsi and Poethig, 2000) [4].

$$\text{But } \tau_{max} = F_t/A_s \quad \text{--} \quad (2)$$

Where F_t is the tangential load on the blade and A_s , the surface area.

From equation (2)

$$F_t = \tau_{max} \text{ x } A_s$$

$$\text{Where } A_s = \pi R_1^2 \quad \text{--} \quad (3)$$

$$A_s = 3.142 \text{ x } 60^2 = 11311.2 \text{ mm}^2$$

$$\text{Hence } F_t = 112 \text{ x } 11311.2 \text{ Nm/mm}^2$$

$$\text{Torque } (\tau) = F_t \text{ x } R \quad \text{---} \quad (4)$$

$$\text{Where } R = R_2 - R_1$$

$$\text{Hence Torque} = \frac{1266854.4}{1000} = 1266.854 \text{ Nm}$$

But Power = torque x angular velocity

$$= \frac{No\ of\ revolution/\min x\ Circumference\ of\ blade\ x\ \tau}{1000\ x\ 60}$$

$= \frac{1085 \; x \; 408.46 \; x \; 1266.854}{60000}$

= 9357.36 Watts = 9.357KW

But 1 horsepower = 1.34KW

Therefore, 9.357KW = 7 horsepower

3.6 Loads on the Gear

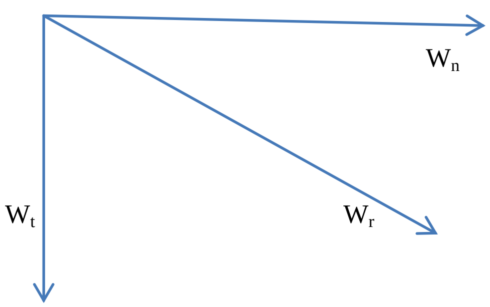

Fig. 4

From Fig. 4 above, W_t , W_r, and W_n represent tangential, radial and normal loads respectively.

Using the relationship below,

$W_t = \frac{\tau(required)}{D/2}$ -- (5)

Where D is the diameter of the gear (i.e. 80mm)

$W_t = \frac{120 \; x \; 2 \; x \; 1000 \; Nm}{80 \; m}$ = 3000N

Normal load, $W_n = {Wr}/{Cos\theta}$ ------------------------------ (6)

Weight of the pinion, W_r = 7 N

$Cos\Theta = {Wr}/{Wt}$ --- (7)

$= {7}/{3000}$ = 0.00233

$\Theta = Cos^{-1}$ (0.00233) = 89.90^0

3.7 Design of Drive Shaft

From equation (6)

$W_n = {7}/{Cos(89.9)}$ = 4010.7 N

Let the gear/pinion overhang on the shaft be 40mm.

Therefore the bending moment on the shaft due to the resultant load is $M_{wn} = W_n$ x 40 = 160400 Nmm (160.4 Nm)

Twisting moment on the shaft is:

$T = {Wt \; x \; Dp}/{2}$ -- (8)

$= \frac{3000N \; x \; 80 \; mm}{2}$ = 120,000 Nmm

The equivalent twisting moment from the bending and twisting moments is:

$T_e = \sqrt{(M_{wn}{}^2 + T^2)}$ -- (9)

$= \sqrt{(160400\,^2 + 120000^2)}$

= 280400 Nm

Also

$T_e = (ɿ \; x \; \pi d^3) / 16$ --(10)

Where d is the diameter of shaft. ɿ is maximum allowable shear stress for shaft with keyway.

From equation (10),

$d^3 = (T_e \; x \; 16) / (ɿ \; x \; \pi)$

NB: ɿ = 56 Nmm^2 (from standard transmission shaft with keyway, Machine Design by R. S Khumi) [5].

$d^3 = \frac{280400 \; x \; 16}{3.142 \; x \; 56}$

d $= \sqrt[3]{25498.2}$

=29.4

= 30 mm

3.8 Radial Load on Bearing

This is determined as follows:

$W_r = W_n$ x sin(20)

= 696.45 N

3.9 Cutting Force on the Blade

$F = \frac{Torque}{Diameter \; of \; blade}$ ------------------------------------ (12)

Where, diameter of blade = 250 mm or 0.25 m

Therefore, $F = \frac{1266.85}{0.25}$

= 5067.4 N

4.0 Factor of Safety, FS

$FS = \frac{Maximum \; Stress}{Allowable \; Working \; Stress}$ --------------------------- (13)

But, maximum Stress $= \frac{Cutting \; force \; of \; blade \; (F)}{Area \; of \; the \; blade}$

$= \frac{5067.4}{13.275}$

= 381.725 N/m

Allowable Working Stress $= {Wn}/{A}$ -------------------- (14)

But, $W_n = {Wr}/{Cos\theta}$ ------------------------------------ (15)

$= {696.45}/{Cos(0.1)}$ = 696.4511 N

From equation (14)

A is area of the blade (i.e. 13.275m^2)

Also from equation (14)

Working Stress $= {696.4511}/{13.275}$

= 52.4634 N/m

$$FS = \frac{Maximum\ Stress}{Working\ Stress}$$

$$= {}^{381.725}/_{52.4634}$$

= 7.2760

= 7

5.0 Process Efficiency of the Machine

During testing, one square metre of grass was cut in 20 minutes.

Therefore, the Process efficiency = $\frac{20\ x\ 100}{60\ x\ 1}$

= 66.67%

= 67%

6.0 Conclusions

The hand-held grass mower was constructed with good and locally available materials. During testing, the performance was very satisfactory. The total production cost is quite affordable, as seen in the appendix.

References

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APPENDIX: MATERIALS AND COST ANALYSIS OF THE HAND-HELD GRASS MOWER

S/N	COMPONENTS	QTY.	MATERIALS	UNIT COST(₦)	COST(₦)
1.	Steel Plate	1	Mild Steel	800	800
2.	Steel Pipe	1	Mild Steel	800	800
3.	Gear Case	1	Cast Iron	1700	1700
4.	Housing or Linker	1	Cast Iron	1600	1600
5.	Bracket	1	Cast Iron	800	800
6.	Two- Stroke Engine(7Hp)	1		25,000	25,000
7.	Drive Shaft	1	Hard Steel	1200	1200
8.	Screws			800	800
9.	Tin Steel			500	500
10	Bolt/Nut		Steel	900	900
11	Washers			500	500
12	Rivet pins		Steel	300	300
13	Spraying			1000	1000
14	Labour			6,600	6,600
15	Miscellaneous			3,000	3,000
			TOTAL COST		70,600