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Design of Small Tractor Operated *in-situ* Crop Residue Disintegrator

S. A. Patil, V. P. Khambalkar, A. S. Ghadge*, S. H. Thakare and D. S. Karale

Department of Farm Power and Machinery, Dr. PDKV Akola, India

**Corresponding author*

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A B S T R A C T

Crop residues contain large amount of essential elements which is most important for improve soil fertility. Therefore, it is most important operation to convert these residues in to trashes. Cotton is most important crop in vidarbha region therefor various components of this machine were designed according to agro technical parameters of cotton stalk. Crop residue disintegrator designed for small tractor ranges from 15 hp to 25 hp. The working width of the machine is considered according to row to row spacing of cotton. For better efficiency flail type "L" shape blades are used which rotates in opposite direction of travel. The designed power transmission system deliver the power with rotor RPM 1695 at which torque is found to be 5.83 kg-m.

Introduction

The crops residues have importance if get converted appropriately in the field. The cotton, sorghum, sugarcane and pulses are regularly sown crops in Maharashtra and produce million tons of crop waste per year. After the picking of cotton, the standing crop residue is thrown away from the field or collected by the villagers for domestic purpose. In many cases, this agro residue is burnt directly on farm by the farmers without intervention of conversion of waste in to organic material. The use of suitable machines and their availability to convert these crop residues in to small trashes at the field is very crucial task. The machine for this operation is rarely available in the state and country too.

Crop residue disintegrator converts the stalk into the small trash and spread on the soil surface which is advantageous that it protects soil from wind erosion, water erosion and improves the soil nutritive value.

Necessity

Crop residues contain large amount of essential elements which is most important to improve soil fertility which is presented in table 1.1.

Crop residue disintegrator converts the stalk into the small trash and spread on the soil surface which is advantageous that it protects soil from wind erosion, water erosion and improves the soil nutritive value. The maintenance of organic matter is most important source of nutrient for improve the soil properties which affect tillage operation, soil compaction, water infiltration and water holding capacity. Under rain-fed conditions, water losses take place through evaporation, which result in reduction in crop yield. Crop residue disintegrator may be a better option to cover soil surface of vegetative matter.

Scope

This investigation includes design and development of the crop residue disintegrator. There is vast scope for disposal of crop residue. The chopped up materials will decay faster rate. As such the soil is protected from rainfall erosion and water runoff; the soil aggregates, organic matter and fertility level naturally increase and soil compaction is reduced. Furthermore, less contamination of surface water occurs, water retention time and storage is enhanced, which allows recharging of aquifers.

Design considerations

Agro technical parameters

For development of crop residue disintegrator, physical characteristics of residues were taken into consideration like crop spacing, moisture content of crop, crop canopy, number of plants per meter and mechanical properties. In design and development procedure cotton crop has been considered due to its higher cutting strength and more area are under cultivation in Vidharbha region.

The row spacing 60-120 cm and hill to hill spacing 45-60 cm was considered. The theoretical data was collected from farmer's field of different locations of this region. The average moisture content of cotton crop after picking it was observed in the range 50%-20%. Mechanical properties like shearing energy, tensile strength and shear strength of cotton stalk was 0.074-0.086 J/mm^2, 23-41 N/mm^2 and 14-20 N/mm^2(Persson, 1987).

Effect of feed rate on power requirement for disintegrator

PTO Power requirement of the disintegrator was calculated by using the following formula reported by Srivastava (2006).

$$P = 10 + 4 \times mf$$

Where,
P =PTO Power required for disintegrator, kW
mf = feed rate, kg/s

Speed requirement for blades

The impact cutting principle was applied in this machine. The machine has "L" shape blades (inverted "T" type) rotating in vertical plane in opposite direction to the travel. Blades rotating speed required for cutting stalk was calculated as,

$$\text{RPM} = \left(\frac{V}{\pi D}\right)$$

Where,
V = Linear velocity (m/sec)
D=Diameter of cutting circle (m)

Design of power transmission system

Selection of belt and pulley

The power transmission system was designed to increase PTO shaft speed from 1000 rpm to 1700 rpm in two stage is given below.

PTO power of the tractor

Total power delivered to PTO can be calculated as, (Sharma and Mukesh, 2008).

$$= \text{tractor hp} \times \frac{75}{100};$$

Torque at 1000 rpm,

$$HP = \frac{2\pi N_1 \tau_1}{4500}$$

Where,
N_1 = Speed at PTO, rpm
τ_1 = Torque at PTO, kg-m

First stage of speed transmission

In first stage, power is transmitted from PTO to pulley assembly through gear box having bevel type gear which has 13 and 23 teeth on driving and driven gear respectively. Output of gear calculated as,

$$\text{Gear ratio} = \frac{\text{Teeth on driving}}{\text{Teeth on driven}}$$

Gear box output is calculated by using speed and teeth relation as following,

$$\frac{N_1}{N_2} = \frac{\text{teeth on driven gear}}{\text{teeth on driving gear}}$$

Where,
N_1 = Speed at input gear box, rpm
N_2= Speed at output of gear box, rpm
The torque at the output of gear box

$$HP = \frac{2\pi N_2 \tau_2}{4500}$$

Where,
N_2 = Speed at output of gear box, rpm
τ_2=torque at the output of gear box, Kg m

Second stage of speed transmission

In this stage, a belt and pulley system has been selected. Diameter of driver pulley is 30 cm with speed ratio 1: 3 was considered. The diameter of the driven pulley was calculated by using formula;

$$\text{speed ratio} = \frac{D_2}{D_1}$$

D_1= Diameter of driver pulley. cm
D_2 =Diameter of driven pulley, cm

Available corresponding pulley was selected.

$$\frac{\text{Speed of driven pulley (N3)}}{\text{speed of driver pulley (N2)}} = \frac{\text{diameter of driver pulley (D1)}}{\text{diameter of driven pulley (D2)}}$$

$$\frac{N_3}{N_2} = \frac{D_1}{D_2}$$

Torque at the rotor calculated as,

$$HP = \frac{2\pi N_3 \tau_3}{4500}$$

Where,
N_3 = Speed at Rotor shaft, rpm
τ_3= Torque at rotor shaft, kg-m

Length of the belt

The length of open belt was calculated by following formula given by (Khurmi,2005).

$$L = \frac{\pi}{2}(d1 + d2) + 2x + \frac{(d1 - d2)^2}{4X}$$

Where,
d_1 =Diameter of larger pulley, cm
d_2 =Diameter of smaller pulley, cm
x = Distance between the center of the two pulley, cm

Tension in the belt on pulley

The speed of the belt (v) …(Khurmi, 2005).

$$V = \frac{\pi d_1 N_1}{60} = \frac{\pi d_2 N_2}{60}$$

Where,
d_1 = Diameter of driving pulley
N_1 = Revolution at the driving pulley
d_2 = Diameter of driven pulley
N_2 = Revolution at the driven pulley
Power capacity of the belt,

$$P = (T_1 - T_2)\, V$$

Where,
P=Power transmitted, w
T_1 = Tension in the tight side of the belt, N
T_2= Tension in the slack side of the belt, N
Angle of contact at the smaller pulley,

$$\sin \alpha = \frac{r_1 - r_2}{x}$$

Where,
r_1= Radius of driving pulley, m
r_2 = Radius of driven pulley, m
x = Distance between the center of pulley, m

Angle of contact in radian (Θ),

$$\theta = 180° - 2\alpha$$

$$2.3 \log\left(\frac{T_1}{T_2}\right) = \mu\theta$$

Where,
μ = Coefficient of friction between the belt
T_1 = Tension in the tight side of the belt, N
T_2= Tension in the slack side of the belt, N

Design of rotor shaft

The torque transmitted by the shaft, (Khurmi, 2005).

$$\tau = (T_1 - T_2)\, R$$

Where,
τ = Torque transmitted by shaft, N-mm
R = Radius of driven pulley, mm
T_1 = Tension in the tight side of the belt, N
T_2= Tension in the slack side of the belt, N
Total vertical load acting on the pulley,
W = (T_1 + T_2 + Total weight of blades + Total weight of flange + Weight of shaft), N
Bending moment (M),

$$M = W \times L$$

Where,
M = Bending moment, N-mm
L = Length of shaft, mm

The equivalent twisting moment, N-mm

$$Te = \sqrt{M^2 + \tau^2}$$

Where,
Te = Equivalent twisting moment, N-mm
M = Bending moment, N-mm
τ= Torque transmitted by shaft, N-mm

$$Te = \frac{\pi}{16} \times \tau \times d^3$$

Where,
d = Diameter of shaft, m
τ = Allowable shear stress in shaft, Mpa
T_e= Equivalent twisting moment, N-mm

Blade parameters

The details blade parameters were used which is given below.

Type of blade	:	L-shaped
Number of cutting blades on each flange	:	6
Total number of blades	:	30
Material of cutting blades	:	High carbon steel
Width of blade	:	45 mm
Length of cutting blades	:	185 mm
Diameter of one flange	:	205 mm
Direction of blade rotation	:	Reverse rotation
Width of one flange	:	5 mm

Development of crop residue disintegrator

Main frame

The frame of the disintegrator hold entire component together for efficient functioning. The components holds are *i.e.* gear box, hitching unit, rotor shaft, blades etc. The main frame is made up of mild steel material. This frame consist of size of 50 X 50 mm hallow square section having length 710 mm and plate having 950 mm in length. This plate is attached to the covering hub by two side of the machine. Hitching system is fitted on this frame.

Hitch assembly

1.2 Dimension concerning tractor hitch point

SN	Description	Dimension (mm)
1.	Diameter of hitch pin	19°
2.	Width of ball, maximum	44
3.	Linch pin hole distance	76
4.	Diameter of hitch pin hole	22.4
5.	Width of ball	35
6.	Lateral distance from lower hitch point to centerline of tractor	359
7.	Lateral movement of lower hitch point, minimum	100
8.	Distance from end of power take-off to centre of lower hitch point, with the lower link horizontal	450 to 575

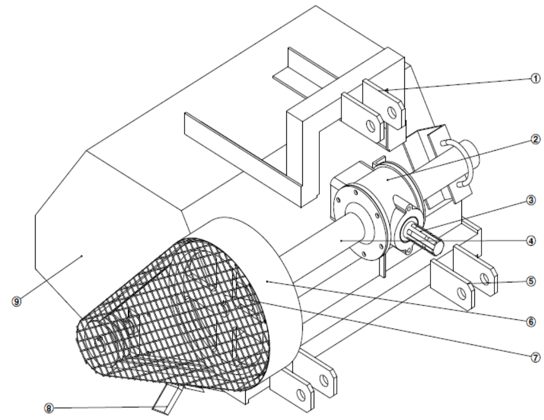

Fig.1 Isometric view of disintegrator

1. Top hitching, 2. Gear box 3. PTO shaft 4. Intermediate shaft 5. Lower hitch Point 6. Pulley cover 7. Pulley 8. Blades 9. Shield

Machine working in the field of cotton crop.

Summery and Conclusion of the study are as follows:

It is found that, feed rate and travel speed effect on the power requirement and it come to be 12-14 hp.

The optimum peripheral speed of blades is 1695 rpm.

The optimised blade length and thickness is 650 mm and 6 mm respectively.

The diameter of rotor shaft is 40 mm.

The effective length of open belt has been determined as 157.36 mm.

Sizes of pulley used in power transmission are 30 cm and 10 cm for driving and driven pulley respectively.

Table.1 Percentage of essential elements in residues of various field crops

Crop Residues	Elemental analysis, (%)										
	C	H	N	Na	K	P	Mg	Ca	SiO_2	O	S
Arhar Stalks	53.30	4.70	0.60	0.05	0.57	0.08	0.40	0.11	0.68	-	-
Cotton Sticks	51.00	4.90	1.00	0.09	0.61	0.08	0.43	0.12	1.33	43.87	0
Maize Cobs	46.20	4.90	0.60	0.03	0.54	0.07	0.28	0.09	2.00	-	-

(Dubey *et al*., 2015)

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