



Innovative Approach in Development of an Attachment with Rotavator for Minimizing Dust Accumulation

Dr. K. K. Jain, Professor (FMP), CAET, JAU, Junagadh, Gujarat, India (kkjain@jau.in)

Kamani B. H., Ex. B.Tech. student (brijeshkamani@ymail.com)

Kansagra P. R., Ex. B.Tech. student (pratikkansagra5@gmail.com)

ABSTRACT

Rotavator is a tillage machine designed for preparing land suitable for sowing seed (without overturning of the soil), for eradicating weeds, mixing manure or fertilizer into soil, to break up and remove pastures for crushing clods etc. rotavator is a better implement which does the operation like tillage, pulverizing and levelling of land at a time. Hence, the study was conducted to improvise the working of rotavator with particular reference to minimize dust accumulation near the operator including analysis of field efficiency of rotavator and effectiveness of the attachment. Developed novel attachment consisted of a metal sheet (MS-14 gauge) equal to the length of the rotavator bolted with a rubber belt suitably.

The effective field capacity and theoretical field capacity of rotavator was observed as 0.42 ha/h and 0.52 ha/h, respectively. Thus, field efficiency obtained was observed as 80.76 %. The measurement of dust was performed by an instrument Respirable Dust Sampler (RDS) using air flow rate and total suspended particulate matter in it. The effectiveness of the rotavator attachment for minimization of dust accumulation to operator was obtained about 76%. The attachment can easily be fabricated by a local manufacturer in affordable price. This also offers simplicity in fitting, adjustments etc. during working in the field.

KEY WORDS: Dust measurement, respirable dust sampler, tillage, rotavator,

INTRODUCTION

Rotavator is a tillage machine designed for preparing land suitable for sowing seed, for eradicating weeds, mixing manure or fertilizer into the soil, to breakup and renovates pasture, crushing clods etc. It offers an advantage of rapid seedbed preparation and reduces draft compare to conventional tillage. Here the engine power is transferred into work by means of PTO and not through the tractive device and therefore the transforming efficiency is higher (Shinde and Kajale, 2011).

Rotavator however is proved to be costly operation in terms of energy use. Rotavator required about 70 % of the power used in farm. Rotavator uses rotary action and its frictional resistance is high. It has disadvantages such as improper working in the hard soil (Pandey, 2002).

They are becoming popular in rice growing countries throughout the world for low land cultivation. Many makes of rotary tillers are available in India with various brand name viz. Rotavator, Krishivator, Zyrovator.

The earth's surface is covered by approximately 29% land area. Most of this surface area consists of soils, whose composition is changing over time. Various biological, chemical and physical factors determine the degree of weathering of the surface rocks and the organic matter content of the soils. Natural forces like wind, sun, and rain can have a big influence on the composition of the soils. If the soil surface is dry and not covered by vegetation, on-going wind can lead to the process of wind erosion, where small soil particles can become suspended in the air. Those particles can be re-deposited back to the soil surface very fast, but some may stay in the atmosphere for a long time and get transported far away from their source. The composition of these soil particles in the atmosphere is very complex. It is a mixture of organic and inorganic material and thus can contain a lot of mineral particles. Soil dust can affect human population by several ways of action. Dust particles get in or on the human body by inhalation, ingestion or touching. While some mineral dust is toxic by the mineral composition itself, other dust particles can carry toxic substances, which get in or on the human body together with the dust particles.

People who live or work close to one of the big dust source regions, agricultural operations zones, construction activity zones or mines are at higher risk of health effects of mineral dust. Mostly affected is therefore agriculture workers, construction workers and miners, but there is also a risk for the general population (WHO, 1999). So, it is very important to consider the adverse effects of dust on the farmers during agricultural operations especially while operating the Rotavator, as it increases the drudgery of farmer. So for reducing the dust accumulation around the operator, this study was undertaken with the following objectives-

OBJECTIVES

1. To develop the attachment for reducing dust accumulation in the working area with tractor operated Rotavator.
2. To test the effectiveness of developed attachment of Rotavator for the work.

MATERIALS & METHODS

The Rotavator used for test purpose was of "Shaktiman" brand and operated by "John Deere-5103" tractor. The specification of the Rotavator, Tractor and Respirable Dust Sampler (RDS) are given Table-1,2 & 3, respectively. The testing of Rotavator with attachment was carried out in two stages i.e. without attachment and with the developed attachment.

Type of soil

The field of wheat research centre was used for experiment the soil was medium black and covered partly with roots and trashes of last crop grown.

Operating speed

The speed of operation of tractor with Rotavator was measured with the help of stopwatch. The time taken by the tractor to travel the fixed distance of 30 m in the field operation was noted and based on this data the speed was determined using this formula :

$$\text{Operating Speed } \left(\frac{\text{m}}{\text{sec}} \right) = \frac{\text{Distance covered} \times 3.6}{\text{Total productive time}}$$

Theoretical field capacity

Theoretical field capacity means actual area covered based on actual width based on 100 % time consideration. The theoretical field capacity was measured by given formula:

$$\text{TFC} = \frac{W \times S}{10}$$

Where, TFC = Theoretical field capacity (ha/h)

W = Working width of implement (m)

S = Travel speed of tractor (kmph)

Effective field capacity

The actual output in terms of area covered per hour is expressed as the effective field capacity. In calculating the effective field capacity the time consumed for actual work and that lost for other activities such as turning, adjustment etc. should be taken. Time for refuelling be deleted because usually filling of before starting the test can make refuelling unnecessary except for specially large field. It can be calculated as:

$$\text{EFC} = \frac{A}{(T + t)}$$

Where, EFC = Effective field capacity (ha/h)

A = Area covered (ha)

T = Productive time (h)

t = Non-productive time (h)

Field efficiency

It is the ratio of effective field capacity to the theoretical field capacity expressed as percentage. This give an indication of time lost in the field and the failure to utilize the full working width of machine. It was calculated as follows:

$$\text{Field efficiency}(E_t) = \frac{\text{EFC}}{\text{TFC}} \times 100$$

Where, E_t = Field efficiency (%)

EFC = Effective field capacity (ha/h)

TFC = Theoretical field capacity (ha/h)

Fabrication of Attachment

A simple and innovative attachment was developed. A M.S. sheet of 14 gauge of (176 × 15) cm and rubber belt of (176 × 20) cm was used to develop and fabricate the attachment (Fig. 1) and

they both were attached to the Rotavator suitably as shown in Fig. 2 with the help of nut and bolts. The rubber belt was provided with vertical cuts at equi spacing for smooth and trouble free operation. This attachment can easily be fabricated by a local manufacturer in affordable price. This also offers simplicity in fitting, adjustments etc. during working in the field.

Details of materials / items involved in fabrication of a prototype of this innovative attachment including labour charges etc. is presented in Table- 6.

Dust Measurement

During the operation of Rotavator there is an accumulation of dust around the operator. The measurement of dust is performed by using Respirable Dust Sampler (RDS) (Fig. 3) brought from the Gujarat Pollution Control Board (GPCB), Junagadh. The procedure (as mentioned by the manufacturer) for measuring the dust accumulated by operation of Rotavator was measured as below:-

1. First of all the device “Respirable Dust Sampler” was installed and set up at the selected location (A-4 field, Wheat Research Station, Junagadh).
2. Then Rotavator “Shaktiman Semi-Champion “ (with and without developed attachment) was attached with the tractor (John Deere 5103).
3. The instrument used (RDS) for this requires 240 V, 1-Ø, 50 Hz AC supply, so a battery and inverter were also arranged on the farm.
4. After the installation set-up and calibration were completed, the experiment is performed. The operation of the tractor was started by keeping the Respirable Dust Sampler (RDS) at the center of the working area of the field.
5. The test was run in two phases: - i) Without Attachment, ii) With newly developed attachment (Fig. 4, 5 & 6).
6. In both the cases the test is run for 45 minutes and after each phase the readings were taken for dust trapped in filter paper, Flask and reading of water which indicates their flow rate, with the help of a precision weighing balance.

The dust collected during both the cases for rotavator field operation was presented in Table- 4&5.

Table- 1: Specification sheet for Rotavator

Sr. No.	Particulars	Specification
1	Make	Shaktiman
2	Model	Semi-Champion
3	Length of machine(cm)	78
4	Width of machine(cm)	140
5	Height of machine(cm)	114
6	Type of transmission system	Gear drive
7	Length of shaft(cm)	63

8	Dia. of shaft(cm)	11.5
9	No. of flange	6
10	Thickness of flange(cm)	1
11	Type of blade	L-shape
12	No. of blades on flange	3-6-6-6-6-3
13	Total no. of blades	30
14	Length of blade(cm)	26
15	Cutting width of blade(cm)	13
16	Cutting angle of blade(degree)	30°
17	Thickness of blade(mm)	0.5
18	Dia. of rotor	24
19	Type of linkage system	3-Point linkage
20	Weight of machine	498
21	Type of the gear system	Bevel pinion

Table-2: Specification sheet for tractor

Sr. No.	Particulars	Specification
1	Make	John Deere
2	Model	5103
3	Horse power	40 hp
4	Cylinder	3
5	Air filter	Dry type dual elements
6	Clutch	Single
7	Steering	Mechanical steering
8	Gear Box	8-Forward & 4-Reverse
9	Lifting capacity	1200 kgf
10	3 Point linkage	Category-II

11	PTO RPM	540 $\pm$ 10
12	Tyre size	6.0 $\times$ 16.8 PR (Front) 12.4 $\times$ 28.12 PR (Rear)
13	Fuel tank capacity	62 litres
14	Battery	88 Ah, 12 Volt
15	Alternator	40 A
16	Starter motor	12 V, 2.5 kW
17	Total weight	1790 kg
18	Wheel base	1950 mm
19	Overall length	3335 mm
20	Overall width	1650 mm
21	Ground clearance	430 mm
22	Turning radius with brakes	2840 mm
23	Price	510000/-

Table- 3: Specification sheet for Respirable Dust Sampler (RDS)

Sr.No.	Particular	Specification
1.	Flow Rate	0.9 – 1.4 m ³ /min free flow
2.	Particle Size	A cyclone is used for fractioning the dust into two fractions. D-50 for the cyclone is at 10 microns. PM10 dust is accumulated on the filter paper (8"×10" size) while coarse dust is collected in a cup placed under the cyclone.
3.	Recommended Filter	Whatman GF/A for common and Whatman's type No. EPM 2000 for special research
4.	Sampling Time	28 hours (Maximum)
5.	Sampling Time Record	0 to 9999.99 hours
6.	Automatic Sampling Control	24 hrs. A programmable digital timer is used to shut off the sampler after a pre-set sampling interval

7.	Power Requirements	Nominal, 220V, Single phase, 50-Hz AC mains supply
8.	Overall size	Approximately 430×320×930 mm
9.	Weight	42 kg

RESULTS & DISCUSSIONS

The observations recorded during the experiment with its analysis is presented as below-

Preliminary observations pertaining to soil and rotavator

i) Soil type-

The soil was medium black and covered partly with roots and trashes of last crop grown.

ii) Average soil moisture content- 7.92% (db)

iii) Average soil bulk density- 1.75 g/cc

iv) Average depth of cut by rotavator blades – 11 cm

v) Average width of cut by rotavator- 155 cm

Operating Speed

The Rotavator operation time was recorded for the fixed distance of 30 m. The average time consumed for 30 m distance obtained as 36 seconds. The average speed of operation of Rotavator was 3 kmph.

Theoretical Field Capacity (TFC)

The average value of the theoretical field capacity using Rotavator was found as 0.52 ha/h. The average speed of operation of Rotavator was observed 3 kmph.

Effective Field Capacity (EFC)

The average value of the effective field capacity using rotavator was found as 0.42 ha/h.

Field efficiency

The field efficiency was calculated from theoretical field capacity and effective field capacity and average of them was obtained. The average value of the field efficiency was found as 80.76 %.

Dust measurement and its analysis

The various observations pertaining to measurement of dust accumulation at the selected location during working with a rotavator in the field (with & without attachment) is presented in Table- 5 & 6.

Table- 4: Dust collection observations while working without attachment

Sr. No.	Particular	Initial Reading	Final Reading	Difference
1	Filter Paper	2.8 gm	3.02 gm	0.22 gm
2	Flask	12.5 gm	14.6 gm	2.2 gm
3	Water Reading	0.90 m ³ /min	0.20 m ³ /min	0.55 m ³ /h

$$\text{Average Air Flow} = \frac{0.9 + 0.2}{2} = 0.55 \text{ m}^3 / \text{min}$$

Total air flow = Average flow × Time of experiment

$$= 0.55 \times 45 = 24.75 \text{ m}^3 \text{ of air}$$

$$\text{RSPM} = \frac{\text{Final wt. of filter paper} - \text{Initial wt. of filter paper}}{\text{Volume of air}}$$

$$\text{RSPM} = \frac{(3.02 - 2.80) \times 10^6}{24.75} = 8888.88 \frac{\mu\text{g}}{\text{m}^3} = 8.88 \frac{\text{mg}}{\text{m}^3}$$

$$\text{NRSPM} = \frac{\text{Final wt. of flask} - \text{Initial wt. of flask}}{\text{Volume of air}}$$

$$\text{NRSPM} = \frac{(14.6 - 12.5) \times 10^6}{24.75} = 84848.4848 \frac{\mu\text{g}}{\text{m}^3} = 84.8484 \frac{\text{mg}}{\text{m}^3}$$

$$\text{Total SPM} = \text{RSPM} + \text{NRSPM} = 8.88 + 84.8484 = \mathbf{93.7284 \text{ mg/m}^3}$$

Table-5: Dust collection observations while working with developed attachment

Sr. No.	Particular	Initial Reading	Final Reading	Difference
1	Filter Paper	3.02 g	3.12 g	0.1 g
2	Flask	12.50 g	13.50 g	1.00 g
3	Water Reading	1.3 m ³ /min	0.90 m ³ /min	1.1 m ³ /min

$$\text{Average Air Flow} = \frac{1.3 + 0.9}{2} = 1.1 \text{ m}^3/\text{min}$$

Total air flow = Average flow × Time of experiment

$$= 1.1 \times 45$$

$$= 49.5 \text{ m}^3 \text{ of air}$$

$$\text{RSPM} = \frac{\text{Final wt. of filter paper} - \text{Initial wt. of filter paper}}{\text{Volume of air}}$$

$$\text{RSPM} = \frac{(3.12 - 3.02) \times 10^6}{49.5} = 2020.2020 \mu\text{g}/\text{m}^3 = 2.02 \text{ mg}/\text{m}^3$$

$$\text{NRSPM} = \frac{\text{Final wt. of flask} - \text{Initial wt. of flask}}{\text{Volume of air}}$$

$$\text{NRSPM} = \frac{(13.5 - 12.5) \times 10^6}{49.5} = 20202.020 \mu \frac{\text{g}}{\text{m}^3} = 20.202 \text{ mg}/\text{m}^3$$

$$\text{Total SPM} = 2.02 + 20.202 = \mathbf{22.222 \text{ mg}/\text{m}^3}$$

Effectiveness of attachment

$$= \frac{\text{Wt. of dust without attachment} - \text{Wt. of dust with attachment}}{\text{Wt. of dust without attachment}}$$

$$= \frac{93.7284 - 22.222}{93.7284} = \mathbf{76.29 \%}$$

Table- 6 Costing of prototype attachment with rotavator

The experimental findings revealed that during field operation of the rotavator, dust accumulation for the operator can be drastically reduced by about 76% simply by attaching the innovative attachment with the rotavator. It seems that the most of the dust formation was

Sr.No.	Particular	Dimensions	Nos.	Rate	Price (Rs/-)
1.	Clamp	10×10 cm	4	20	80/-
2.	Metal sheet (Mild Steel) 14gauge	176×15 cm	7.54 kg	Rs. 65/- per kg	490/-
3.	Flap (Rubber belt)	176×15 cm (about 1.90 m)	1	80 Rs. per 30 cm length	510/-
4.	Nut-bolts, spring washers etc.	-	As required	-	85/-
5.	Labour / fabrication charges etc.	(Taken as 10% of the material cost)			116/-
6.	TOTAL (Rs./-)	1281/- or Say 1300/-			

trapped by the developed attachment within the actual rotavator working enclosed space. The approximate costing of materials including labour & fabrication charges for attachment was also provided in Table- 7.

CONCLUSIONS

The experiment on field testing of rotavator with and without attachment was carried out at research plot of Wheat Research Station, Junagadh Agricultural University (JAU), Junagadh. From the study, the following conclusions were summarized:

- 1) The effective field capacity and theoretical field capacity was found as 0.46 ha/h and 0.52 ha/h, respectively. Thus, the field efficiency of the rotavator was found as 80.76%.
- 2) Total dust collected / accumulated for rotavator without attachment was found as 93.7284 mg/m³ and dust accumulation with the developed innovative attachment was found as 22.22 mg/m³. Thus, the effectiveness of the prototype attachment was found as 76.29%.
- 3) The approximate cost of the prototype attachment with rotavator was estimated as about Rs. 1300/- (2014) only.

Special remarks from authors

Considering the above research findings, it is strongly suggested that looking to the drastic reduction in dust collection / accumulation (about 76%) by incorporating a simple and low cost / economic and efficient attachment with the rotavator implement, drudgery associated with the operator with special reference to dust collection / accumulation can be minimized to a great extent. It is therefore advised to undertake more rigorous and intense efforts on this aspect. Few reviews were made available and searched are being reported.

Acknowledgement

The authors expressed their warm feelings and thanks towards Gujarat Pollution Control Board (GPCB), Junagadh office bearers for their willingness to provide the Respirable Dust Sampler instrument for dust measurement and its analysis.

REFERENCES

1. Shinde, G. U. and, Kajale S. R. (2011), Computer aided engineering analysis and design optimization of rotary tillage tool components, IJABE, 4(3).
2. Pandey, M. M. (Editor) (2002), Tractor mounted rotavator – A success story, AICRP on Farm Implements and Machinery, CIAE, Bhopal.
3. Manufacturer Catalogue, Respirable Dust Sampler, Envirotech Instruments Pvt. Ltd. , New Delhi.
4. WHO, 1999, Occupational health- Hazard prevention and control in the work environment: Airborne dust- http://www.who.int/occupational_health/publications/airdust/en/

Figures-



Fig. 1 Newlydeveloped attachment for rotavator



Fig. 2 Rotavator with attachment



Fig. 3: Respirable Dust Sampler (RDS)



Fig. 4: Rotavator field operation without attachment



Fig. 5 Rotavator field operation with newly developed attachment



Fig.6 Onfarm testing of newly developed attachment with instrumentation set up



Fig.7 Adjustments / fitting of attachment with rotavator