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# DESIGN AND DEVELOPMENT OF PULVERIZING ATTACHMENT TO CULTIVATOR

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***Abstract:*** In tillage, active and passive tillage tools used in India faces problem like, poor soil-tire interface, clod formation, compaction due to heavy traffic and timeliness in operation. Hence, it was planned to fabricate a pulverizing attachment to cultivator and to study its performance. Major components of machine developed are frame, cultivator tines, pulverizing roller attachment, power transmission system and protecting cover. A frame is for holding different components. Cultivator tines were hold with help of adjustable clamps which are mounted on frame. Behind cultivator tine *PTO* operated pulverizing roller was attached which is operated at 225 $min^{-1}$. The average field efficiency, fuel consumption and cost of operation was 78.89%, 12.94 $l \cdot ha^{-1}$ and 2157.42 $Rs \cdot ha^{-1}$ respectively.

***Key words****: combination tillage tool, performance, active-passive tillage tool, design*

## INTRODUCTION

Tillage is the mechanical manipulation of the soil and plant residue to prepare a seedbed where seeds are planted to produce grain for our consumption. Also tillage breaks soil, enhances the release of soil nutrients for crop growth, destroys weeds and enhances the circulation of water and air within the soil [6]. Nearly all tillage tools utilize passive tillage elements in India. A draft force is applied to the tool, which causes the elements to move through the soil. The power required is developed by the tractor engine and is transmitted through the soil-tire interface and the tractor drawbar. Because of the poor efficiency of power transmission at the soil-tire interface, tillage energy

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efficiencies are low. Also, because tractors require considerable weight to provide necessary traction, soil compaction may occur and increased power is required to overcome the wheel slip and rolling resistance of the tractor tires. According to the previous researches, about 60% of total energy required for preparing the soil is used for tillage and preparing a good seedbed. In addition, the high cost of energy, makes the farmers to find alternative economic tillage methods [1].

There is way to bypass the inefficient soil-tire interface is through active powered tillage elements. These active elements are usually powered by the tractor *PTO* drive. Due to repeated use of primary, secondary and active tillage implements soil layers become compacted. Machines for tillage operation usually pass the farm four times or more which causes soil compaction, increases cost of labor and energy [2]. Tillage implements works on the basis of two working motion sliding type and rotating type. The implements like M.B. plough, cultivator cut the soil by sliding action. Disc plough, disc harrow, rotavator, clod crusher or roller cut and pulverize the soil by working in rotary action. Clod formation subsequent to ploughing or disking is a major problem in arid and semi-arid zones of India. Clods create obstruction to penetration of furrow openers of seed drill and do not allow intimate contact between seeds and soil. Pulverization of clods is necessary to avoid the above problems.

However, the combination of implements that enables the task to be completed in the shortest time with minimum operating cost and energy requirement is usually selected. Among these types of implements, sliding type implements consume more draft than rotating type implements due to soil frictional force and contact area of implement. While the rotary type of implements produce negative draft. That’s why the idea behind the combining these sliding and rotary type implements saves more power, time, cost very efficiently.

A few researchers have also conducted studies on development and performance evaluation of *2WD* tractor drawn active–passive combination tillage implements have also been conducted in India and confirmed the same results as obtained in western countries. The combination tillage tool mounted on a tractor does the primary and secondary tillage operations simultaneously in a single pass and added that combination tillage tool reduced bigger size clods in the soil and improves aeration and moisture holding capacity and medium uniformity of soil and finer pulverization modulus obtained by using combination tillage. And also added that maximum loosening of the soil was obtained by the combination tool as reflected by the low soil bulk density range of 1.15±0.05 $g \cdot cm^{-3}$ as against the normal 1.4±0.20 $g \cdot cm^{-3}$ encountered in the conventional implements operated field. Savings of 44 to 55 per cent in cost and 50 to 55% in time are possible by the use of combination tillage tool for seed bed preparation [4]. Using cultivator with spiked tooth roller the soil parameters measured in the range of 12 to14 mm, 1.21 to 1.36 g/cc and 0.568 to 1.5 $kg \cdot cm^{-2}$ in case of clod *MWD*, dry bulk density, and clod index of soil respectively [5].

## MATERIAL AND METHODS

*Conceptual design of pulverizing attachment to cultivator.* A pulverizing attachment to cultivator was designed and developed to combine primary and secondary tillage operations in single pass to ensure timeliness in seed bed preparation. The pulverizing attachment to cultivator consist of a frame with cultivator tines, pulverizing attachment having helical blade, power transmission system to provides power to pulverizing attachment, framework to mount roller and three-point linkage unit. The working principle behind the pulverizing attachment to cultivator which is having pulverizing roller as active unit behind implement and in front cultivator tines are attached as passive unit. Cultivator tines open furrow and in the rear PTO operated roller cut and pulverize the soil at optimum condition for tillage.

*Design considerations:* The components of pulverizing attachment to cultivator were designed and fabricated based on the parameters like functional requirements, engineering and general considerations. The assumptions made in the design of pulverizing attachment to cultivator are as follow [3]:

1. No draft was included for pulverizing attachment because it is rotating unit and has negative draft.
2. Speed of Power Take Off shaft was taken as 540±10 $min^{-1}$.
3. Average speed of operation of tractor in the field was kept as 3 $km \cdot h^{-1}$.
4. Maximum soil resistance was considered as 0.75 $kg \cdot cm^{-2}$.
5. A seven tine cultivator having spacing 20 cm and working depth 15 cm was considered.
6. Coefficient of friction in un-ploughed soil was taken 0.85.

*Assessment of draft and power requirement.* The draft requirement of the tractor operated pulverizing attachment to cultivator would be estimated using factors related to implement and the type of soil. The specific soil resistance of medium black soil of the area was considered as 0.75 $kg \cdot cm^{-2}$.

*Total working width of cultivator = No. of tine × tine spacing = 7 × 20 = 140cm = 1.4m*
*Cross section area of 7 furrows = 140 × 15 = 2100* $cm^2$
*Maximum draft = 2100 × 0.75 = 1575 kg*
*Speed of travel =* $3\ km \cdot h^{-1} = 3000\ m \cdot h^{-1} = 0.833\ m \cdot s^{-1}$

The power required for the designed draft was estimated using following formula.

$$P = \frac{D \times S}{1000} \tag{1}$$

where:
$P$ [kW] - power required,
$D$ [N] - maximum draft,
$S$ [$m \cdot s^{-1}$] - forward speed.

*P = (1575 × 9.8 × 0.833)/1000 = 12.857 kW = 17.24 HP*

*Horse power required to operate the implement in un-ploughed soil;*
*= (Total power required)/ (Coefficient of friction)* (2)
*= 17.24/0.85 = 20.28 HP*

Hence, this implement can easily be hitched and operated by most of the Indian makes tractors of 35 HP capacity.

*Design of functional components of pulverizing attachment to cultivator.* The detailed design of the functional components and different mechanisms were carried out. The machine consists of frame, cultivator tines, pulverizing roller and power transmission system. The design of (1) Helical blade of pulverizing roller (2) Bevel gear mechanism (3) Chain sprocket mechanism was taken up:

*1. Design of helical blade:* The pulverizing members which are helical blades were fabricated similarly to lawn mower blades and are inserted in disc at 900 with tangent in such a way that it forms helical shape and progressively come in contact with soil. Five numbers of helical blades were fabricated and designed as follows [3].

*Total area of helical blade striking on soil = Inclined length × thickness*

$= 135\ cm \times 0.5\ cm = 67.5\ cm^2$

*The maximum soil resistance* $= 67.5 cm^2 \times 0.75\ kg/cm^2 = 50.625\ kg$

*Maximum bending moment in the blade,*

$M_b$ *= Soil resistance × radial distance* $= 50.625\ kg \times 22.5\ cm = 1139.0625\ kg\text{-}cm$

Maximum bending stress for mild steel is 700 MPa. Calculating actual bending stress as per following formula [3].

$$\sigma_b = \left(\frac{M_b \times y}{I}\right) \quad (3)$$

$$700 = (1139.0625 \times 12 \times w \times 2) / (2 \times 0.5 \times w^3)$$

$$W = 6.395\ cm \approx 64\ mm$$

Hence design is safe. Selecting 75 mm width and 1350 mm length and 5 mm thick for helical blade.

*2. Bevel gear mechanism:* The power was transmitted to shaft through bevel gear mechanism. The size selection of bevel gear was carried out using standard formula.

$$\frac{N_1}{N_2} = \frac{T_2}{T_1} \quad (4)$$

where:

$N_1$ [min$^{-1}$] - No. of revolution of driving wheel (540),
$N_2$ [min$^{-1}$] - No. of revolution of driven wheel,
$T_1$ [-] - No. of teeth on driving sprocket (10),
$T_2$ [-] - No. of teeth on driven Sprocket (18).

Substituting the values as above the number of revolution of driven wheel comes out as:

$$N_2 = 540 \times 10/18 = 300\ min^{-1}$$

To get required number of min$^{-1}$ standard bevel gears of 10 and 18 teeth were used.

*3. Chain and sprocket mechanism:* The power was transmitted to shafts of pulverizing roller through chain and sprocket mechanism. The selection of size was carried out using standard formula. Dimension of the chain i.e. thickness, width and length of chain were 25, 38.1 and 3500 mm respectively.

$$\frac{N_1}{N_2} = \frac{T_2}{T_1} \quad (5)$$

$$N_2 = (300x15)/20 \text{ so, } N_2 = 225\ min^{-1}$$

Standard sprockets of 15 and 20 teeth were used.

*Fabrication of pulverizing attachment to cultivator.* Ease of assembling and dismantling for repairs and inspection were duly considered. Major components of machine developed are as follow:

- *Frame:* The frame is meant for holding different components of pulverizing attachment to cultivator. It is subjected to bending, tension, and vibrations. The frame was fabricated using double L section having size 65 mm × 65 mm × 6 mm for accommodating cultivator tines as well as power transmission system and cultivator tines. The three point hitch was fabricated using 75 mm × 5 mm flat as describe in Fig. 1.

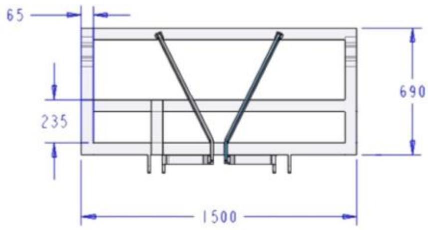
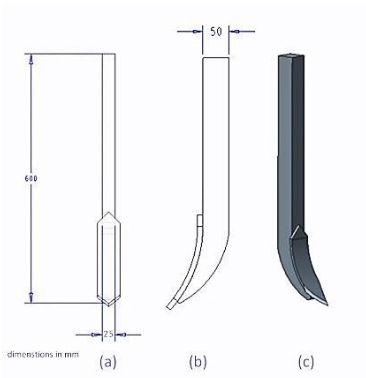
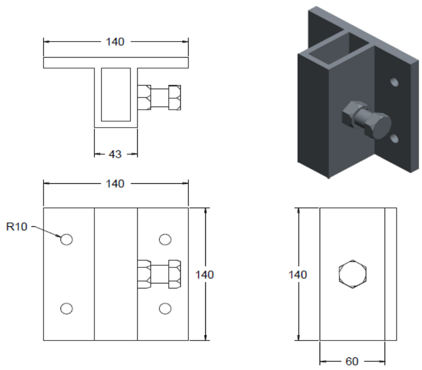



*Figure 1. Detailed drawing of frame (top view)*

- *Cultivator tines:* Cultivator is much popular implement used as primary as well as secondary tillage operation and it requires relatively less power per meter of width in these conditions. It is essential that this operation should be performed at the appropriate moisture content. Since the basic objective is to achieve good tilt, cultivation should be done when the soil is in the most workable conditions. Standard heavy duty reversible shovel type tines used with adjustable clamps so tines can be moved vertically and horizontally. Drawing of cultivator tine and adjustable clamps are in Figs. 2(A) and 2(B).




*a.* *b.*

*Figure 2. a. Detailed drawing of cultivator tine; (a) front view (b) side view (c) perspective view*
*b. Detailed drawing of adjustable clamp plate*

- *Pulverizing roller:* Pulverizing roller attachment to cultivator with helical blades pulverizes the soil to a greater degree. Tractor-drawn pulverizing roller attachment for cultivator was mounted at the back of the cultivator. The pulverizing roller consists of disc, central shaft, pulverizing members and mounting link. The pulverizing roller was designed for cutting, mixing, and clod breaking which ultimately pulverizes the soil by impact force. The cutting and clod breaking action of this unit provides excellent land preparation.

The incorporation is done by pulverizing blade welded over no. of discs which are mounted on the single horizontal shaft operated by *PTO* power. The pulverizing blade run in helix pattern from one disc to another in such a way that not more than one portion of a particular blade is in contact with ground at a time. Hence medium speed was usually selected as it is adequate for both the wet or dry soil conditions. Based on review collected, speed of the roller was selected as 225 $min^{-1}$. Design of pulverizing roller is shown in Fig. 3.

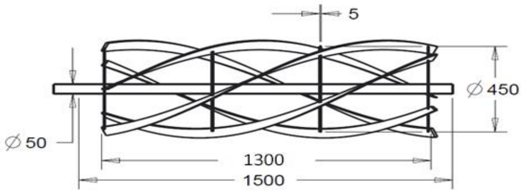



*Figure 3. Detailed front view drawing of pulverizing roller*

- *Power transmission system:* Power transmitted from *PTO* to Hub which is having 1: 1.8 bevel gear ratio. So that shaft-I transmits 540 $min^{-1}$ to shaft-II at 300 $min^{-1}$. Shaft-II is connected to chain and sprocket transmission system which transmits 225 $min^{-1}$ at 1:1.33 velocity ratios of sprockets. Following are design specifications of whole power transmission unit. As a general principle fine tilts are produced by a combination of slow tractor speeds, fast rotor speeds. Schematic diagram of power transmission is shown in Fig. 4.

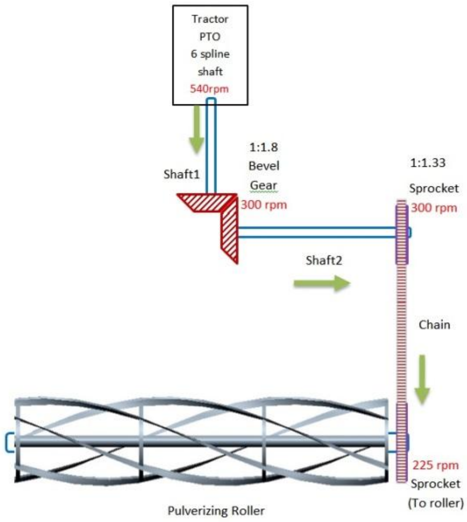



*Figure 4. Schematic diagram of power transmission system*

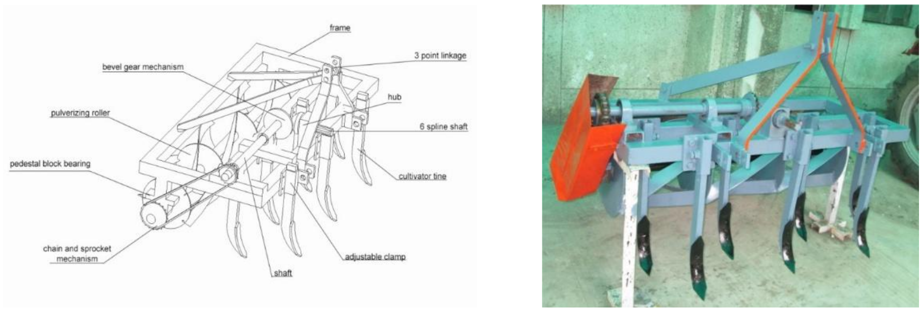
*Experimental procedure:* As such there was no standard test code for rotary implement testing i.e. rotavator and developed pulverizing attachment to cultivator which is having pulverizing roller, all laboratory and field tests were carried out indirectly as per the recommendation of the Regional Network for Agricultural Machinery (*RNAM*, 1983) and other related test code.

The instruments and equipment used for the field test were tractor, measuring tape, developed pulverizing attachment to cultivator, digital dynamometer, stop watch, etc.

Before conducting the actual field test, necessary settings and proper attachments were made and preliminary tests were conducted. Marking of the test field was done with white powder as per layout. Tractor drive wheel was marked with coloured tapes for easy counting of number of revolutions during slip measurement and tractor was operated in B1 gear setting for controlling forward speed between 2.4 to 3 km/h. The performance parameters depth of cut, fuel consumption, draft, field capacity and slip were determined. The other details of experimental fields are given in Tab. 1.

*Table 1. Details of experimental field*

| ***Parameters*** | ***Field*** |
|---|---|
| *Type of soil* | *Medium black* |
| *Previously grown crop* | *Sorghum* |
| *Moisture content [%]* | *12.57* |
| *Bulk density [g·cm$^{-3}$]* | *1.6* |
| *Cone Index [kPa]* | *738.74* |




*a.* *b.*

*Figure 5. a. Detailed drawing of pulverizing attachment to cultivator,*
*b. Developed pulverizing attachment to cultivator*

## RESULTS AND DISCUSSION

While designing and development of the tractor operated pulverizing attachment to cultivator, the basic emphasis was given on simplicity of fabrication, use of locally available material and minimum cost of fabrication. Anticipated view of developed pulverizing attachment to cultivator shown in Fig. 5(b) and its specifications with all units is shown in Tab. 2. Results obtained during the field performance of the developed pulverizing attachment to cultivator are shown below performance parameters like draft, wheel slip, fuel consumption and field efficiency are discussed.

*Table 2. Detailed specifications of pulverizing attachment to cultivator*

| *Sr.* | *Particulars* | *Specifications* |
|---|---|---|
| *1* | *Name of implement* | *Pulverizing attachment to cultivator* |
| *2* | *Type of hitch and its detail* | |
| | *Linkage* | *3 – Point* |

| | | |
|---|---|---|
| | *Power source* | *Tractor PTO ( John Deere - 5310)* |
| 3 | *Overall Dimensions* | |
| | *Length, mm* | *1500* |
| | *Width, mm* | *680* |
| | *Height, mm* | *1050* |
| | *Weight, kg* | *260* |
| 4 | *Frame* | |
| | *Material of fabrication* | *Mild Steel (L – channel size: 65 mm × 65 mm × 6 mm)*<br>*Three point hitch (75mm × 5mm)* |
| | *Length, mm* | *1500* |
| | *Width, mm* | *690* |
| | *Height, mm* | *850* |
| 5 | *Cultivator Tine* | |
| | *Material of fabrication* | *Mild Steel* |
| | *Nos. of tine* | *7 with reversible type shovel* |
| | *Height, mm* | *600* |
| | *Width, mm* | *25* |
| | *Thickness, mm* | *55* |
| | *Spacing between tines, mm* | *210* |
| 6 | *Pulverizing Roller* | |
| | *Material of fabrication* | *Mild Steel* |
| | *Length, mm* | *1300* |
| | *Nos. of dics* | *4* |
| | *Nos. of helical blade* | *5* |
| | *Dia. of disc, mm* | *450* |
| | *Method of fixing* | *Pedestal roller bearing (Nos. 2)* |
| | *Width of helical blade, mm* | *75* |
| | *Length of helical blade, mm* | *1350* |
| | *Thickness of helical blade, mm* | *5* |
| 7 | *Power transmitting shaft* | |
| | *Material of fabrication* | *Mild steel rod* |
| | *Length, mm* | *750* |
| | *Diameter, mm* | *60* |
| 8 | *Chain and sprocket mechanism* | |
| | *Type* | *Pintle chain* |
| | *Width, mm* | *25* |
| | *Length, mm* | *3500* |
| | *Thickness, mm* | *15* |
| | *Pitch, mm* | *30* |
| | *Velocity ratio* | *1 : 1.33* |
| 9 | *Bevel gear* | |
| | *Material of fabrication* | *Cast iron* |
| | *Velocity ratio* | *1:1.88* |
| 10 | *Pedestal block bearing* | |
| | *Material of fabrication* | *Casting with press fitted bearing* |
| | *Diameter, mm* | *(1) 40 (2) 50* |
| | *Length, mm* | *265* |
| | *Height, mm* | *152* |

Overall dimensions of developed pulverizing attachment to cultivator are 1500 mm length, 680 mm width and 1050 mm height. Developed pulverizing attachment was test in field and following performance parameters were obtained. Average depth of cut 16.92 cm for pulverizing attachment to cultivator was observed. Pulverizing attachment to cultivator worked at higher working depth of operation. The effect of wheel slip during operation of developed pulverizing attachment to cultivator was recorded The wheel slip was recorded 4.01% for pulverizing attachment to cultivator which is less due to active and passive units operate simultaneously. Draft was also determined and the value of draft 1423.86 N for pulverizing attachment to cultivator was recorded. Pulverizing attachment to cultivator having lower draft because the *PTO* operated pulverizing roller actually pushed tractor in direction of travel. Field efficiency was determined by standard procedure during tillage operation. The mean value of field efficiency was calculated 78.89% for pulverizing attachment to cultivator. Fuel consumption was determined by standard procedure. Quantity of fuel during the operation of pulverizing attachment to cultivator was recorded 12.94 $l\cdot ha^{-1}$.

## CONCLUSIONS

The developed pulverizing attachment to cultivator has worked satisfactorily in the field. The average field efficiency, fuel consumption and cost of operation was 78.89%, 12.94 $l\cdot ha^{-1}$ and 2157.42 $Rs\cdot ha^{-1}$ respectively. The developed pulverizing attachment to cultivator was found effective in the Saurastra region of Gujarat. The performance evaluation of pulverizing attachment to cultivator was satisfactory for working in the well prepared seed bed. A medium size of tractor can meet the draft. The reduced wheel slip and draft was found. The field efficiency was found satisfactory and fuel consumption was significantly reduced compared to other tillage implement.

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## KONSTRUKCIJA I RAZVOJ PRIKLJUČKA ZA USITNJAVANJE NA KULTIVATORU

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***Sažetak:*** Pri obradi zemljišta aktivnim i pasivnim oruđima u Indiji postoje problemi kao što su: slabo trenje podloge i pneumatika, formiranje grudvi, sabijanje zbog kretanja teških mašina i trajanja operacija. Zato je planirana izrada prikjučka za usitnjavanje na kultivatoru i ispitivanje njegovih performansi. Glavne komponente mašine su ram, kultivatorki prsti, valjak za usitnjavanje, sistem prenosa pogona i zaštitna hauba. Ram nosi sve delove. Prsti su pričvršćeni podesivim sponama na ramu. Iza prstiju je postavljen valjak za usitnjavanje sa pogonom od *PV*, koji rotira brzinom od 225 $min^{-1}$. Srednja efikasnost, potrošnja goriva i troškovi rada su iznosili: 78.89%, 12.94 $l \cdot ha^{-1}$ i 2157.42 $Rs \cdot ha^{-1}$, redom.

***Ključne reči****: oruđe za kombinovanu obradu, performanse, oruđe za aktivnu-pasivnu obradu, konstrukcija*

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