Journal of Advanced Engineering Research
ISSN: 2393-8447
Volume 11, Issue 2, 2024, pp.90-96

Recent Advances in Rotavator to Enhance its Performance

Partha Sarathi Singha[1, *], Avinash Kumar[1]

[1]Department of Agricultural Engineering, Assam University, Silchar, 788011, Assam

*Corresponding author email: parthasarathisingha123@gmail.com, Tel.: +91-8056019043

ABSTRACT

India constitutes 10 % of the world's tractor market share whereas in implements only 1 % market share of the world is held by India. Among implements, the rotavator is one of the highest-sold implements by volume. Hence advancement and improvement in the performance of rotavator operation are of importance via the advancement of technology. Currently, there have been such advancements and the products are available in the market to increase the performance of the rotavator. This study segregates the current advancement in rotavator technology into two sections namely mechanical advancements and instrumentation-based systems. Mechanical advancement technology includes multiple shaft rotavators that intend to reduce the operation time and achieve the pulverization level with a single pass. Another technology is the multi-rotor gear system, wherein the drive ratio is changed manually or through a shift lever to provide different rotavator blade RPM for different crop and soil conditions to attain desired performance. There has also been a lot of development in the design of blades which is covered in this study since rotavator blades pulverize the soil. Hence it is an important mechanical part that directly interacts with the soil. In an instrumentation-based system, a digital rotavator system has been studied indicating the optimal zone of operation with rental and serviceability parameters intended to improve pulverization, achieve high field capacity, and less fuel consumption. There has been a study to indicate the ratio of the peripheral speed of the rotavator and the forward speed of the tractor through instrumentation to improve the pulverization over the current practice.

This paper intends to present a study on the current rotavator products being developed which are presently in operation to have a whereabouts and comparison of the recent trend in the advancement of the technology, the way forward, and the amount of improvement from the earlier practices.

Keywords - Implements; Pulverization; Rotavator; Soil; Tractor

1. INTRODUCTION

Rotavator is an active tillage implement, which means that it takes power from the tractor's power take-off. The power from tractors enables its blade to cut the soil into slices which are important for sowing operation. Rotavator operation is categorized as secondary tillage implement since the basic function of the rotavator is to pulverize the soil and prepare the same for the sowing operation. Since rotavator reduces the fatigue of farmer for agricultural operation, hence rotavator plays a predominant role in farm mechanization. A noticeable rise in agricultural mechanization has been observed in recent years as farmers have become better able to understand the benefits of using machinery in agricultural productivity [1,2]. In the upcoming 10 years, the market for agricultural machinery is anticipated to expand at a cumulative annual growth rate (CAGR) of roughly 8–10%. The market's demand for rotavators is supported by the fact that its present yearly need is 1,20,000 units. However, the rotavator industry is now quite disorganized and heavily dominated by small and medium-sized businesses (SMEs) [3]. However, large-scale businesses have started spending a lot more money on research and development as a result of recent innovations and high-volume demand [1,2,3].

The need for innovation in the rotavator operation is to enhance its performance since in the current system the farmer doesn't have the correct knowledge about the optimal zone of operation in terms of revolution per minute (RPM) for different soil conditions. Another drudgery faced by farmers is that he/she doesn't have any idea about the hours of operation. The hours of operation of the rotavator play a predominant role since it is associated with capital. In India rental farming business is charged according to the hours of operation being done. The blades of the rotavator play an important role in cutting the soil and pulverizing it. Pulverization is basically breaking the bigger clods into finer clods of soil. The finer clods allow optimal reluctance for the plant to germinate and come out of the soil. Hence the level of pulverization is very important for any agricultural field preparation. The usage of the blade according to soil type is unknown to a farmer, hence the farmer has to sometimes compromise with the degree of pulverization and field capacity. There have recently been studies done to address the aforementioned issues facing farmers. To address the aforementioned issues, rotavator improvements with mechanical and instrumentation concepts have been used. These approaches have been discussed in this study [4,5].

In order to understand the current state of the technology, the direction it is headed in, and how much it has advanced over previous methods, this article will present a review of the current rotavator products being produced that are currently in use [6,7].

1.1 ROTAVATOR COMPONENTS

A rotavator or rotary tiller assembly consists of subsequent parts which are shown in Fig.1.

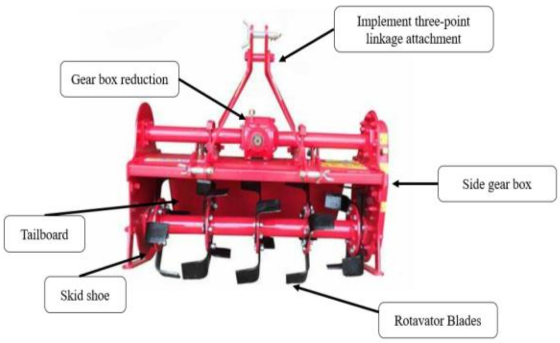

Fig.1: Components of Rotavator [8]

Since the rotavator is attached to the tractor, hence there are three hitch points in the rotavator, two lower links and one top link to be attached to the tractor known as the implement three-point linkage attachment. For power transmission to the rotavator blades from tractor PTO, the rotavator has gearbox reduction which converts the power flow into right angles, and via side reduction gears it reaches to the rotavator blades. The rotavator has a skid shoe for depth adjustment and a tailboard to level the field as well pulverize the same [8].

1.2 FACTORS AFFECTING THE PERFORMANCE OF THE ROTAVATOR

Since rotavators are attached to the tractor hence, the effect of tractor speed is also there in the performance of the rotavator. The trace of the rotavator blade is a trochoidal path that depends both on the tractor's forward speed and the rotational speed of the rotavator. Since this path plays an important role in Pulverization, hence pulverization also depends on both factors. The velocity ratio is defined as the ratio of peripheral velocity (u) to the forward velocity (v) of the tillage tool. It is the crucial factor affecting the performance of any tillage machinery involving active tillage tools in terms of both reductions in draft and tillage effectiveness [2,3,9,10]

2. INSTRUMENTATION-BASED ADVANCEMENTS

In this section applications based on instrumentation to enhance the performance of the rotavator have been discussed.

2.1 SENSOR-BASED ROTAVATOR UNIT

As shown in Fig. 2, this system primarily consists of three systems. The sensing rotavator unit, which is built inside the rotavator, comes first. The component parts of the rotavator unit were a cage, a controller, and a sensor. As depicted in Fig. 2, the rotavator unit was mounted on the side gear's input outer shaft. To shield the controller connected with the sensor system from the outside environment, a cage was created on the outer shaft. The battery management system, a Bluetooth module, and a Hall effect speed sensor make up the majority of the controller. The speed sensor detects this difference upon rotation of the input shaft of the side gear, which has grooves to produce a difference in permeability effect. The controller then processes the signal using a moving average algorithm, internally calculates the rotavator blade rpm by taking into account the side gear reduction ratio, and transmits it to the mobile app via Bluetooth module. Using an internal time clock, the Bluetooth module also transmits the total and current operating hours. The second operating system is a mobile app that notifies the user of the ideal operating zone via a green zone and flashes sound and vibration alerts when operating in any other zones. A change oil alert is one of the features of the mobile app, while a check oil alert is one that is sent after every 50 hours of operation. The mobile app needs to be configured with the rotavator's appropriate rotor gear. The user interface of the mobile app includes a charge indicator for the internal battery and is available in multiple languages. The third system is a bracket and a mobile holder for the tractor's mobile mounting configuration. The device was incorporated into the tractor's mirror scuttle assembly with consideration given to how easily mobile phones could be seen while in use [4].

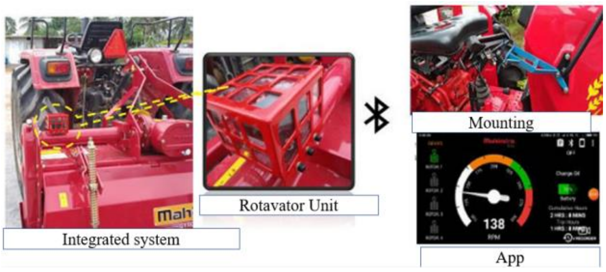

Fig.2: Working of sensor-based rotavator [4]

2.1.1 BENEFITS OF THE SYSTEM

In comparison to the current system's rotavator, it is asserted that the above-discussed system has superior field capacity, pulverization, and reduced fuel usage. The selection of the best rotavator blade RPM for the soil conditions, the display of the total number of trips made by the rotavator, and the indication of the system's serviceability are its important features.

2.2 DEVELOPMENT OF A VELOCITY RATIO INDICATION SYSTEM

In this system, the speed of the tractor was determined using a Hall effect speed sensor, and the speed of the excavator was determined using a smart box that included a speed sensor. When the forward wheel rotates and the rotavator unit sends a signal, the system starts sending a signal. The controller then determines the real forward speed as well as the surrounding speed. These speeds are sent to the controller, and the ratio between the tractor's real speed and its peripheral speed is used to calculate the kinematic parameter. According to various soil conditions entered by the user, the controller was fed a variety of kinematic parameters, including low, optimal, and high [5].

2.2.1 MOBILE APP

The kinematic parameter was displayed on the mobile app as an output signal from the ECU. After connecting via Bluetooth, the initial screen appears. In the initial screen of the mobile app as shown in Fig. 3 the soil type had to be selected namely hard, medium, or soft by the user and then the next screen appears. In the next screen as shown in Fig. 4 the peripheral and rotavator speed is displayed and the actual speed was also displayed. The kinematic parameter was displayed in three zones. Where the green zone indicated optimal, the yellow and red zones are non-optimal zones. The green zone values vary according to the soil condition derived experimentally where the mean clod diameter was minimal, or the pulverization was better [5].

Fig.3: Initial screen of mobile app [5]

Fig.4: Final screen of mobile app indicating velocity ratio [5]

2.2.2 BENEFITS/DEMERITS OF THE SYSTEM

This system also claims to have better pulverization, filed capacity, and less fuel consumption with respect to normal rotavators. Since it is indicating the farmer operates at the optimal kinetic ratio hence benefits from the same can be understood. But varying the kinematic parameter in the field is a trivial task since upon throttle both speed of the tractor and rotavator RPM increases. Hence it is a time-consuming process to set the optimal rotavator RPM.

2.3 ANALYSIS OF DEVELOPED INSTRUMENTATION-BASED ROTAVATORS

It was observed that both for sensor-based rotavator unit system and the velocity ratio indication system showed significant improvement over three parameters with respect to the current system rotavator operation namely pulverization, field capacity and fuel usage. The average clod diameter is used to gauge the degree of soil pulverization. The weight of soil retained on each sieve is calculated after a sample cube of soil with a side of 0.15 m is sent through a succession of sieves. There are sieves with variety of sizes, however, in this case, 10, 20, 30, 40, and 50 mm mesh sizes were used. Field capacity is the area covered by the rotavator per hour and fuel usage is the amount of fuel used in rotavator operation per hour.

Table 1 shows the results obtained by comparing the performance of the sensor-based rotavator unit system with the current rotavator system in red and black soil conditions.

Table 1: Comparison between sensor-based & current rotavator [4]

S. No	Parameter	Red soil		Black soil	
		Sensor based rotavator	Current system rotavator	Sensor based rotavator	Current system rotavator
1.	Field Capacity (Acre/hr)	0.92	0.75	0.81	0.71
2.	Pulverization (mm)	6.03	7.55	5.98	7.45
3.	Fuel usage (l/hr)	4.5	6	4	5.2

It is observed that the developed system has higher field capacity, lower mean clod diameter, and low fuel usage due to operation in the optimal zone. The findings revealed improvements in area coverage (Acre per hour) by 14.08 to 22.67% for red and black soil conditions, fuel consumption (liter per hour) by 7.78% to 11.17% for red and black soil conditions, fuel usage (liter per acre) by 25% to 23.08% for red and black soil conditions, and field quality by lowering the mean clod diameter by 20.13% for red soil condition and the 19.73% for black soil-condition [4].

Table 2 shows the results obtained by comparing the performance of the velocity ratio indication system with the current rotavator system in red and black soil conditions.

Table 2: Comparison between velocity ratio indication system & current rotavator [5]

S. No	Parameter	Hard soil		Medium soil		Soft soil	
		Velocity ratio indication rotavator	Current system rotavator	Velocity ratio indication rotavator	Current system rotavator	Velocity ratio indication rotavator	Current system rotavator
1.	Field Capacity (Acre/hr)	0.51	0.47	0.47	0.45	0.45	0.43
2.	Pulverization (mm)	5.6	6.6	5.8	6.7	5.8	6.8
3.	Fuel usage (l/hr)	4.2	4.5	4.0	4.2	3.8	4.0

It is observed from Table 2 that the developed system has higher field capacity, lower mean clod diameter, and low fuel usage due to operation in the optimal zone velocity ratio indication.

The actual field capacity of the developed system was 2.75 percent lower for hard soil conditions than the existing system. Similar reductions were seen for medium and soft soil, at 1.2% and 2.13%, respectively. Trends in fuel usage also indicated that the designed system performed better. Hard soil conditions saw a drop of 6.66%, medium soil conditions saw a loss of 5.9%, and soft soil conditions saw a reduction of 5%. The mean soil clod diameter determines the pulverization quality. For medium soil it was 13.43%, for soft soil it was 15.44%, and for forward soil the reduction percentage of mean clod diameter was 13.90%. Overall, it was found that the developed system outperformed the existing system for all three metrics [5].

3. MECHANICAL BASED ADVANCEMENTS

In this section applications based on mechanical attachments and modifications to enhance the performance of the rotavator have been discussed.

3.1 MULTI GEAR ROTAVATOR

To accommodate the soil variation and different speed requirements for rotavator blade operation, multiple gear concepts have been introduced to many rotavator brands. Herein, the gears are manually or using the lever shifted to desired rotor gear such that the required RPM of the rotavator blade can be achieved.

3.1.1 MULTI GEAR DRIVELINE

The multiple-gear driveline is shown in Fig. 5. Wherein power is taken as input from the tractor PTO. And is given to drive gear. Here two or even four more gears are put as spare such that they can be changed manually or used as a lever as per the required RPM for the rotavator blade for specific soil conditions. The side gear or even belt drives are used to transmit the power to rotavator blades. The arrangement of the drive and spare gear together is known as rotor gears [11,12,13,14].

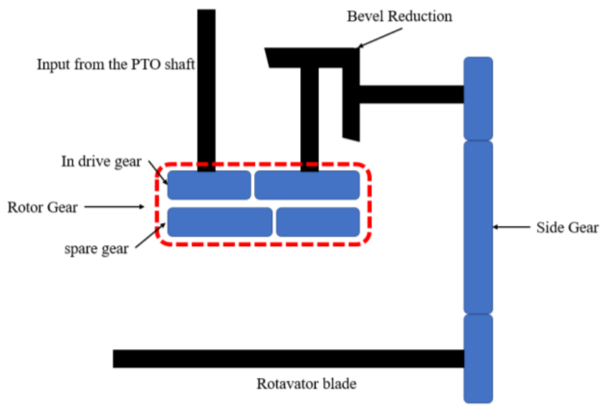

Fig.5: Multiple gear driveline

3.1.2 OPERATIONAL ZONE FOR DIFFERENT SOIL CONDITION

For different soil conditions, the optimal rotavator blade RPM is given in Table 3

Table 3: Operational rotavator blade RPM for different soil conditions: [4]

S.No	Type of soil	Rotavator blade RPM
1.	Hard	158 to 182
2.	Medium	176 to 204
3.	Soft	216 to 250

Maintaining the above RPM zones through rotor gear arrangement is possible. At this zone of operation, farmer can achieve better field capacity, pulverization and less fuel consumption [4,5].

3.2 DOUBLE SHAFT ROTAVATOR

When using a regular (single shaft) rotavator for farming, it has been discovered that the soil in the field needs to be effectively ground up over the course of two to three passes. double rotating shafts for pulverizing the soil in a single pass. It is a tractor-powered (minimum 40 hp) PTO rotavator that improves soil pulverization in a single pass by having both axles revolve in the same direction and at the same speed [15.16]. It may be found in sizes ranging from 7 feet to 12 feet, and to pulverize the dirt, various blade shapes such as L, J, and C kinds can be mounted to the rotor. The Northern Region Farm Machinery Training and Testing Institute tested it and determined that it met the following requirements. Working width: 203 -205 mm, Speed of operation (kmph): 3.63-3.91, field capacity: 0.629-0.734 ha/hr; field efficiency: 82.9-94.1%, Depth of cut: 6.0-6.3 mm, Fuel consumption: 5.90-6.29 l/hr . The picture of the rotavator is shown in Fig. 6.

(https://nif.org.in/innovation/double-axle-rotavator/1110)

Fig. 6: Double shaft Rotavator (https://nif.org.in/innovation/double-axle-rotavator/1110)

3.3 TYPES OF BLADES USED IN ROTAVATOR

There are generally three types of blades used in rotavator operation. They are as follows:

L-type blade: They are generally used in trashy lands and are more efficient in cutting weeds. They do not pulverize the soil as much.

C-type blade: They are suitable for deep tillage. It is generally used in orchard applications.

J-type blade: They are used as mulchers to conserve moisture.

In general, domestic market L and C-type blades are retrofitted on the rotavator, but as per customer need these can be changed but it is a drudgery and time-consuming process [16,17,18,19,20].

4. CONCLUSIONS

With the advancement of technology in rotavators both by mechanical modifications and instrumentation-based development it is possible to enhance the performance of rotavators. Instrument-based developed products for rotavators are generally indicative systems and they provide better field capacity, less fuel consumption, and better pulverization for different soil conditions. In the mechanical advancement of the rotavator, now provisions have been made to accommodate the variation of rotavator blade RPM for different soil conditions. To reduce time and drudgery double-shaft rotavators are also now available.

It is evident from studying the above technologies that factor affecting the performance of the rotavator are rotavator blade RPM and the forward speed of the tractor. Also, work has been done to reduce drudgery and time of operation.

5. SCOPE OF FUTURE WORK

Following future study in different field can be foreseen after going through these studies:

I. Automation: Automatic control of rotavator blade RPM can be done using a closed loop system. This will eliminate driver hindrance while in operation.

II. Electric drive: With emphasis on sustainable farming the power from the tractor can be eliminated and a separate electric motor can be used to drive the rotavator. Using controllers, control of speed is even easier.

III. Auto shifting of rotor gear: Rotor gear should be auto shifted instead of manual intervention.

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