PERFORMANCE EVALUATION OF SHREDDER FOR AGRICULTURAL WASTES

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ABSTRACT

The newly developed shredder having 6 hp diesel engine was evaluated for its working performance for agricultural crop wastes shredding viz., castor, cotton and pigeonpea stalks in order to utilize them as organic matter as well as in industrial applications. At the critical speed of cutter head i.e. 500 rpm, more than 80 per cent cut stalks pieces were observed in the length group of 15- 30 mm and 30 - 45 mm with capacity for all three crop stalks. The fuel consumption was found as 1.15, 1.26 and 1.04 l/h with the shredding capacity of 162, 156 and 179 kg/h, respectively for castor, cotton and pigeonpea stalks. The average power consumption of the machine at critical speed was observed as 5.23 hp. The total cost of fabrication (including engine) was Rs. 41,000/-. It was also observed that, the required shredding operation period for one-ton stalks of castor, cotton and pigeonpea was 6.17, 6.41 and 5.59 hours, resulted in the respective shredding cost of Rs. 272/-, 282/- and 246/-, respectively.

KEY WORDS: Castor, cotton, , crop waster, pigeonpea, shredder, stalk

INTRODUCTION

Presently the large quantity of agricultural wastes is being unutilized annually because of handling, storage and management difficulties. It is realized that if waste is treated in such way that reduced its storage space as well as its utilization as a manure or industrial becomes more viable. The shredded waste can be utilized for industrial application such as for the production of hard boards, particle boards, corrugated boards and boxes, pulp and paper, microcrystalline cellulose, sugar and furfural for industrial chemical. It is also a useful source of lignin, as filler and in animal feeds. In order to utilize agricultural waste in industries as well as manure, by reducing the storage volume, a shredder was designed and developed to reduce the storage volume for easy handling of wastes. The machine was evaluated for its shredding performance for agricultural crop wastes like castor, cotton and pigeonpea stalks, in order to find out the cost benefit ratio of the machine.

MTERIALS AND METHODS

The concept of disc flywheel type chaff cutter was considered in the design for the capacity of 200 kg/h. A 6.0 HP, 1800 rpm, air-cooled diesel engine was selected as power source. The various assembly of machine was designed such as frame, concave,

cutting and feeding units, while the other components and parts were selected for power transmission for cutting and feeding mechanism.

Materials for testing

The stalks of castor, cotton and pigeonpea were considered as agricultural wastes in the study. The physical properties of selected waste were determined as shown in Table 1.

Functional components of unit

The main working components of the machine *viz*., cutting unit, feeding unit and power transmission system were designed and developed at the Department of Farm machinery and Power, College of Agricultural Engineering and Technology, Junagadh Agricultural university, Junagadh.

Cutting unit

The cutting unit consists of a disc-flywheel type cutter head having cutting blades, finer cutting blades, shear plate, shaft and concave.

(a)Flywheel and Shaft

The disc flywheel was fabricated from 14 mm thick MS plate. The outer diameter of disc flywheel was kept as 671.3 mm and inner diameter was the same as outer diameter of hub i.e. 88.9 mm. The length of hub was taken as 149 mm, so as to facilitate the fastening of bolts on both the sides of hub. The two pedestals with bearings were used to support MS shaft of 50.8 mm diameter (615 mm long).

(b)Cutting blades

Considering the strength required for stalk's cutting, three blades from leaf spring were constructed. The size of the blade was taken as 362 x 80 x 11 mm. One side of the blade was sharpened and the edge was made 30^{o} beveled for smooth cutting. The length of blade (362 mm) was kept more than the radius of disc flywheel by 80 mm in order to re-cut the long pieces and to prevent clogging. Three finer cutting blades fabricated from "charkha blade" (362 x 82.5 x 2.25 mm) were provided for further cutting of long pieces.

(c)Concave

The concave was fabricated from 18 gauge (1.22 mm) GI sheet and MS angle of 25 x 25 x3 mm. The concave grate was made from MS square (9 mm) and round (ϕ 6 mm) bars in such a way that the slot size was maintained as 25 x 45 mm. The shield was fabricated from 20 gauge (0.91 mm) GI sheet and bolted to the main frame. The shear plate (300 x 80 x 11 mm) was made from cutting blade material with square corners, so that they can be turned to use all the four corners before being sharpened or discarded.

Feeding unit

The feeding unit consists of a feeding trough and feed rollers. The objective of feeding trough is to provide the passage to feed the material to be cut. While the functions of feed rollers are to catch, compress and convey the material towards the cutter head.

(a) Feeding trough

The feeding trough was fabricated from 20 gauge (0.91 mm) GI sheet. The trough was completely horizontal for easy feeding and easy entry of long stalks.

(b)Feed rollers

The two rollers (upper and lower) were fabricated from GI pipe having diameter of 88.9 mm. In both the rollers 8 bars of MS square of 12 x 12 mm were welded axially on the periphery. In case of lower feed roller about 60 spikes (ϕ 12 x 30 mm) were welded in between square bar throughout the periphery. The upper feed roller was kept hanging by providing compression spring at both the ends, which helped to compress the

material to be cut at the time of feeding. The MS channel of 75 x 40 x 5 mm and MS angle of 50 x 50 x 5 mm were used to fabricate the main frame for the machine and engine platform.

Power transmission system

The power transmission system consisted of speed reduction unit, V-belts, chains and sprockets. The engine speed of 1800 rpm was reduced to 500 rpm with speed reduction ratio as 3.6.The necessary speed reduction was made to obtain the designed speed of feed roller. The location of speed reduction unit was as per the recommended optimum center distance by Krutz *et al*. (1984) for chain and V-belt drive (Plate 1).

Performance evaluation

The machine was evaluated for its working performance. The stalks of castor, cotton and pigeon pea were used for determining its capacity, fuel consumption and length of cut at different speeds of cutter head. The bulk density of crop stalks before and after shredding was determined in order to find out the reduction of storage volume due to shredding.

Cost of machine

The total cost of machine was Rs. 41000/- including the material cost, engine cost and fabrication cost. The cost of operation was found to be Rs. 44 per hour.

RESULT AND DISCUSSIONS

The testing of machine was conducted at the time of testing moisture content and bulk density of stalks of selected crops like castor, cotton and pigeonpea were measured on sample basis. The output of machine, fuel consumption and length of cut at varying cutter head speeds of 200, 350, 500 and 600 rpm for selected wastes have been recorded in Table 3.

The curves as shown in Figure 1 and 2 were also plotted to find out the relationship between fuel consumption and capacities of the machine with the speed of cutter head. The capacity of machine increased with an increase in the cutter head speed from 200 to 500 rpm, after that a negligible change in the capacity was found. The length of cut pieces was measured on the sample basis. The cut pieces were categorized in five groups depending on their length of cut viz. 0-15, 15-30, 30-45, 45-60 and 60-75 mm. The percentage of cut pieces increased gradually in the length group of 15-30 and 30-45 mm by increasing the cutter head speed from 200 to 500 rpm.

The speed of cutter head at which the machine capacity with higher percentage of finer cut pieces was considered as critical speed of the cutter head as shown in Table 2. The cutter head speed of 500 rpm more than 80 % cut pieces of stalks were observed in the length group of 15-30 and 30-45 mm in case of all crop stalks. The fuel consumption was found as 1.15, 1.26 and 1.04 l/h, respectively with capacity of 162, 156 and 179 kg/h, respectively in case of castor, cotton and pigeon pea stalks. The volume reduction was calculated from initial stalk volume and final cut stalk pieces volume. As seen from Figure 3, due to shredding the original volume of the stalks could be reduced to 0.23, 0.17 and 0.21 m^3 respectively from 1 m^3 stalk of castor, cotton and pigeon pea crops. After determining the capacity of the machine at critical speed for each crop stalks, the operation period and cost of shredding for one ton of material were also worked out. Considering the shredded material cost as @ Rs. 800 to 1000 per ton, and the average cost of raw material as about Rs. 100 per ton, the average shredding cost was determined as Rs. 266 per ton. The machine was found economical and feasible to the

farmer with the benefit-cost ratio of 2.44.

CONCLUSION

Based on the evaluation of the machine, the cutter head speed of 500 rpm, more than 80 per cent cut pieces of stalks were observed in the length group of 15-30 and 30-45 mm in case of all selected crop stalks. At critical cutter head speed the fuel consumption was found as 1.15, 1.26 and 1.04 l/h and capacity as 162, 156 and 179 kg/h, respectively in case of castor, cotton and pigeon pea stalks. The average power consumption of the machine at critical speed of cutter head was observed as 5.23 hp. Due to shredding the original volume of the stalks could be reduced to 0.23, 0.17 and 0.21 cu m respectively in case of 1 cu m stalks of castor, cotton and pigeon pea crops. The required operation period for one ton stalks of castor, cotton and pigeon pea crops was 6.17, 6.41 and 5.59 hours, respectively. The required cost of shredding for one-ton stalks of castor, cotton and pigeon pea was Rs. 272/-, 282/- and 246/- , respectively.

REFERENCES

Krutz, G.; Thomson, L. and Claar, P. (1984). Design of Agricultural Machinery. John Wiley & Sons, New Delhi.

Table 1: Physical properties of the selected agricultural wastes

Sr. No.	Crop Waste	Moisture Content of Stalks (%)	Diameter of Root/ Stem (Avg.) (mm)	Top Width of Stalks (Avg.) (mm)	Length of Stalks (Avg.) (mm)	Bulk Density of Stalks (kg/m^3)	Density of Shredded Stalks (kg/ m^3)
1.	Castor	9.65	27.50	220	145	25.05	109.7
2.	Cotton	11.05	22.25	300	130	19.90	119.6
3.	Pigeonpea	10.95	25.25	200	175	22.15	104.5
Average		10.55	25.00	240	150	22.37	111.3

Table 2: Length of cut stalks pieces of castor, cotton and pigeon pea at the cutter head speed of 500 rpm (i.e. 17.58 m/s)

Sr. No.	Crop Waste	Moisture Content of Stalks (%)	Sample Weight of Cut Stalk Pieces (g)	Cut Stalk Pieces		
				Length (mm)	Number	Per Cent
1	Castor	9.65	90.5	0 – 15	10	6.21
				15 – 30	68	42.24
				30 – 45	64	39.75
				45 – 60	18	11.18
				60 - 75	1	0.62
2	Cotton	11.05	70.0	0 – 15	3	2.83
				15 – 30	53	50.00
				30 – 45	41	38.68
				45 – 60	9	8.49
				60 - 75	---	---
3	Pigeonpea	10.95	84.5	0 – 15	5	4.07
				15 – 30	57	46.34
				30 – 45	44	35.77
				45 – 60	15	12.20
				60 - 75	2	1.63

Table 3: Test performance results of shredder

Sr. No.	Crop Waste	Moisture Content of Stalks (%)	Speed		Fuel Consumption (l/h)	Length of Cut Pieces (mm)	Capacity (kg/h)
			Cutter Head rpm (mps)	Feed Roller rpm (mps)			
A-1	Castor	9.65	200 (7.03)	27 (0.16)	0.310	---	58.5
A-2	Cotton	11.05	200 (7.03)	27 (0.16)	0.400	---	56.5
A-3	Pigeonpea	10.95	200 (7.03)	27 (0.16)	0.280	---	67.0
				Average	0.330	10 - 70	60.7
B-1	Castor	9.65	350 (12.30)	50 (0.30)	0.700	---	109.5
B-2	Cotton	11.05	350 (12.30)	50 (0.30)	0.880	---	105.5
B-3	Pigeonpea	10.95	350 (12.30)	50 (0.30)	0.630	---	126.5
				Average	0.737	10 - 65	113.8
C-1	Castor	9.65	500 (17.58)	69 (0.41)	1.150	---	162.0
C-2	Cotton	11.05	500 (17.58)	69 (0.41)	1.260	---	156.0
C-3	Pigeonpea	10.95	500 (17.58)	69 (0.41)	1.040	---	178.5
				Average	1.150	10 – 60	165.5
D-1	Castor	9.65	600 (21.09)	82 (0.49)	1.210	---	168.0
D-2	Cotton	11.05	600 (21.09)	82 (0.49)	1.290	---	162.5
D-3	Pigeonpea	10.95	600 (21.09)	82 (0.49)	1.135	---	180.0
				Average	1.212	10 - 60	170.2

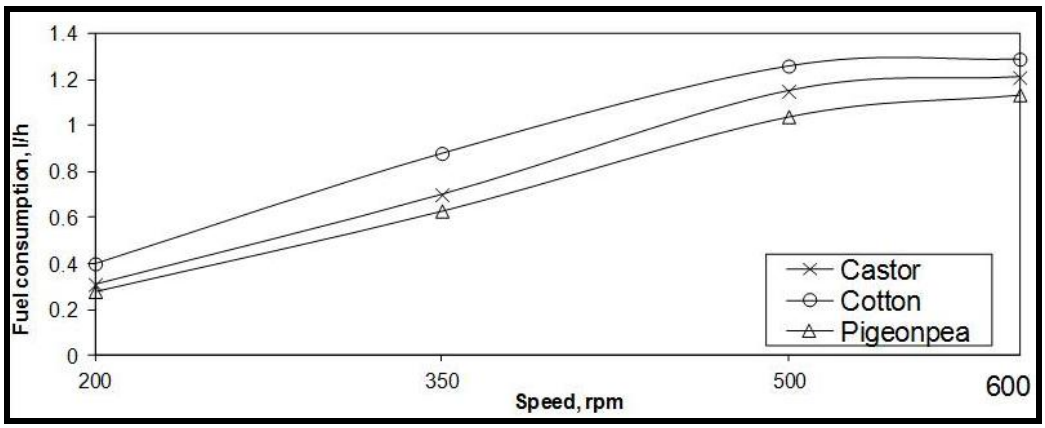

Figure 1: Relationship between speed and fuel consumption

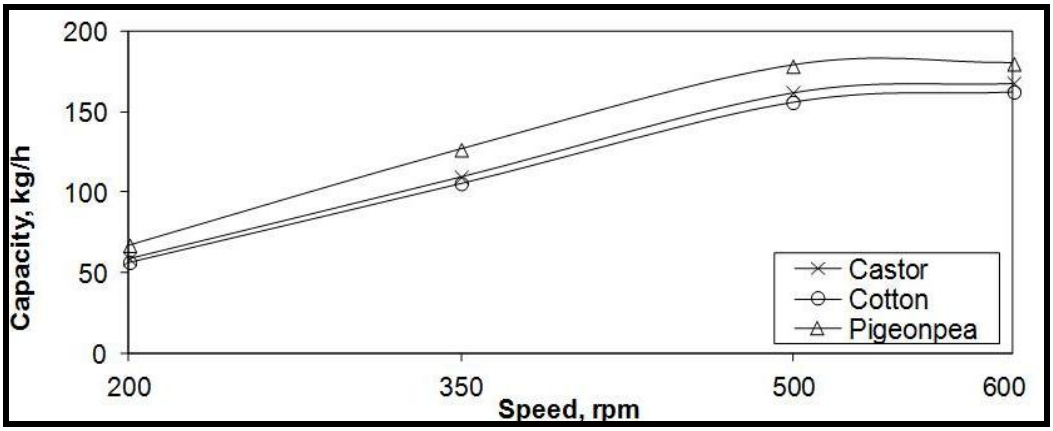

Figure 2: Relationship between speed and capacity

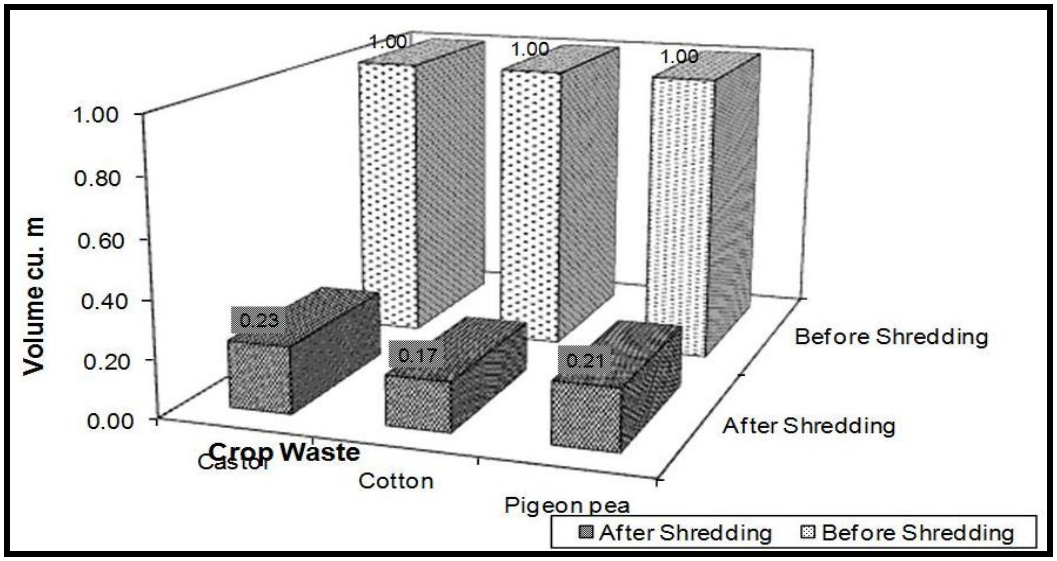

Figure 3: Volume reduction due to shredding

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