RESEARCH PAPER | International Journal of Agricultural Engineering | Volume 5 | Issue 2 | October, 2012 | 249 –253

Development and evaluation of maching rotavator for low horsepower tractor

D. PADHEE, B.M. NANDEDE AND RANJEET KUMAR

Received : 18.07.2012; Revised : 27.08.2012; Accepted : 29.09.2012

See end of the Paper for authors' affiliations

Correspondence to:

D. PADHEE
Department of Agricultural and Food Engineering, Indian Institute of Technology (IIT), KHARAGPUR (W.B.) INDIA

ABSTRACT : Software for design of rotavator for low hp tractors were used to design the rotavator and based on the results of the software a rotavator was developed and evaluated its performance in the field. It comprised a rotary unit with overall width and rotor diameters were 0.79 m 440 mm, respectively. The rotary unit was consisting of 20 'C' type blades arranged spirally on a shaft of diameter 62 mm. The angular interval between the blades was kept 18^0 to prevent clogging. The speed of rotation of rotor shaft of the developed rotavator was found to be 185 rpm and 230 rpm corresponding to the PTO speed of tractor at low and high gears, respectively. For designing the matching size rotavator, a computer programme was written in Visual Basic 6 and compared with some of the commercially available rotavators in the power range of 9.6 kW. The developed rotavator was evaluated in actual field and its performance parameters such as field capacity, field efficiency, tillage performance index and fuel consumption was found to be 0.14 ha/h, 68 per cent, 0.796 k and 1.56 l/h, respectively.

KEY WORDS : Rotavator, Tillage performance index, Matching rotavator, Performance

HOW TO CITE THIS PAPER : Padhee, D., Nandede, B.M. and Kumar, Ranjeet (2012). Development and evaluation of maching rotavator for low horsepower tractor. *Internat. J. Agric. Engg.*, **5**(2) : 249-253.

The Indian tractor market is flooded with tractors in the power range of 15-30 kW which are suitable only for large holdings. The tractor industry has divided their product range into 5 main segments namely, below 15 kW, 15-30 kW, 30-40 kW, and above 40 KW (Anonymous, 2012). Being the world's largest tractor industry, the market is flooded with tractors in the power range of 15-30kW which are suitable only for large holdings. As they are highly priced, they are beyond the reach of small and marginal farmers which comprise about 80 per cent of farmers of India. The alternative of purchasing of tractor can be thought of hiring a tractor during the peak period of crop production. The average land holding of an Indian farmer is very small and in these small pieces of lands, maneuverability of the large sized tractors is difficult. Farm mechanization level in India is only 1.75 kW/ha (Kulkarni, 2005), which is very low as compared to other developing countries. Dalin and Pavlov (1950) conducted several experiments by using pick type tine and 'C' type tines operating in forward and reverse rotation. In each test, rotary power requirement was found greater for forward than for reverse rotation. The horizontal component to move the tiller was found negative during the reverse rotation. Tsuchiya and Honami (1963) conducted studies on the power reduction of rotary tillers. It was found that reducing the rotor speed reduced the power requirement. They also found that torque variation drastically reduced when two or three tines cut the soil at the same time. Matyashin (1968) reported that at shallow tilling depths (*i.e.* H<R), forward rotation requires 10 to 15 per cent less energy than reverse rotation. When tilling deep (H>R), reverse rotation reduced the energy requirement by 20 to 30 per cent. Butterworth (1972) has presented a brief description of favorable design features of available rotary tillers. The use of 'C' type tines were recommended for deep tillage and 'L' shaped tines for shallow tillage. Bite length of 100 mm was found to be optimum for power and cultural optimization. Raheman and Sahu (2006) designed a rotary cultivator with 'L' type blades and developed a computer program to assist with the design calculations. The working width of the machine with the number of working sets were predicted for 30, 35 and 45 hp tractors by varying the forward velocity and the ratio of peripheral to forward velocity. Taking maneuverability into account, the optimum dimensions of rotary cultivator for each of these tractors were determined. The predicted values of working width, number of working sets and dimensions of the shaft and blade of rotary cultivator were compared with the market available rotary cultivator for a 35 hp tractor indicating a maximum variation of 4.5 per cent. Keeping these factors in mind, a study was conducted to develop a rotavator for low horsepower tractor considering the various three-point linkage geometric dimensions of the tractor developed at IIT Kharagpur with specific objectives to write a program in a Visual Basic for designing rotavator to match the developed tractor, Fabricate the matching rotavator for the developed tractor based on the results obtained from the program and evaluate the performance of the developed rotavator in the field.

■ METHODOLOGY

Development of software for matching size of rotavator:

Software for design of matching rotavator for low hp tractor was development by writing a programme in Visual Basic 6.0. The input parameters used were power source, type of soil, material of shaft and blades, u/v ratio, forward speed of travel, number of blades working in the same plane and rotor radius whereas the output parameters were overall width of machine, total number of blades, outer and inner diameters of the shaft, thickness and width of blade, width of shank and angular interval between the blades. Provisions were made to change these input parameters depending on the requirement and thus making the software users friendly. Input and output screen for rotavator design software is shown in Fig. A.

Validation of software developed for rotavator design:

For validating the developed software, the dimensions of rotavator predicted were compared with some of the commercially available rotavator in the market. The comparison for 9.6 kW and 26.11 kW rotavator at an operating speed of 3 km/h and 4 km/h are shown in Table A.

The variations between predicted and available data were found to be within 5- 6 per cent (Table A). Raheman and Sahu (2006). The predicted values of working width, number of working sets and dimensions of the shaft and blade of rotary cultivator were compared with the market available rotary cultivator for a 35 hp tractor indicating a maximum variation of 4.5 per cent. Hence, the developed software was used for designing rotavator for low horsepower ranges of tractor and soil conditions.

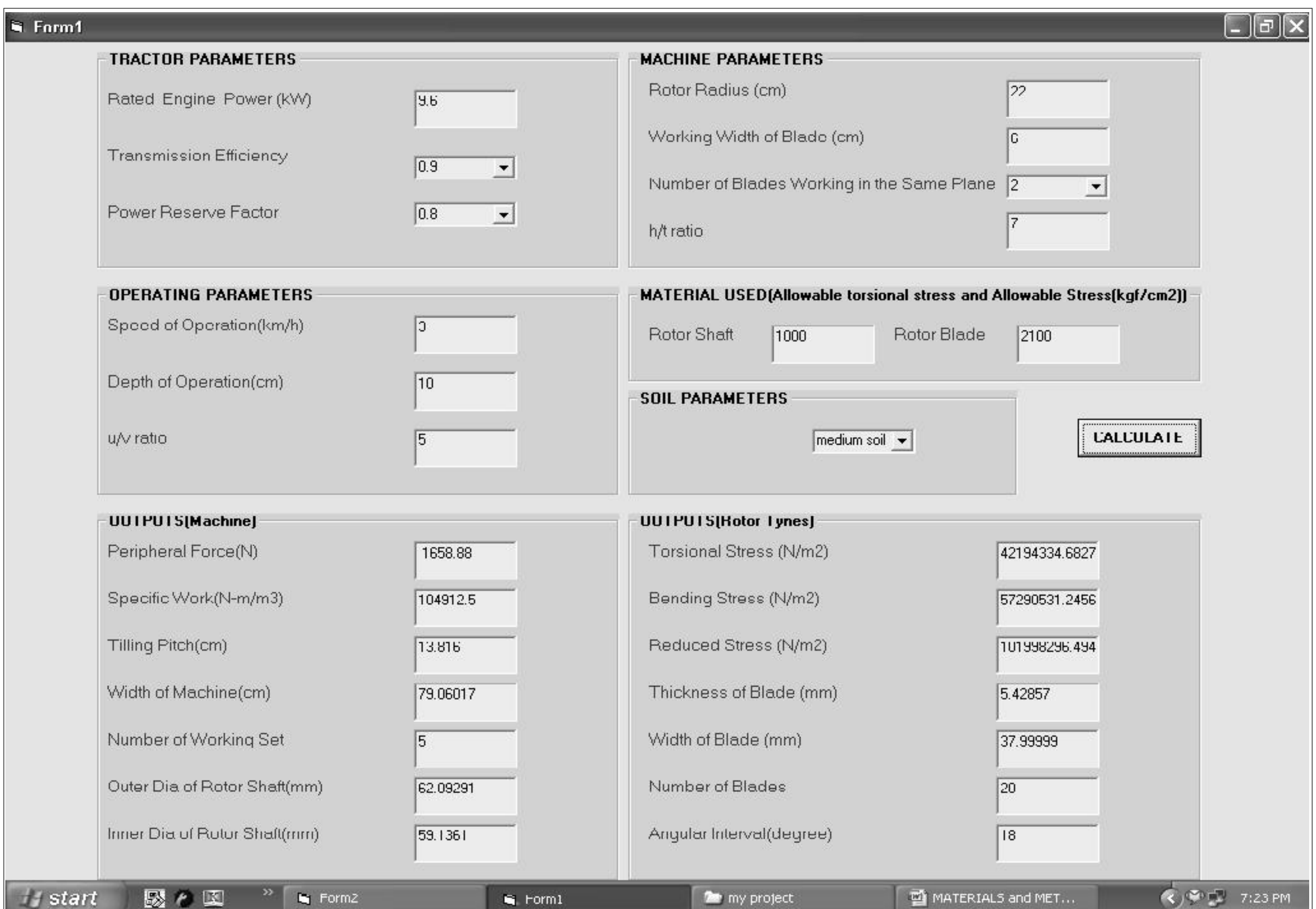

Fig. A : Input and output screen for rotavator design software

Table A : Comparison of predicted values and available rotavator dimensions

Parameters	Rotavator for 9.6 kW tractor at 3 km/h		Rotavator for 26.11 kW tractor at 4 km/h	
	Predicted values	Available values	Predicted values	Available values
Overall width, cm	103.8	105.0	132.0	129.0
Number of working set	5	5	4	4
Number of blades	20	20	24	24
Thickness of tines, cm	0.54	0.6	0.6	0.6
Width of blade shank, cm	3.8	6.0	12.0	12.5

Table B : Input and output parameters of the developed software

Sr. No.	Input parameters		Output parameters	
	Parameters	Values	Parameters	Values
1.	Power source	9.6 kW	Overall width of machine, mm	790
2.	Type of soil	Sandy loam soil (medium type of soil)	Total number of blades	20
3.	Material used for shaft	Mild steel	Outer diameter of the rotor shaft, mm	62.09
4.	Material used for blades	C50 steel	Inner diameter of the rotor shaft, mm	59.13
5.	u/v ratio	5	Thickness of blade, mm	5
6.	Forward speed of travel, km/h	3	Working width of C type blade, mm	60
7.	Number of blades working in the same plane	2	Width of shank, mm	38
8.	Rotor radius, mm	220	Angular interval between the blades, ^{0}	18

Development of rotavator:

A low hp tractor (IIT mini tractor) was used for further testing. Therefore, after validating the software for various dimensions of the IIT mini tractor, it was used for predicting the dimensions of rotavator for IIT mini tractor (9.6 kW) for a maximum forward speed of 3 km/h. The input parameters considered and the corresponding output parameters obtained from the developed software are as given in Table B.

RESULTS AND DISCUSSION

The results of the present study as well as relevant discussion have been summarized under following heads:

Performance evaluation of the developed rotavator:

Considering the dimensions obtained in Table B, the matching rotavator was fabricated in the workshop of Agricultural and food Engineering Department, IIT Kharagpur. Developed rotavator was evaluated in the Research Farm of the Department. The BIS test code (BIS 6316, 1996) was followed for evaluation of the rotavator. The soil type was sandy clay loam with average moisture content of 11.0 per cent (db). Three plots of harvested paddy field of size 25 x 10 m each were selected for its evaluation. Developed rotavator with IIT mini tractor during one of the filed trail is shown in Fig. 1.

Fig. 1 : Developed rotavator with IIT mini tractor during one of the filed trail

Field capacity, field efficiency, fuel consumption and fuel power:

Performance parameters of the rotavator are shown in Table 3. The average speed of operation was found to be 2.08 km/h with an average actual field capacity of 0.14 ha/hr. The field efficiency of the rotavator was found to be varying between 65 to 72 per cent. The total power requirement of the developed rotavator was computed in terms of fuel power. This was computed by measuring the fuel consumption and calorific value of fuel. The average values depth and width of operation along with fuel consumption and fuel power were varied from 7.9- 8.8 cm, 70 cm, 1.31-1.75 l/h and 47.16-63 MJ/h, respectively.

Table 1 : Performance parameters of the rotavator								
Plot No.	Row length (m)	Speed (km/h)	Actual field capacity (ha/h)	Field efficiency (%)	Average depth (cm)	Width (cm)	Fuel consumption (l/h)	Fuel power (MJ/h)
1	25	2.08	0.14	67.76	7.9	70	1.31	47.16
2	25	2.07	0.14	69.37	8.3	70	1.62	58.32
3	25	2.08	0.14	69.35	8.8	70	1.75	63.00

Mass mean diameter of soil aggregates:

The sieve analysis data are presented in Table 2. From this table, it can be seen that the MMD of soil aggregates was 21.59 mm before tilling and it reduced to 13.27 mm after tilling for one pass. This could be due to both cutting and pulverizing actions by the rotavator.

Table 2 : Sieve analysis of soil sample				
Sr. No.	Sieve size (mm)	Quantity retained (kg)	Percentage of soil retained (%)	Mass mean diameter (mm)
Before tilling				
1	10	1.56	39	
2	20	0.92	23	
3	30	0.48	12	
4	40	0.40	10	21.59
5	50	0.28	7	
6	>50	0.37	9	
After tilling				
1	10	2.32	68	
2	20	0.67	20	
3	30	0.23	7	
4	40	0.39	5	13.27
5	50	0	0	
6	>50	0	0	

$$\text{Degree of pulverization} = \frac{\text{MMD before tilling} - \text{MMD after tilling}}{\text{MMD before tilling}}$$

= (21.59 mm – 13.27 mm)/ 21.59 mm
= 0.38

Tillage performance index:

A composite parameter was developed to express the performance of the rotavator in terms of quantity (volume of soil handled by the implement during field operation) and quality (performance of rotavator which included degree of pulverization).

Volume soil handled by the implement = actual field capacity × depth of operation

Power requirement = fuel consumption x calorific value of fuel

Table 3 : Performance index of rotavator				
Plot No.	Quantity (volume of soil handled) m^3/h	Quality (degree of pulverization) decimal	Tillage performance index	Average
1	107.25	0.38	0.864 k	
2	111.87	0.38	0.729 k	0.796 k
3	131.87	0.38	0.795 k	

$$\text{T.P.I.} = \frac{\text{k x Quantity x Quality}}{\text{Power requirement}}$$

where, k = constant of proportionality

The overall performance of the developed rotavator during field was expressed in terms of tillage performance index (TPI). The computed values of the TPI for three plots are summarized in Table 3.

TPI of the developed rotavator was found to be 0.796 k. The value of 'k' will be one when the machine will be compared with another machine at the same soil and operating conditions.

Conclusion:

The rotavator developed for IIT tractor was having working width 700 mm, rotor diameter 440 mm, with 20 number of blades arranged at an angular interval of 18° over a shaft of diameter 62 mm and could be operated at either 180 or 230 rpm.

The average field capacity of the developed rotavator was found to be 0.14 ha/h at a forward speed of 2 km/h with average field efficiency of 68 per cent and fuel consumption of 1.56 l/h.TPI of the developed rotavator was found to be 0.796k. The value of k will be one when the machine will be compared with another machine for the same soil and operating conditions.

Authors' affiliations:
B.M. NANDEDE AND RANJEET KUMAR, Department of Agricultural and Food Engineering, Indian Institute of Technology (IIT), KHARAGPUR (W.B.) INDIA

■ REFERENCES

Anonymous (2012). Agricultural census data. Department of Agricultre, Government of India.

Butterworth, B. (1972). Rotary cultivators. *Power Farming*, **10**(1): 91-92.

Dalin, A.D. and Pavlov, P.V. (1950). Rotary soil working and excavating machines. *J. Agric. Engg. Res.*, **6**(1): 25-33.

Kulkarni, S.D. (2005). Food safety and security issues in India: Challenges and approach. Lead Paper for presentation in National Seminar on Post Production Systems and Strategies to the Issues and Challenges of Food Safety and Security during Sept. 22-23, 2005 at TNAU, Coimbatore – 641003

Yu, Matyashin (1968). Means of decreasing energy requirement of rotary tillers. *Tekhnika V. Sel skom Khozyaistve*, **5**: 81-82.

Raheman, H. and Sahu, R.K. (2006). Design of tractor operated rotary cultivator-a computer simulation. *Agric. Mechanization in Asia, Africa & Latin America*, **37**(3): 27-31.

Tsuchiya, M. and Honami, N. (1963). Studies on the power reduction of rotary type power tillers. *J. Agric. Machinery*, **24**(4): 207-214.

***