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Design fabrication and testing of vertical axis rotary tiller

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ABSTRACT
Vertical Axis Rotary Tiller has been designed with a view to do primary and secondary tillage operation in one pass, particularly in light soils. However this can be used as secondary tillage in heavy soils. This designe has only one rotor but in second phase the machine would have rotors in pairs. The designe and fabrication of the machine was done in the Agricultural Engineering Department in A.A.I. in the year 92-93. The field capacity of the machine has been observed between 0.085 ha/h to 0.066 ha/h at 100 mm depth. The actual field capacity will increase considerably when the machine will be designed for pair of rotors .

Key words : Rotors, Tiller, Vertical, Performance.

INTRODUCTION

Since the beginning of the civilization man has toiled to till the earth for the production of food and fiver. It was recognized early that stirring of the top crest of the soil enhanced plant growth. Man power and latter animal power was utilized to accomplish this task by means of new and improve soil tools. In this endeavour to in crease agricultural production the emphasis is now on to replace more advanced equipments and machinery in place of conventional machinery.

Present day tillage tools which even though accomplish the given task are generally not very efficient in energy utilization. The importance of this problem can not be over emphasized when one realized that only one percent increase in ploughing efficiency one of the many tillage operations would result in an annual savings of crores of rupees in India.

The compacting effect due to machine weight alone is increased by the draft forces applied to soil by tractor drive wheels. As tractor power increased so has draft capability as well as the wheel loading required for development of the maximum draft.

Transmission of the power directly to the tillage tool by mechanical means offers opportunity for reducing drawbar pull requirements there by reducing the soil compacting forces of traction wheels. Forced vibration or oscillation of the tillage tool and multipowered rotating tools are the methods of direct power utilization. Multipower rotating implements are available in western countries in different configuration and arrangement including vertical axis, horizontal axis and transverse axis units. The Vertical axis machine have a series of two tine paths of adjacent rotors overlap. This project is intended only on single powered rotating implement to examine the feasibility of utilization of this type of tillage in Indian farms.

This machine “Vertical Axis Rotary Tiller” has two tine and single rotor mounted on gear shaft but provision is made to convert the machine to two or four unit with the help of chain and sprocket for further development of the machine. The tine paths of adjacent rotor overlap in multipowered units. The machine is driven by P.T.O. with the help of bevel gear arrangement. Power is transmitted from P.T.O. to pinion shaft and then to gear shaft.

This research was undertaken in the year 1992-93 to ascertain the rotary concept of tillage operation on Indian farms and to achieve the following objectives:

1. To design the powered “Vertical Axis Rotary Tiller.”
2. To fabricate the designed machine.
3. To test the machine in idle as well as in running and in the field for the functional performance.

MATERIALS AND METHODS

The designe and fabrication of the machine was done in the Agricultural Engineering Department in A.A.I. in the year 92-93.Vertical Axis Rotary machine basically has a series of 2 tine vertical rotors across the width of the machine. The tine paths of adjacent rotors overlap. The machine is powered through P.T.O. of tractor and mounted behind the tractor by means of 3 point linkage. When the tractor is moved forward and the machine is operated by P.T.O. it digs the soil and pulverizes simultaneously. This particular machine has been made with only one rotor in the first phase to see the functional performance and feasibility of operation. The machine can be converted in to a multi power rotating tillage tools in next phase.

(i) Detail description of the machine

The Vertical Axis Rotary Tiller consists of following parts:

(a) Frame

On which the gear box is mounted and three point linkage is included in the frame.

(b)Gear Box

Set of bevel gears and bearings are assembled inside the gear box to transmit the horizontal rotation in to vertical rotation, it is properly sealed to prevent oil leakage.

(c) Rotor

Is fitted with gear box out put shaft and has arrangement for mounting the blades at both ends.

(d) Blades

Two blades of carbon steel are fitted at both the ends of the rotor to dig and pulverize the soil.

(ii) Design of gears

Pair of bevel gears has been design for Vertical Axis Rotary Tiller. It was assumed that gear box should we able to transmit 30 hp. safely for pinion rpm. 540 (P.T.O.Speed).

(iii) Design of shaft

The material of both gear and pinion shaft is 45C8 steel whose ultimate tensile stress is 7000 kgf/cm and ultimate shear stress is 5000 kgf/cm factor of safety as 5.

(iv) Selection of bearings

Selection of bearings have been done on the basis of static and dynamic load acting on the shafts through bevel gear and pinion tooth and speed in rpm. Selected bearings are a pair of taper roller bearings for pinion shaft and gear shaft.

(v) Test procedure

First the complete machine was assembled providing proper backlash adjustment to this pair of gear in the gear box. Then idle running was carried out in the laboratory then the machine was taken to the field to test its functional performance .

Soil samples were collected at several places for finding out texture and moisture content of the soil. Soil texture of the field were found out by sieve analysis and percentage sand, silt and clay were determined separately.

The moisture content of soil was measured in the laboratory by gravimetric method.

Field testing was done at 100 mm depth of operation of the rotor. Three forward speed were selected i.e. 2.4 km. /h., 3.2 km/h. and 4.3 km/h. for testing. Forward speed measurement was done by selecting 50 meter clear length and time was taken several times for operation of the tractor with the help of stop watch then the speed was calculated taking the average reading. Actual depth of cut was measured taking reading at several places. The theoretical and actual field capacities were calculated after taking field data.

RESULTS AND DISCUSSION

1. Design of bevel gear

The design of bevel gear has been done on the basis of input power of 30 hp and P.T.O. speed 540 rpm. It presumed that rotor will operate between 260 to 300 rpm. (Culpin Claude 1991: Farm Machinery) The velocity ratio for pair of gears has been taken as 1.8: 1 to achieve 300 rpm. Output speed when P.T.O. is operating at 540 rpm. speed. Dynamic and static load on the pinion and gear teeth have been calculated. The requirement for the safe design is that the static load should be grater than dynamic load.(Ws>Wd)

Static and Dynamic Load on gear and pinion

Load	Pinion	Gear
Static (Ws)	2074.64 kg.	3615.25 kg.
Dynamic (Wd)	2057.4 kg.	2057.49 kg.

Static load is more than Dynamic load both in pinion and gear hence design is safe.

(ii) Selection of bearings

A pair of taper roller bearing for pinion and another pair taper roller bearing for gear was selected. Taper roller bearing can take care of radial and thrust loads. With this type of bearings it is possible to make adjustment for the radial clearance.

(iii) Functional Performance of the Machine

Idle testing of the machine has been carried out from 35 hp Massey Ferguson Tractor in order to check the various components in operating conditions. This was ascertain that the machine would work satisfactorily in the field. It was found that during idle testing all the components were working properly and it was observed that there was no oil leakage from the gear box. The machine has been tested in laboratory for 6 hr. and observed that no undue heating of bearings and all the nuts and bolts remained tight after idle testing of the machine.

The machine has been tested in the field for primary tillage in sandy clay loam soil at the moisture content of 15.5 % (Detail of percentage of clay, silt, and loam given in table A and percentage of moisture content of soil given in table B). The field capacity of the machine has been found out by operating the machine in the field at three predetermined forward speed. The actual field capacity was calculated by observing the time lost in 60x10 mtr Sq. area. Theoretical field capacity was calculated by taking theoretical width of cut i.e. 36 cm and the speed of operation in to account. The rotor speed during the field capacity of the machine was kept constant at 300 rpm. The actual and theoretical field capacities at three forward speeds are given in table 1 & 2.

Table A

S.No.	(%) of Sand	(%)of Silt	(%)of Clay
1.	50	14	36
2.	52	16	32
3.	54	18	28

Average: Sand 53%, Silt 60%, Clay 32 %

Table B

S.No.	Weight of wet soil sample (gm.)	Weight of dry soil sample (gm)	% of moisture content
1.	22.3	19.3	15.21
2.	25.6	22.1	15.49
3.	20.8	17.9	15.80

Average: Moisture content 15.5 %

Table 1 : Observed values during field testing

Sr.	Area covered in (mtr.sq.)	Forward speed (km/h)	Actual depth of cut (mm)	Time taken (minute)
1.	600	4.3	109	42
2.	600	3.2	108	48
3.	600	2.4	115	56

Table 2 : Calculated Value of Field testing

S.No.	Theoretical width of cut (mm)	Theoretical field Capacity (ha/h.)	Actual Field capacity (ha/h.)	Field efficiency (%)
1.	360	0.154	0.085	55.10
2.	360	0.154	0.075	65.21
3.	360	0.086	0.066	76.64

The field test has been carried out at 100 mm depth of operation for all three tests. The actual depth of operation was measured at several places, it was found 100 mm to 115 mm. There was no unploughed land observed in the full width of cut at all three forward speed.

The machine has been working in the field as primary tillage implements satisfactorily and the soil pulverization was also good. The machine can be used as a primary as well as secondary tillage implement in light soil. This was also observed that the seed bed preparation can be done in only one operation with this type of machine in light soil.

Since this particulars design has been made with single rotor hence there was side thrust observed during field operation. This can be eliminated when the machine will be fabricated with pair of rotor.

CONCLUSIONS

Following conclusions can be made from the present machine and its testing.

1. Operation of the machine is satisfactory and can be used for primary and secondary tillage operation in light soils.
2. There is no unploughed land in the full width of cut even at 4.3 km. /h. speed.
3. Fabrication of the machine can be done with the available components in the market without much difficulty.
4. Field capacity for single rotor unit has been observed between 0.066 ha/h. to 0.085 ha/h.

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