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Design and Construction of a Motorized Pruning Machine

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ABSTRACT: *Motorized pruning machine is mainly use by gardeners to trim or cut off flower. In this project, a motorized pruning machine was designed and constructed. The development of the motorized pruning machine was achieved with the aid of conceptual designs based on certain engineering design principles like the torque of shaft, power, centrifugal force, mass of given blade, thickness, resistance force of plant stem, theoretical field capacity, effective field capacity and effective field efficiency. In this, certain considerations were made such as; the type of material use for the construction, source of power, mode of operation, shape and size of the different part of the machine, safety of the machine and cost of construction. The designed machine can be easily operated by an individual and is capable of cutting or trimming flower horizontally and vertically.*

KEYWORDS*: Design, Construction, Motorized, Pruning, Machine*

I. INTRODUCTION

According to El-Hofy (2005), agriculture production has its own unique ergonomic hazards and musculoskeletal injury problems. Although some hazards are similar throughout, each activity imposes unique and specific demands on the conditions of workers. Risk exposure analysis of farm workers related to different crops and commodities clearly demonstrates the involved risk factors and available preventive methods in the form of work practices or labour aids. However, the problem is little recognized and is not given priority for risk preventive research by most of the farm safety research organizations (Praveena *et'al*., 2011).

According to Hamdy *et'al.* (2013), pruning is the cutting away of dead or overgrown branches or stems, especially to encourage growth. Pruning in agriculture (horticulture) is the removal or reduction of parts of a plant, tree or vine that are not requisite to growth or production, are no longer visually pleasing, or are injurious to the health or development of the plant. Pruning can be divided into four types namely: Dead wooding, thinning, raise canopy, and canopy cleaning (Heath, 2014).

II. MATERIALS AND METHODS

2.1 Description of the Study Area

The study area for the design and construction is in River state university, which is located in Port Harcourt being the capital and largest city of Rivers state, Nigeria. Having an area of 369km2, It's the fifth largest city in Nigeria, it lies along the Bonny river having its latitude 44638.71N and mid-day latitude 7.0048.24 of the Greenich meridian and is located in Niger Delta, the inland part of the state consist of tropical rain forest and towards the coast, the typical Niger Delta environment features many mangrove swamps (McGeough, 2015).

River state has a total area 11,077km^2 making it the 26th largest state in Nigeria, surrounding states are Imo, Abia and Anambra to the north, Akwa-lbom to the east and Bayelsa, delta to the west, on the south it is bounded by the Atlantic ocean. Its topography ranges from plaints, with a network of rivers to tributaries (Rubin *et'al.*, 2019).

The pruning machine was conceived to be a hand-held mechanical device which will cut or trim off flowers/leaves with a rotary blade mechanism. The pruning device has a gun shape and the rotary motor and battery are placed at the barrel end of the device to give balance to the operator while pruning (Wagner, 2002).

2.2 Material and Selection

The material used is made up of mild steel because its ferrous metal is made from iron and carbon. It is a low-priced material with properties that are suitable for most general engineering applications. The blade of the device is made of galvanized steel owing to its resistance to rust or corrosion. The shafts and bearing are made of cast iron because of its hardness and have the ability to absorb energy.

2.3 Source of Power

The source of power is generated from a d.c battery with high power storage to last long during operation. The d.c battery was chosen because it is to be placed in a handheld machine for free movement.

2.4 Safety

The safety of the operator has been put into consideration, such that the part of the device that will be held by the operator has a handle, to ensure a firm grip by the operator and avoid shipping that may be caused by mechanic vibration. Furthermore, the part of the blade of the device also has a guide shielding it and protecting the operator against it, in the event of a pull out.

2.5 Design Theory and Principle

This is the fundamental approaches taking to design the pruning machine.

2.6 Design for Shaft:

The maximum shear stress theory (guest's tresca's theory) According to this theory, the failure or yielding occurs at a point in a member when the maximum shear stress in a bi-axial stress system reaches a value equal to shear stress at a yield point in a shaft tension test

$$\tau_{max} = \frac{\tau yt}{F.s} \qquad (1)$$

Where:

τ_{max}= maximum shear stress in a bi-axial stress system

τyt = shear stress at yield point as determined from simple tension test

F.s = factor of safety

2.6.1 Torque of shaft:

This shows the fundamental principles of force applied to rotate the shaft in a given diameter.

$$T = \frac{\pi x \tau x d^3}{16} \qquad (2)$$

Where:

T = torque required (M.m)

τ= shear stress (M/nr)

d^3= diameter (mm)

2.6.2 Power of blade:

This is the power require by the electric motor to give rotational force to the blade.

$$P = \frac{Tx2\pi N}{60} \qquad (3)$$

Where:

P = power (w)

T = torque of blade (N.m)

N = angular speed (m/s)

2.6.3 Centrifugal force:

This is an inertia force that act on the blade when it is rotating

Fc = ($mr\pi^2N$N) (4)

Where:

Fc = centrifugal force (N)

m = mass (kg)

r = distance from the engine (m)

N = angular speed (r/m)

2.6.4 Mass of a given blade thickness:

This is to show the maximum thickness of the blade

M = pV — Density x volume = p x (h x f x r) (5)

Where:

M = mass of given blade thickness (kg)

p = density (k/m^3)

v = volume (m^3)

2.6.5 Force required to overcome the resistance offered by the plant stem (F):

The shearing lead by the plant stem (kneaf) is given as 124.83 (Ibrahim, 2011). Therefore, the force required to overcome the resistance offered by the plant stem is expressed as:

Where:

$$Fs = mr\omega^2 = mr\left(\frac{2\pi N}{60}\right)2 = m\left(\frac{4\pi 2N^2}{3600}\right) \quad (6)$$

Fs = resistance offered by plant stem (N)

m = mass of plant stem (m)

r = distance from the origin (m)

ω^2= angular velocity (m/s)

N = angular speed (r/m)

2.6.6 Force acting on blade:

This is the force require to overcome resistance offered by external body such as wind, temperature or gravity

$$F = \frac{T}{r} = mg \quad (7)$$

Where:

F = force acting on blade (N)

r = radius of blade (m)

T = torque of blade (N/m)

m = mass of given blade thickness (kg)

g = gravitational force (m/s)

2.6.7 Theoretical field capacity:

This is the rate at which a machine would do a job if there were no interruption, no clogging, turning or slowing. This capacity is expressed in term of acres per hour (Gutierrez, 2017).

$$FC_{th} = SxW \quad (8)$$

Where:

S = speed of machine (m/hr)

W = width of machine (m)

2.6.8 Effective field capacity:

The effective field capacity of a machine in the field can be easily calculated by dividing the acres completed by the hoards of actual field time (Grzesik, 2017).

$$FC^{eff} \cong \frac{Land\ (ha)}{Use\ Time\ (hr)} \tag{9}$$

2.6.9 Theoretical field efficiency:

Theoretical field efficiency is the ratio of effective field capacity to theoretical field capacity in percentage.

$$f(\%) = \frac{FC^{eff}}{FC_{th}} \tag{10}$$

III. ESULTS AND DISCUSSION

3.1 Results

From the various calculations made for the design and evaluation of the motorized pruning machine, the following results in table 4.1 were obtained;

Result from Component/Operational Parameter

S/N	Machine Component/Operational Parameter	Design Value	Computation
1	Length of pruning blade	240 mm	
2	Width of pruning blade	40 mm	
O 3	Thickness of pruning blade	2 mm	
4	Length of drive shaft	300 mm	
5	Diameter of drive shaft	30 mm	
6	Length of driving shaft	90 mm	
7	Diameter of driving shaft	15 mm	
8	Length of machine case	600 mm	
9	Width of machine case	100 mm	
10	Length of motor	75 mm	
11	Diameter of motor	80 mm	
12	Length of battery	150 mm	
13	Width of battery	65 mm	
14	Height of battery	95 mm	
15	Torque of shaft	0.259 N-m	
16	Maximum bending moment	0.1325 N-m	
17	Power needed to rotate the motor	49.43 Watt	
18	Centrifugal force	475.40 N	

19	Resistance Force of plant stem	295.154 N
20	Theoretical field capacity	0.22 ha/hr
21	Effective field capacity	0.108 ha/hr
22	Effective field efficiency	49.1 %

3.2 DISCUSSION

The equipment is conceived to cut or trim flower horizontally and vertically, with the machine been held by both hands by the operator to have good balance during pruning.

The machine consists of 2 blades with a dimension of 120 mm x 40 mm (length and width). The machine is powered by a 43.49 Watt DC battery which power a 0.5 hp motor that gives a rotational force to the blade of 2 mm thickness. The rotational force is transmitted through a shaft of 300 mm length with shaft diameter of 30 mm, the drive shaft drives a driven shaft of 90 mm length and 15 mm diameter that givers 0.259 N-m torque and centrifugal force of 475.40 N to the blade for cutting, while the resistance force of plant stem is 295.154 N. The length of the 0.5 hp motor use is 75 mm and diameter of 110 mm while the length of the DC battery is 150 m, the width of the battery 65 mm and height of the battery is 95 mm. for the machine to operate effectively all components were placed in a case of 600 mm length and 130 mm width.

The theoretical field capacity of the machine was determined as 0.22 ha/hr and effective field capacity as 0.108 ha/hr. putting the field efficiency of this machine at 49.1%, this means that lor an 8hr daily operation this machine will effectively cover an area approximately 0.864 ha/hr.

IV. CONCLUSION

The successful design of the pruning machine is mechanical conceived to boost the agricultural industry and particularly to gardener since the concept of the machine was made to prune flowers. The machine has the ability to prune flowers vertical and horizontally, the machine has the ability to cut any stem to the shower stress of below 3.57 MPA because the yield strength exceeds the shower stress of the flower stem.

4.1 RECOMMENDATIONS

- The machine should be used only for the function it is designed for
- The use of gloves should use, to reduce vibration
- The government should help in making mass production and distribution of the machine to local gardeners.
- The government should partner with the institution in creating awareness to gardeners and other agricultural institutions.
- The gardeners should be taught on how to handle the machine in terms of operation maintain and repairs
- The machine will be operating on horizontal and vertical way

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