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DEVELOPMENT OF TRACTOR OPERATED TWO ROW FORWARD REVERSE ROTAVATOR FOR SUGARCANE CROP

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ABSTRACT

Sugarcane (*Saccharum officinarum*) is vegetative propagated crop, grown in more than 80 countries. India is the second largest global producer of sugarcane next to Brazil. Maharashtra state plays vital role in Indian sugar industry. The area under sugarcane cultivation in Maharashtra was 10.22 lakh ha with the total cane production of 712.45 lakh tons, average productivity is 69.71 t/ha in the year 2017-18. Sugarcane cultivation is very labour consuming, requires about 3300 man working hours for different operations for its duration. Use of farm machinery helps in labour saving, ensures timeliness of operations, reduces human drudgery, helps in improving quality of work, reduces cost of operation and ensures effective utilization of resources. Considerable mechanization gap was found in usage of farm machinery especially in sugarcane planting, intercultural (weeding and earthing up), harvesting, detrashing and ratoon management. Earthing up plays an important role in maintaining the growth, yield of the sugarcane crop as well as ratoon. Introduction of multitasking implements is a step towards maximizing the economy of farmer in minimum expenditure. Therefore, based on the above facts the tractor operated two row forward reverse rotavator is developed. It is a tillage implement particularly used for inter culturing operation in sugarcane crop. In forward direction, it is used for weeding operation and pulverization in two rows. In reverse application earthing up in sugarcane crop is performed. The developed machine has provision to adjust the working width as per the row to row spacing of sugarcane crop. The height of ridge form after earthing up was 32 cm and its field efficiency was found to be 83.32 and 80.85% for forward and reverse operation respectively.

Key words : Earthing up, Inter culturing, Mechanization, Reverse – forward.

Introduction

India is the second largest global producer of sugarcane next to Brazil and the world's leading sugar consumer. India's total sugarcane cultivation area is 5.08 million ha. Uttar Pradesh, Maharashtra, Karnataka, Gujarat, Andhra Pradesh and Tamil Nadu are the major sugarcane growing states contribute about 81% of the total production in India. Maharashtra is a leading producer of sugarcane crop. Adsali, pre-seasonal and seasonal or suru are the three different periods of sugarcane crop in Maharashtra. Sugarcane crop cultivation is very labour consuming (Kumar *et al*., 2018). Sugarcane is one crop in which there has been little mechanization in India, all farm operations from planting to harvesting being labour dependent. Sugarcane requires number of intercultural operations for weed control, moisture conservation and creation of better environment for overall growth of plant. Mechanization can eliminate the drudgeries involved in sugarcane crop cultivation. Mechanization has been identified as the major factor for increasing agricultural productivity worldwide (Tiwari *et al.*, 2019). Weeding and earthing up of sugarcane crop are the important intercultural operations. Earthing up operation is done when 2 to 3 internodes are visible. It is done to support the plants with soil and avoid the direct contact of water of plants. Earthing up plays an important role in maintaining the growth, yield of the sugarcane plant. Besides, it has added advantages in terms of pruning/ cutting of old roots, moisture conservation, addition of organic matter, enhanced availability and uptake of plant nutrients, efficient utilization of solar radiation, suppression of weeds and preventing canes from lodging (Yadav and Shukla, 2008). These intercultural operations mostly done with the help of farm labour and self-propelled machineries which directly affects the productivity of crops.

Material and Methods

Development of tractor operated two row forward reverse rotavatror

Tractor operated two row forward reverse rotavtor was designed using specific work method (Bernacki *et al*., 1971 and Zareinforoush *et al*., 2010).

Specific work

It is the work carried on by rotary tiller at each rotation of tillage blades per the volume of broken soil.

Power requirement

It is calculated by the following equation

$$N_c = \frac{10A_{cABv}}{75\eta_c\eta_z}$$

Where,

η_c = Tractor efficiency = 0.8 - 0.9

η_z = Coefficient of reservation of tractor power = 0.7-0.8

$$N_c = \frac{10\times155\times1.2\times15\times0.083}{75\times0.85\times0.8}$$

$$N_c = 45.40\ hp \cong 45\ hp = 33.09\,kW$$

Length of slice

Length of slice is calculated using following equation,

$$L = \frac{2\pi R}{\lambda\ Z}$$

$$L = \frac{2\times3.14\times20}{5\times2} = 12.5\,cm$$

Design of Rotary Shaft

The maximum tangential force (K_s) is calculated by

$$K_s = C_s\frac{75\eta_c\eta_z}{u_{\min}}$$

Where,

C_s = Reliability factor = 1.5 for non-rocky soil and 2 for rocky soil

$$\lambda_{\min} = \frac{2\pi R}{z\ L_{\max}}$$

$$\lambda_{\min} = \frac{2\times3.14\times20}{2\times12} = 5.23$$

$$u_{\min} = v\lambda_{\min}$$

$$u_{\min} = 0.83\times5.23 = 4.34\ m/s$$

$$K_s = 1.5\ \frac{75\times0.8\times0.85\times45}{4.34} = 793.20\ kg.$$

The maximum moment on rotor shaft is,

$$M_s = K_s \times R$$

$$M_s = 793.20\times20 = 15864.05\ kg.\,cm$$

Allowable Stresses

The rotor will be made from roll steel (AISI302) having yield stress 520 MPa.

As the allowable stress in rotor calculated by

$$\tau_{all} = \frac{0.577\sigma_y}{f}$$

Where,

σ_y = 500 MPa

F = Factor of safety = 2

K = coefficient of stress = 0.75

$$\tau_{all} = \frac{300\ K}{2}$$

$$\tau_{all} = \frac{300\times0.75}{2} = 112.5\ m\ Pa = 1147.18\ \text{kg/cm}^2$$

Diameter of rotor shaft

The diameter of rotor shaft calculated using the equation of torsional moment

$$d = \sqrt[3]{\frac{16M_s}{\tau\times\pi}}$$

$$d = \sqrt[3]{\frac{16 \times 15864.04}{147.18 \times \pi}} = 4.13 \text{ cm}$$

Width of rotary tiller

Let, moment acting, $M = \frac{A \times z \times l \times a \times b_m}{2\pi}$

Rotary tiller width,

$$b_m = \frac{2 \times 3.14 \times 15866.05}{1.31 \times 2 \times 15 \times 12} = 209.65\,cm \cong 210\ cm$$

Number of blades

$$= \frac{Width\ of\ one\ unit}{Distance\ between\ blades}$$

$$= \frac{65}{3.6} = 18$$

Total no of blades on both unit = 18 × 2 = 36

Angle of blade inclination

$$= \frac{360^0}{No.\ of\ blades}$$

$$= \frac{360^0}{18} = 20^0$$

Design of Power Transmission System

a. Speed reduction

First stage speed reduction : Assume number of teeth on pinion gear which mounted on input shaft as 13 with speed ratio 1.76:1. No of teeth on crown gear, which mounted on gearbox shaft was calculated by using following formula (Khurmi and Gupta, 2006).

$$Speed\ ratio = \frac{T_2}{T_1}$$

Where,

T_1 = No. of teeth on pinion gear which mounted on input shaft

T_2 = No. of teeth on crown gear which mounted on gearbox shaft

$$Speed\ ratio = \frac{T_2}{T_1} = 1.76$$

$$\frac{T_2}{13} = 1.76$$

$$T_2 = 1.76 \times 13$$

$$= 22.88 \cong 23$$

Selected no. of teeth on crown gear as 23.

The speed of gearbox shaft in power train of transmission system was calculated using the formula.

$$N_1 T_1 = N_2 T_2$$

$$N_2 = \frac{N_1 T_1}{T_2}$$

Where,

N_1 = Speed of input shaft (rpm)

N_2 = Speed of gearbox shaft (rpm)

T_1 = No. of teeth on pinion gear which mounted on input shaft

T_2 = No. of teeth on bevel gear which mounted on gearbox shaft

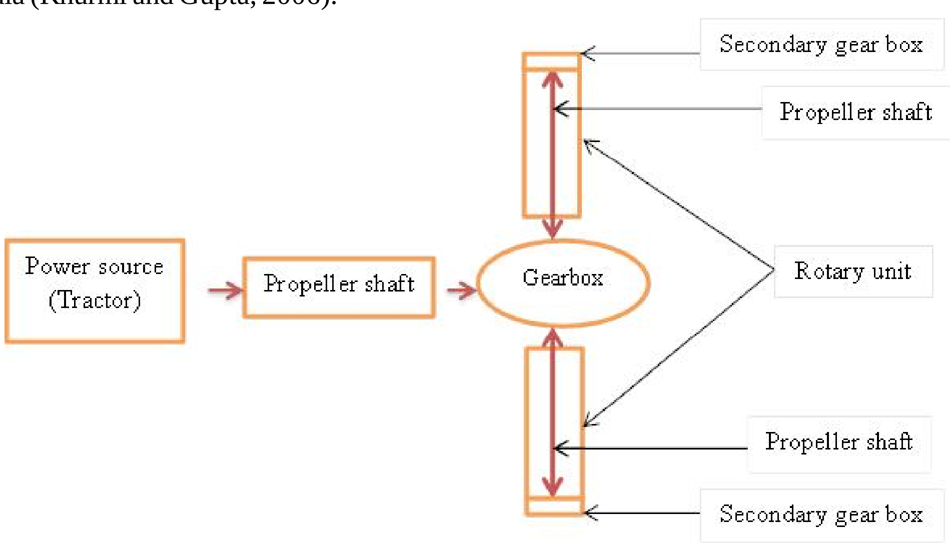

Fig. 1 : Block diagram showing power transmission of tractor operated two row forward reverse rotavator.

N_1 = 540 rpm, T_1 = 13 teeth, T_2 = 23 teeth

$$N_2 = \frac{540 \times 13}{23}$$

$$= 305.2\ rpm$$

In first reduction stage tractor P.T.O speed reduced from 540 rpm to 305.2 rpm.

Second stage speed reduction : Assume number of teeth on sprocket which mounted on secondary propeller shaft as 12 with a speed ratio 1.25:1. Number of teeth on sprocket which mounted on rotor shaft was calculated by using formula

$$Speed\ ratio = \frac{T_4}{T_3}$$

Where,

T_3 = No. of teeth on sprocket which mounted on secondary propeller shaft

T_4 = No. of teeth on sprocket which mounted on rotor shaft

$$Speed\ ratio = \frac{T_4}{T_3} = 1.25$$

$$= \frac{T_4}{12} = 1.25$$

$T_4 = 15$

15 teeth on sprocket which mounted on main rotor shaft will be selected.

The speed of secondary propeller shaft in power train of transmission system was calculated using the formula

$$N_3 T_3 = N_4 T_4$$

$$N_4 = \frac{N_3 T_3}{T_4}$$

Where,

N_3 = Speed of gear box shaft, rpm

N_4 = Speed of Secondary propeller shaft, rpm

T_3 = No. of teeth on sprocket which mounted on gearbox shaft

T_4 = No. of teeth on sprocket which mounted on rotary shaft

$N_2 = N_3$ = 305.2 rpm, T_3 = 12, T_4 = 15

$$N_4 = \frac{305.2 \times 12}{25} = 244.16\ rpm$$

b. Chain sprocket transmission

The length of chain in terms of number of pitches, for power transmission from gear box shaft to rotary shaft was calculated by using the following expression

$$L = \frac{T_1 + T_2}{2} + \frac{2C}{P} + \frac{T_2 - T_1}{2\pi^2} + \frac{P}{C}$$

Where,

L = Length of the chain in terms of pitches

T_1 = Number teeth in pinion

T_2 = Number teeth in sprocket

C = Center to Center distance between the pinion and the sprocket, cm

P = Pitch distance, cm

$$L = \frac{13+15}{2} + \frac{2 \times 48}{2.54} + \frac{15-13}{2\pi^2} + \frac{2.54}{48}$$

= 51.94 = 52

Therefore the length of chain was **52 pitches** selected.

Performance evaluation of tractor operated two row forward reverse rotavtor

During the performance test of rotavator methodology followed as per IS: 17045:2018 and different observation were taken for assessment of the machine performance. The more than one hectare area of the test plot was selected. The ratio of width and length of the plot was as possible as 1:2. Soil moisture content, bulk density, fuel consumption, etc. were recorded.

1 Moisture content on a dry basis

The moisture content was determined on a dry basis, using oven dry method. Soil samples were dried in the oven for 24 hours at 105°C. The dried sample was re-weighed and the weight was recorded. Soil moisture content (dry basis) was estimated by using the formula

$$Moisture\ Content(\%) = \frac{Weight\ of\ moist\ soil - Weight\ of\ dry\ soil}{Weight\ of\ dry\ soil} \times 100$$

2 Bulk density

Undisturbed soil cores were collected by driving with an iron hammer 10 cm diameter metal cylinder into the depth in the plot. Bulk density was calculated based on volumes and dry weights of the soil samples by using a

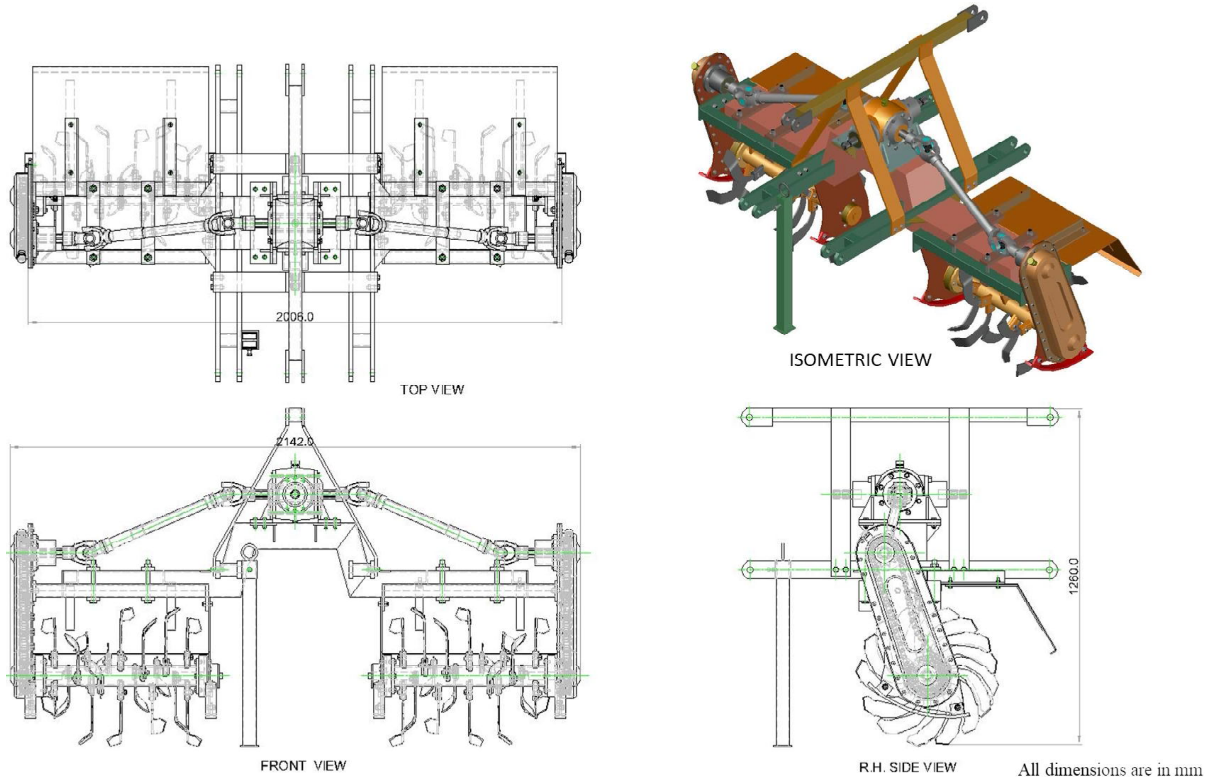

Fig. 2 : Top, Front, RH side view and Isometric view of developed tractor operated two row forward reverse rotavator.

a. Forward operation **b. Reverse operation**

Fig. 3 : Experimental setup for field trials of developed tractor operated two row forward reverse rotavator for sugarcane crop.

core penetrometer of 10 cm diameter and 13cm height. Bulk density (g/cc) was measured with the help of the following formula.

$$Bulk\ Density\left(\frac{gm}{cc}\right)=\frac{Weight\ of\ soil(gm)}{Volume\ of\ soil(cc)}$$

3 Fuel consumption

For measuring the tractor fuel consumption the fuel tank was filled before and after the test. The amount of refueling after the test was the fuel consumption for the particular operation. While filling up the tank, careful attention was paid to keep the tank horizontally and not to leave any space in the tank. For checking the proper level of the tank spirit level was used.

4 Theoretical field capacity

For calculating the theoretical filed capacity, working width and travelling speed were taken in to consideration. It is always greater than the actual field capacity. Theoretical field capacity was calculated by using following formula.

$$Theoritical\ \ field\ capacity\ (ha/h)=\frac{Width(m)\times Speed(km/h)}{10}$$

5 Effective field capacity

The actual operating time along with time lost for every event such as turning, refueling, and machine trouble

Table 1 : Test results of tractor operated two row forward-reverse rotavator for sugarcane crop (Inter culturing Operation Forward Direction and reverse direction).

S. no.	Parameters	Forward direction	Reverse direction
1.	Net duration of test, h	27.0 (T)	16.8 (T)
2.	Gear used	L-2	
3.	Engine speed, rpm		
	- No load	2000	2000
	- On load	1800	1700
4.	Bulk density, g/cc	1.43	1.43
5.	Soil moisture, %	10.75	10.75
6.	Forward speed, km/h	3.23	2.9
7.	Avg. depth of cut, cm	11.83	-
8.	Average Ridge height, cm	-	30.4
9.	Av. width of cut, cm	311	311
10.	Area covered, ha/h	0.84	0.73
11.	Time required for one ha, h	1.20	1.37
12.	Theoretical Field capacity, ha/h	1.00	0.90
13.	Field efficiency, %	83.32	80.85
14.	Fuel consumption, l/h	5.77	5.84
15.	Fuel consumption, l/ha	6.91	8.01
16.	Operating cost of the machine, Rs/ha	1029.66	1178.95
17.	Net saving by using the machine over traditional method (Forward Operation), Rs/ha	1470.34	3821.05

were recorded for completion of a particular operation. The effective field capacity was calculated as follows:

$$Effective\ field\ capacity\ (ha/h) = \frac{A}{(T_p + T_1)}$$

Where,

A = Area covered, ha.

T_p = Productive time, h

T_1 = Non Productive time, h.

6 Field efficiency

Field efficiency was calculated by taking ratio of effective field capacity to theoretical field capacity. It is always expressed in percentage. It was estimated by following formula.

$$\eta\,(\%) = \frac{EFC \times 100}{TFC}$$

7 Height of ridge

The height of ridge form during the reverse rotation of rotor blade was recorded using the measuring scale.

Results and Discussion

The experimental setup for performance of developed tractor operated two row forward reverse rotavator shown in Fig. 3. The tractor was calibrated in the field using the combination of changing the lever position of gear and high-low stages of gears. Finally, the desired speed level of tractor *i.e.* 2 km.h^{-1} was set for second gear at low lever position with gradual adjustment of the hand throttle. The rotary unit width was adjusted according to the crop row spacing; the depth controlling mechanism was positioned at second for optimum depth. Two poles at 25 m distance apart were fixed for calculating the time taken to cover the 25 m length. Then after preliminary check-up of machine, the machine was operated in the sugarcane field. Both performance trials were carried out, while working in forward direction as well as in reverse direction. The necessary field data was recorded for further calculation. Table 1 depicts the results obtained during the test trials of developed tractor operated two row forward reverse Rotavator for forward direction and reverse direction, respectively. The overall field efficiency was 83.32 in forward operation whereas 80.85 was during reverse direction. The fuel consumption in forward direction was 6.91l/ha and in reverse operation 8.01 l/ha was recorded.

Conclusion

1. Field efficiency of machine was 83.32% in forward operation whereas 80.85% during reverse direction.
2. The ridge height during reverse operation was 250 - 350 mm.
3. The net saving over conventional method 1470.34 Rs/ha and 3821.05 Rs/ha for forward and reverse operation respectively.
4. Overall performance of developed tractor operated two row forward reverse rotavator was found satisfactory.

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Conflict of interest : Authors have no conflict of interest.

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