Design, fabrication and evaluation of a spiral blade lawn mower

S.O. Nkakini * and B.E. Yabefa

Department of Agricultural/Environmental Engineering,
Faculty of Engineering, Rivers State University of science and Technology,
P.M.B.5080, Port-Harcourt, Nigeria

*Corresponding author:
Email: nkakini@yahoo.com

Abstract

A manually operated apparatus for cutting grass was designed, fabricated and tested. The apparatus was designed with an internal spur gear system which transfers the torque to the mower spiral mechanism. The cutting mechanism is made of a flat blade rigidly fixed to the frame behind the spiral arrangement which is configured to contact at least one reel bar of the spiral blades during the rotation of the spiral mechanism. The machine's performance evaluation was conducted in the RSUST research farm. The field capacity of 0.115 ha/hr and field efficiency of 63.2%, were obtained. The cutting effectiveness was achieved with a total power of 934.3watts at a rotary speed of 1500rpm of shaft. Its friendly to the environment, because it does not emits carbon monoxide into the environment and the noise level is drastically reduced. The machine is more efficient in a soil with low moisture content.

Keywords: Lawn, spiral blade, mower, field capacity, field efficiency.

1. Introduction

Lawn maintenance and landscaping remain the most important constraints to keeping a clean and fresh looking gardens and yards. Places that experience incessant rainfall throughout the year results in fast and tall growing grasses which are detrimental to the environment and purpose of keeping the lawn landscapes.

Land clearing involves the removal of vegetation such as trees, bushes, shrubs grasses etc. but the clearing is done with respect to the purpose of the land utilization. For instance, construction works (highway, dam, building etc.) total removal of vegetation is necessary.

Dakogol et al., (2007), stated that in farming practice, removal of vegetation up to 100mm below ground level is very important. Clearing operation is also done in gardens and surroundings of premises. This involves four different methods which are employed for land clearing, via; physical uprooting of trees and vegetation, cutting the vegetation at ground level and collecting the same for burning or allowed to decay, crushing down the vegetation or ploughing and mixing in the vegetation to a soil depth of about 200mm.

These methods of land clearing can be done manually using axes, machetes, brush hooks, power saws and sickles. This can be done mechanically using bulldozers, tree rake, tree pushers, shear blades and mowers. A lawn mower is an apparatus that has one or more revolving blades to cut grass or other plants of a lawn at an even height.
Lawn mower is an essential tool for the maintenance of yards. They vary in size, mode of operation, and power. The power source riding mowers for example are usually powered by a gasoline engine and are ridden and steered by the operator. Walk behind mowers are designed to be pushed by the operator and typically run on gasoline or electricity. Modern gas powered and electric powered lawn mowers cut grass with a single blade revolving at a high speed parallel to the ground. The blade is slightly raised along its rear edge to create draft that lifts the cutting blades before its cutting operation. Mulching mowers suspends clippings and other debris near the blade shredding them before blowing them straight down in the lawn where they serve as manure for future lawn growth. Okoro, (2010) designed a locally operated engine powered lawn mower. The mower is fitted with horizontal cutting blade attached to a vertical shaft. The mower was tested and the average effective field capacity and efficiency were 0.127 ha/hr and 88.4% respectively. However, all the above mentioned type of mowers are not friendly to the environment, because enough carbon monoxide is emitted into the environment, there is much vibration on the part of the operator, and there is also very serious noise pollution. Jeremy, (2005) designed and fabricated solar charged lawn mower. The machine was dependent on weather since the battery would be charged using photovoltaic panel (ie solar panel). The common disadvantage was that the engine runs down easily and the cost of production was high for an average individual to purchase. Victor and Verns ,(2003) designed and developed a power operated rotary weeder for wet land paddy. The complex nature of the machine makes its maintenance and operation difficult for the peasant farmers.
Generally, in areas like ours, the conventional methods of grass cutting involved the use of cutlasses which never met the maximum satisfaction. More so, it is strenuous, time and labour intensive. Therefore, there is the need to develop a locally, fabricated spiral lawn mower which can take care of this operation easily.
The objective of the study is to design and develop a locally fabricated non engine powered spiral blade lawn mower affordable by peasant farmers.

2. Materials and Method

2.1 Design theory

The design theory of the machine is based on the principle of a rotary tiller by Odigboh and Ahmed (1979), which stated that, if R_b is the radius of the hoe, V_w forward speed of the machine and W, angular velocity of the hoe, then for cutting of soil slice to take place,

$$\frac{R_b W}{V_m} > 1 \qquad (1)$$

During operation the machine undergoes two types of motion. The rotary motion and the translational motion. The torque transferred to the reel makes grass cutting effective with the help of the cutter bar. Atkins, (2005).

The helix inclination angle i for a cylinder having n partial helices is given by

$$Cot i = \frac{nL}{2\pi r} \qquad (2)$$

The slice/push ratio $$\varepsilon = \frac{N\cos^2{}_i - \sin^2 i}{(N+1)\sin i \cos i} \qquad (3)$$

where $$N = \frac{rw}{f} \quad (4)$$

where N=gearing of the cylinder with respect to forward speed;

L=Length of the cylinder,

f=machine moving velocity

w=angular velocity

r= radius of the cylinder.

The total cutting force per unit length of the cylinder is given by the relationship

$$\frac{F}{R_w} = \left[\left(\frac{1}{\sqrt{1+\varepsilon^2}} \right) + S \right] \quad (5)$$

where F =total cutting force, R_w = edges in contact with bed-knife, ε = slice/push ratio, S = frictional force between cutting blade and glass.

2.2 Deign Specification

The following were chosen as the design standards. Average forward speed of the machine = 0.8m/s, speed of rotation of the blade = 1,500rpm, number of helical blades = 5, length of bed-knife = 400mm. The above specifications were chosen for operational convenience (Kepner et al.,1980).

2.3 The cutting blades

The cutting blades are chosen as they appear in the spiral blade lawn mower. The blades are in two sets, the bed-knife and the reel. The reel is made up of five smaller blades of sizes 420mm x 25mm x 2mm and is made of steel materials. The blades are mounted on the four spiders rigidly fixed to the shaft and are oriented at a helical angle of 12^o to the horizontal on the circular spiders for efficient grass cutting. The bed-knife is also made of steel material of size 400mm x 60mm x 2.6mm. Both edges grinded with a front relief angle of 30^0 to make grass cutting easy in a scissor action with the reel. The bed-knife is fixed to the machine frame behind the reel.

2.4 Shaft design

The desired rotation of the shaft is 1500rpm. The shaft is subjected to both bending and transitional stresses. Hence the diameter of the shaft is given by Hall et al., (1980) as

$$D^3 = \frac{16}{\pi r_{max}} \left(M^2 + T^2 \right)^{½} \quad (6)$$

where D = diameter of shaft,

T=twisting moment acting on the shaft,

r_{max}= maximum shear stress.

For shaft transmitting power (kw) at a rotational speed (r.p.m) the transmitting torque is given as

$$T = \frac{power}{speed} \quad (7)$$

2.5 The Drive

The drive consists of a gear train, the cranking shaft, the front wheels and the handle. The cranking is about the horizontal which is converted to a rotational motion as the machine is pushed forward.

The gear train consists of a driving internal spur gears fixed to each of the front wheels internally which transmits the torque from the wheels to the reel, through the pinions on the shaft.

By experiment it was estimated that, an average man with a pace factor of 0.988m can cover about a distance of 100,000mm per minute. This is equivalent to 138rpm of the front wheels of the machine. This will then be multiplied to about 270rpm in the internal spur gear fixed to the wheel. Driving gear has 72 teeth. Using the relation after Shigley (1972) .

$$\frac{W1}{W2}=\frac{N2}{N1} \quad (8)$$

where W1 = angular speed of driving gear, W2 =angular speed of pinion, N2 = number of teeth in the pinion, N2 =number of teeth in the driving gear. Table 1, shows the parameters of gear and pinion.

2.6 The handle

The handle is made of a cylinder steel pipe of diameter 20mm which is folded to a length of 1000mm, and 450mm orientation toward the machine frame at an angle of 60^0 which is adjustable for the operator's convenience. The handle is subjected to both axial and bending forces due to the inclined position as given by Khurmi, (2005) .

$$\delta_h=\frac{m_h Y_h}{R_w} \quad (9)$$

Axial stress handle $$\delta_{ah}=\frac{F_h}{A_h} \quad (10)$$

Hence, the total stress in the handle is given as

$$\delta_h=\delta_{bh}+\delta_{Ah} \quad (11)$$

where δ_h = bending stress on handle, m_h = moment in handle, Y_h = distance from neutral axis, δ_{ah} = axial stress in handle, F_h = axial force, A_h = area

2.7 Power requirement

The power required to drive the machine can be obtained from equation 12 as given by Okoro (2010)

i Power to overcome inertia in pulling machine to motion

$$P_{oi}=M_m \; x \; g \; x \; v_o \quad (12)$$

ii Power to overcome grass cutting resistance

$$P_{ct}=F_{ct} \; x \, R_b \; x W_b \quad (13)$$

$$\text{Total power } = P_{oi}+P_{ct} \quad (14)$$

where P_{oi} = power to overcome inertia, m_m = mass of machine,

g= acceleration due to gravitation, v_o = operational speed of the machine,

F_{ct} = cutting force, R_b = radius of blade, w_b = angular velocity.

3. Performance test and evaluation

The performance of the machine was evaluated through a field test. A land predominantly covered with carpet grass *(Axonopus affinis)* was mapped out into plots of 4mx2m. Seven of these plots were selected by randomization process and mowed. The spiral lawn mower uses multiple cutting blade arranged in form of a cylinder which is turned by a gear connected to the wheels. The act of pushing the machine makes the cylinder revolve. As the mower moves, the rotating blades slice the grass against a stationary cutting blade called the bed knife in a scissor action.

The theoretical field capacity (FC_t), Effective field capacity (FC_e), and Field efficiency (η) were computed with equations 13, 14 & 15.

Theoretical field capacity FC_t =forward speed x theoretical width

$$FC_t = V_S \, x W_t \tag{13}$$

Effective Field capacity $FC_e = \frac{Actual\ area\ covered}{Total\ time\ taken}$

$$FC_e = \frac{A}{t} \tag{14}$$

Field efficiency $\eta = \frac{Effective\ field\ capacity}{Theoretical\ field\ capacity} x100\%$

$$\eta = \frac{FC_e}{FC_t} x100\% \tag{15}$$

4. Results and discussion

The performance test of the spiral blade lawn mower is presented in Table 2, indicating the value of the computed effective field capacity (FC_e) and field efficiency(%).The highest effective field capacity is obtained as 0.082ha/hr and Field efficiency (%) as 71.3%, with operating time of 0.00972hr. This may be due to variations in level of moisture contents during the time of field operation. The theoretical field capacity (FC_t) of the machine was calculated to be 0.115ha/hr with forward speed of 0.8m/s and the theoretical width of 0.4m.

The machine was seen to be more effective when working in a dry soil condition, because there is proper gripping of the tyres in a dry condition of the soil.

The field efficiency of plots 1, 2, 4 and 7 are generally low. This is attributed to the wet conditions of these plots as there was poor gripping of the tyres on the soil (.i.e. wheel slip). Figure 4, shows the relationship between the effective field capacity and operational time. There is an increasing linear relationship of effective field capacity with increasing operational time. This is an indication of the effect of more time expended during field operations, resulting to effectiveness in grass cutting. The relationship between field efficiency and operational time is illustrated in figure 5. Field efficiency, increases with increase in operational time.

5. Conclusion

The spiral blade lawn mower was designed, fabricated and tested. This does not have engine and is powered by the operator. Test revealed that, higher grass cutting efficiency is obtained when the lawn is dry before mowing. The machine is simply powered by manual pushing. Therefore, it can be used by both rural as well as urban dwellers. It is also affordable since the cost of production is low. High moisture content and undulated nature of the field surface affected the efficiency of the machine.

Effort should be made to adopt and popularize this design especially for the benefits of rural people who make up a great percentage of the nation's population. It is also hoped that, when mass produced, the unit cost will be reduced. The spiral blade lawn mower is environmental friendly.

References

Atkins, T. (2005). Optimum blade configuration for the cutting of soft solids. Engineering fracture mechanics, *73(*16), 2523-2531

Dakogol, F. A., Kwaya, P.V., & Yusuf, R.E.(2007). Development and performance evaluation of a garden flail mower. *In Proceedings of the 8th International Conference and 29th Annual General meeting Yola, 5-9 Nov. 2007* (pp.73-76).The Nigerian Institution of Agricultural Engineers.

Hall, A.S., Holowenko, M.S., & Loughlin, H.G.(1980).*Theory and problem of machine design.* MG raw Hill, New York.

Jeremy, J. (2005). Solar charged lawnmower. [Online] Available: http://www.appropedia.org/solar lawnmower (28th Jan. 2010).

Kepner, R.A., Bainer, R., & Boroger, E. L . (1980). Principles of farm machinery. Second edition(pp.315-316). A.V publisher, Connecticut, U.S.A.

Khurmi, R.S. (2005)**.** *Engineering Mechanics*. First Edition S. Chand and Company Ltd Publishers.

Odigboh, E.U., & Ahmed, S.F. (1979). Development of a ridge profile weeder. *A paper presented at the conference of Nigerian society of agricultural Engineers (NSAE),* University of Nigeria, Nsukka.

Okoro, K . (2010). *Development of a locally Fabricated Engine Powered Lawn Mower*. (Unpublished Student project). Department of Agric/Environmental Engineering, RSUST,Port-Harcourt, Nigeria.

Shigley, J.E. (1972). *Mechanical Engineering Design (2nd ed)* . MC Graw Hill Book Co. New York

Victor, V.M., Verns, A.(2003). Design and development of power operated rotary weeder for wetland paddy. *Journal of Agricultural Mechanization in Asia, African and Latin America,* 3(4), 27-29.

`

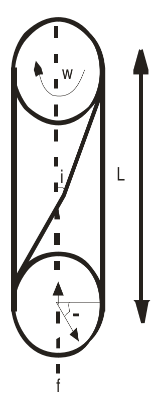

Figure 1 . The helical geometry of the reel.

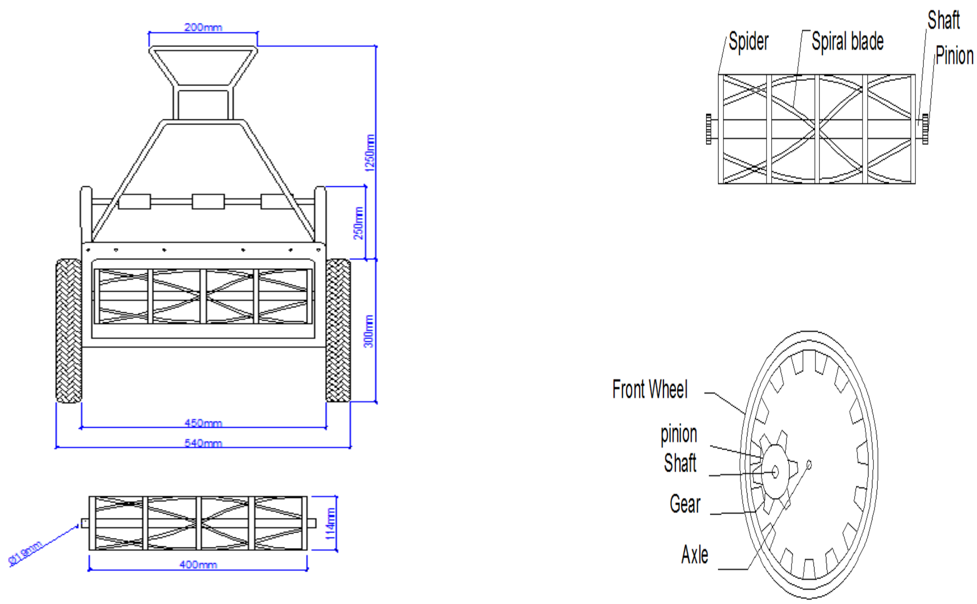

Figure 2. Shows the driving arrangement.

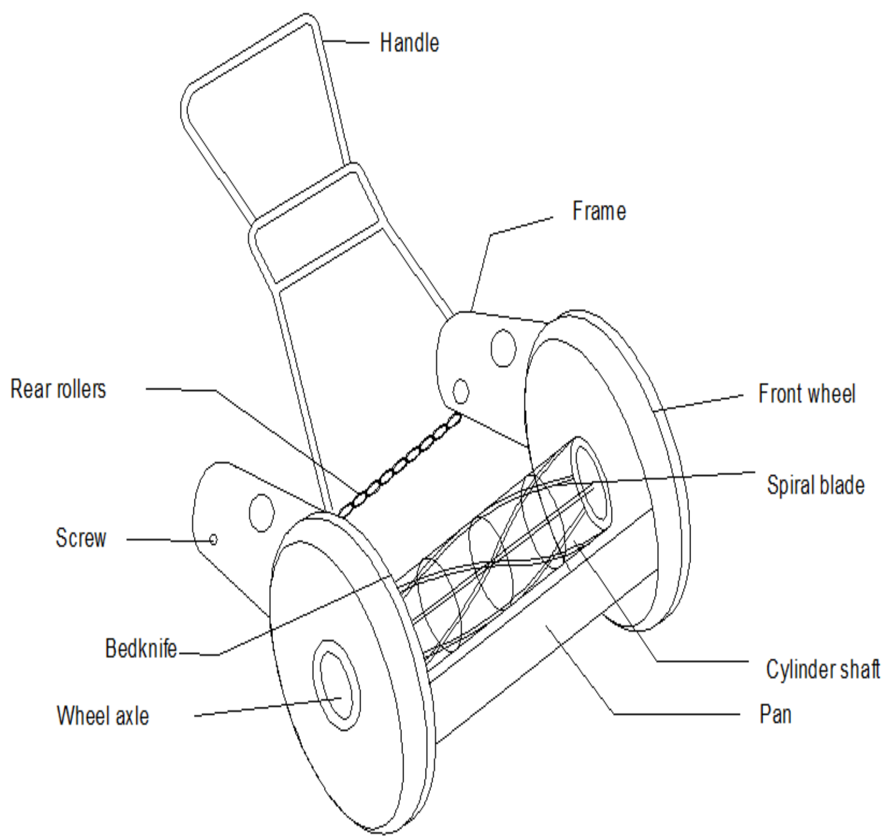

Figure 3. Spiral Lawn Mower

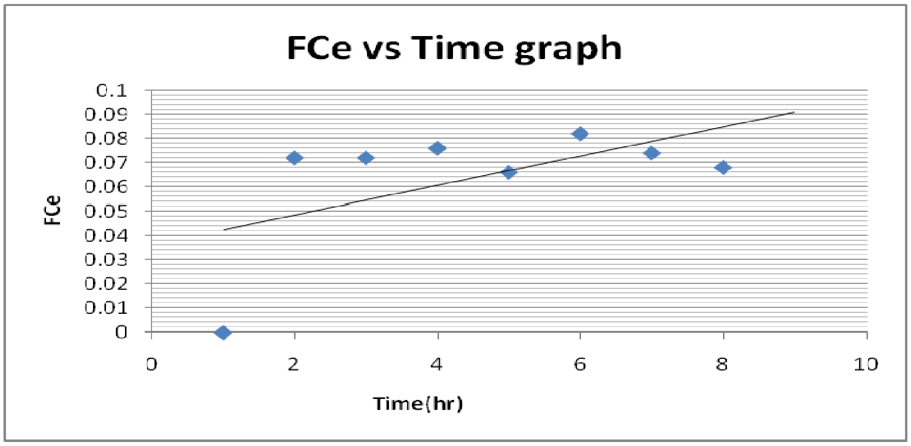

Figure 4: The relationship between the effective capacity and operational time.

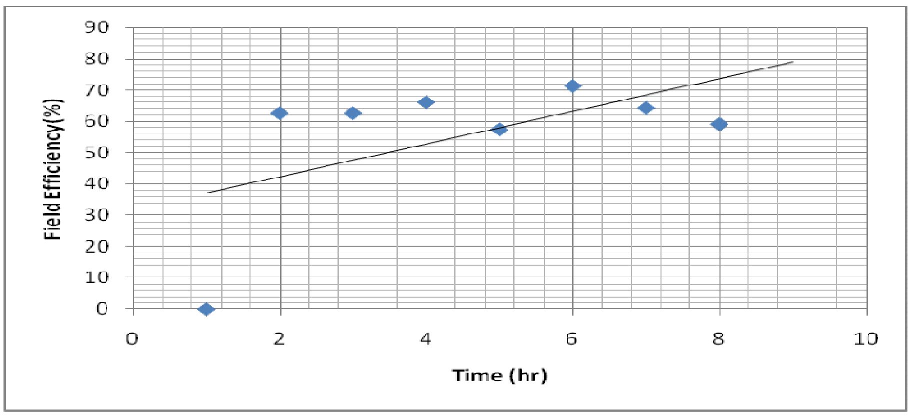

Figure 5: The relationship between field efficiency and operational time.

Table 1: Gear and pinion parameters

Perimeter	Gear	Pinion
Module	3	3
No. of teeth	72	13
Face width(mm)	18.8	18.8
Pitch circle diameter	216	39

Table 2: Results of effective field capacity (FC_e) and field efficiency (%)

Plot No.	Area (ha)	Time(hr)	FC_e (ha/hr)	Field Efficiency (%)
1	0.0008	0.011	0.072	62.6
2	0.0008	0.011	0.072	62.6
3	0.0008	0.0105	0.076	66.1
4	0.0008	0.012	0.066	57.4
5	0.0008	0.00972	0.082	71.3
6	0.0008	0.0108	0.074	64.3
7	0.0008	0.0116	0.068	59.1