Design, Development and Testing of Low Capital and Operational Cost Shrub Cutting Machine

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Abstract. The machine to be designed and developed with a view to resolve one of the irksome problems of this institute has been facing every year. This institute is surrounded by vast non- fertile land area of about 200 acres, which becomes widely occupied by numerous breads of bushes and shrubs during post-rainy season. Due to this unwanted proliferation of such verdant institute gets abysmal look and that dumps off massive fund every year to get rid off it. The shrubs cutting machines comprises a main body (chassis) with two wheels and handle to provide movement in the field. One power unit (small S.I. engine) is mounted on this to give power for the cutting blades through small transmission mechanism. The cutting blades are mounted on a small shaft. Which actually perform the cutting operation? We intend to develop a machine which would provide better cutting action of bushes with low capital and operational cost.

With reference to literature available there are many types of lawn mowers, bush cutters and lawn tractors are exist in the market, which may not fulfill the capital and operational cost criteria. The main concentration of our design is the cost and operational ease. During design, development and fabrication the machine was undergone several laboratory. Field tests like; determination of torque and force analysis, load and speed test on design specifications (for shaft, gear and bearings), impact test, balance test and finally cutting output test. After testing we succeed to have a satisfactory performance, though it requires further more improvements which can be done in due course of time in stage II of the project.

Key Words: Engine, Blade, Shrub, Shear, Cutting.

Introduction

Wild shrubs are very common in an open area. Even when left unattended for a few days grass, weeds and wild shrubs cover the ground. A lot of grass cutter machines are available in market for cutting grass but these machines are not able to cut thick shrubs.

Therefore these shrubs have to be cut manually or by using some special machines like brush cutters. Rack pack type of brush cutter has certain inherent drawbacks, which can be eliminated by a shrub cutter machine on wheeled frame. In this work to revamp an existing setup. Various shortcomings of the machine were carefully examined and machine was customized to meet the requirements of a shrub cutter machine.

Objectives

1. Design of the shrub cutter machine, with special emphasis on design and selection of cutting blade.
2. Fabrication of shrub cutter machine.
3. Testing of machine,
    - Field testing
    - Calculation of cutting force and other performance parameters of the cutting blade

Literature Review at a Glance

History

Rotary mowers were not developed until engines were small enough and powerful enough to run the blades at a high speed. Many people experimented with rotary blades in the late 1920s and early 1930s, and Power Specialties Ltd. introduced a gasoline-powered rotary mower. The story of one experiment in the design of rotary mowing equipment is that of C C Stacy, a farmer in the Midwest region of the United States. His concept was the use of a toothed circular saw blade mounted horizontally on a vertical shaft, which would be suspended at a height of approximately 2 inches (50 mm) and moved across a lawn to cut grass and other lawn vegetation at a uniform height. The power for his experimental mower was an electric motor.

The success of Stacy's design was limited by two factors: the relatively small diameter of the saw blades he used for his experiments, which were about 8 inches (200 mm); and the fact that toothed circular saw blades are not an ideal tool for cutting free-standing grass and other plants. Stacy did not come up with any idea for a cutter similar to modern rotary mower straight blades, and soon dropped his experiments with rotary mowing.

Commercial models available

If look at grass cutting machine scenario, many different designs are available, each suited to a particular purpose. But for cutting shrubs which are comparatively very much thicker than grass and other common weeds, there is only one type of machine available in market which is sold under the commercial name of BRUSH CUTTER. A brush cutter machine is a rotary blade type shrub cutting machine.

This machine has certain disadvantages:

1. User has to carry the engine on his back, which could be very tiresome.
2. Vibrations of the rotating engine can be dangerous for user.
3. Exhaust of engine is very near to user’s mouth and nose.
4. Reaction of cutting force is transmitted directly to the hands of user.

Looking in to all these problems it was decided to develop a good machine with ease in operation and with low cost.

Methodology Specification and description of components

1. Engine
 Maximum Power = 1.1 kW
 Speed = 3000rpm
 Specific fuel consumption = 700g/kW-h
 Fuel = petrol + kerosene
 Lubrication Oil = S A E 40
2. Transmission Mechanism (bevel geared transmission)
 Horizontal rotation of engine output shaft is converted into vertical rotation by bevel Geared transmission case.
 Spline is used to connect to co-axial shafts
3. Rotary Saw Cutter Specifications:-
 Diameter of cutting disc = 300 mm
 No. of teeth = 60 T
 Maximum speed of operation = 5500rpm
 Weight of blade = 480 grams
 4. Transmission shafts
 Diameter of shaft = 1.5 cm
 Length = 22 cm
5. Frame
 Material used: - rectangular pipe
 Section = 1.5" x.75"
 Length = 75cms
 Width = 35 cm

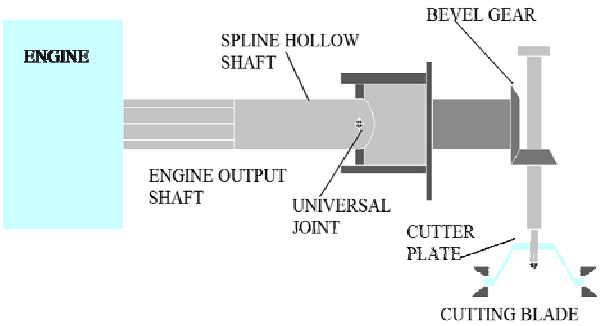

Fig.1. Shrub Cutting Machine Design

Working Mechanism

The output shaft of the engine is machined and fitted into the hollow shaft on which the meshing bevel gears are mounted. The bearings are provided on the shaft to hold the gear and avoid the bending of shaft due to the weight of and high RPM. The bearings are provided on a cylindrical casing to hold it in correct position. Cutter is mounted on the shaft which is passed through meshing gears, the taper rolling bearing is provided to hold this shaft. The main objective is to convert horizontal rotary motion into vertical motion with minimum frictional loses. The power is transmitted throgh output shaft to bevel gears and it is further transmitted to the cutter. The total power loses due to friction is very small. (5 and 7%)

Shortcomings

The old setup worked with a stabber cutter type of blade which is good to cut grass but not so useful for cutting shrubs which are comparatively thick. To improve these defects some additional features to be studied in detail and on the basis of this the necessary updates in the design was incorporated after successful testing.

Design improvements

A rotary saw type Blade is used in place of profile cutter as a rotary saw is more efficient in cutting thick shrubs as compared to profile cutter. RPM of cutter was increased as volume of wood removed by cutter is directly proportional to angular speed of cutter. This was done by replacing gear on bevel gear in the small gear box casing. A special type bush-nut arrangement is used to couple rotary blade to output shaft. It also facilitates adjustment of cutter height. Hence height of cut can be changed.

Blade Design Parameters and Force Analysis

Saw plate: The steel will add durability by preventing warping during heat buildup and strength by absorbing initial shock pressure when cutting hard materials.

Kerfs: The width of the carbide tip measured from the two widest points of the top of the carbide tip.

Arbor hole: The center bore joins the saw blade with the saw.

Diameter: The diameter is measured from the furthest edge of one tip to the furthest edge of the tip directly opposite.
Gauge: The measurement of the plate thickness.
Shoulder: The major functions of shoulder are to add strength and support to the carbide tip.
Gullets: The main purpose of a gullet is to provide clearance for the material being removed.
Hook angle: The hook angle is the amount of forward or backward lean each tooth has.
Number of teeth: This is one variable that will have the most noticeable effect on the cutting action of the saw blade.
Expansion slot: The basic function of the expansion slots, which are used primarily on larger diameter blades, is to create an outlet for heat buildup created during cutting.
Expansion slot base hole: The Expansion slot base holes are round geometric shape swith sharp or square corners.

Calculations

Saw Blade Analysis
Cutting Force per tooth = S. b. f. cos (λ-α).sinφ.co (λ+φ-α)
(1) Where,
S = ultimate shear strength of wood
b = Thickness of saw blade
f = Feed given
φ = Angle of shear
α = Angle of rake
λ = Angle of friction
Volume of wood removed per unit time
= k. b. t. v
= K. b. t. N.D
(2) Where,
b = thickness of blade
t = vol. of wood removed per tooth
N = Angular speed of blade
D = Dia. of blade.
Striking Force per unit tooth=DX RPM2.70400Newton (3) Let,
Ac=Area covered by cutter per unit time
Ac=V.2R1+πR12-πR22 (4)
Let the density of shrub per unit area be=p
No. of shrubs cut per unit time = ρ. Ac
Dimensions of Saw type cutter:
Dia. of blade = 300 mm
Width of Blade = 3 mm
No. of teeth = 60

Test values

ρ = 12 shrubs.metre2
V = 5 m.min
Ac = V. 2R1 + πR12 - π R22
Ac = 1.5 m2
No of shrubs cut = 1.5 x 12
= 18 shrubs per min.
Tanφ = rcosα.1– rsinα (5)
Now,
α = 200
r = 0.73
Putting these values
Tanφ = 0.91
φ = tan-10.91=42.30
By Ernst Merchant theory
Φ = π.4–λ.2+α.2 (6)
Putting
φ = 42.30 and α =200

42.3 = λ.2 + 10
λ = 25.40

Conclusions

The machine is fabricated as per dimensions.
Design of blade and force analysis is done.
The fabricated machine is economical.
Fabricated machine is easy to use and fulfills all the objective

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