Development and Performance Evaluation of A Crop Residue Mobile Disintegrator

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Abstract- This paper focuses on the design and development of an attachment for a farm tractor to effectively shred the plant residues into small pieces. The attachment has been specifically designed to disintegrate the cotton stalk, available in agricultural fields the form of biomass waste after harvesting cotton, with minimal power. The disintegrated biomass can be gainfully used for manufacturing particle boards and similar products instead of just using the stalk as domestic fuel. Different considerations in the development of the compact machine system have been discussed so as to be able to cut the stalk, shred it and then blow it into a container for transportation purposes. Simulated results and field trials show that this low cost farmer friendly compact attachment performs efficiently while ensuring that the operating cost is low. It is shown that this device is compatibly deictic to solve the problems of small farmers while increasing the farm productivity and improving the standard of living of the farmers. *[7]*

Keywords: disintegrator, crop residue, cotton stalk

I. Introduction

Agricultural farming is characteristic of huge scrap and waste material. On completion of harvesting activities, the biomass is invariably left in the fields to decay naturally or disposed of by burning away. The waste generated out of agricultural processes is a matter of great concern to farmers who view it as a necessary evil especially when the waste material has no medicinal value. A small part of the biomass is, however, used as domestic fuel and cattle feed. In general, there is little awareness with most farmers of the fact that the agricultural waste can be put to productive use and products of significance can be manufactured by converting the waste through appropriate manufacturing processes. The biomass, viewed not as waste but a byproduct, can pave way for vulnerable sections of the society being given an advantage whereby they can lead a better and financially more secured life.[2]

A cursory study reveals that the cotton crop in Vidarbha region in India alone produces about 2.5 to 6.0 ton of waste per hectare while for sorghum and pulses, the two other common crops, this may range between 0.5 to 1.0 ton per hectare. [5]Weeds too grow in sizable quantities in varied conditions in the field with cultivated crops as well as in uncultivated areas throughout the year. On the national scene, the quantity of biomass so generated is certainly very large. This underlines the undisputed need for effective end use this form of agricultural waste. It can also be readily realized that the huge quantity of biomass in the form of stalk, if systematically collected and processed, can be gainfully deployed for manufacture of particle boards. It is seen that products made out of the shredded waste is far superior to the particle boards made from timber in terms of material properties and is cheaper too.

Normally, farmers pay a little attention to collection of the widely scattered and strewn stem fragments in the field owing to high cost of labor as also that of transporting the loosely packed stalk to the place of shredding or consumption. A viable alternative that appears workable is to use a mechanized device that cuts the stalk and disintegrates it a low cost. A piece of equipment capable of efficiently cutting the stalk, in other words shaving closely to the land, and simultaneously shredding it into small pieces, is considered a possible solution to the problem of agricultural waste management even for an average farmer. The fuel powered single operation type machines presently available have not received wider acceptance owing to high initial costs and poor overall utility and efficiency. More appropriate system is the one which can be an add-on to an existing power source that is readily available in the field e.g. a tractor. Another matter of great convenience would be that the shredded chips can be packed into containers or cloth bags in the field itself. This would facilitate transporting the crushed stalk in ready to use form to bio-product manufacturers or point of application. This system can very conveniently be used also for preparing fodder feed for livestock. Ready availability of a low cost and operationally efficient machine in the field would reduce several post harvest hassles concerning agro waste.

Fig. 1. O conventional Method

II. MACHINE CONSTRUCTION

A. *Cutting Unit*:

This unit is designed to grasp and cut the cotton stack close to the ground using rotating blades.

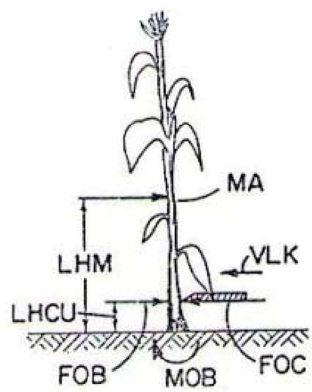

Fig. 2. Forces on plant stem in impact cut

B. *Crusher:*

This is the most important operative part of the machine. The cotton stack picked up by the cutting unit is subjected to crushing by cutters mounted on the periphery of the cutter. This yields shredded biomass which is a mix of powder, chips and wood pieces of different lengths. The crop residue is chipped by swinging beaters rotating at high speed and impacting the material on the fixed knife blades. As a result, crop residues fracture and disintegrate in to small pieces

C. *Blower:*

The blower is placed next to the crusher. This unit is used to throw the residue fragments into the collection bag. Smooth cutting action at the cutting unit is basic to power requirement of the attachment. Important considerations at this stage include the selection of the right cutting blade geometry, including the rake angle, and the cutting velocity. Since the blower speed governs the physical displacement of the biomass, its selection becomes another critical factor in designing the system. Also important is the synchronization of crushing and blower unit. Design of different machine components is based on the force analysis and operating conditions considered appropriate for the quality of the cotton stalk. This is evaluated in terms of the stalk diameter, moisture content and so on.[6]

Power required to drive this machines was determined considering the needs of cutting, shredding and blowing operations and various losses. This was estimated to be 45HP. Since most of the tractor units used by the farmers for assorted agricultural applications had a power rating greater that 45 HP, commonly available tractor unit was considered most appropriate source of power for operating the proposed attachment. A gear box was developed to transmit power from PTO of tractor unit operating at 540 rpm to main cutter shaft selected to run at 2160 rpm in horizontal position. This operating speed is selected for effective cutting of the stalk as per guidelines on selection of

the cutting speed [4]. The cutting velocity, in this case the peripheral speed of the horizontal cutter, is required to be in between 51-76 m/s for so as to keep the cutting force, and hence the power requirement, to a minimum.[5] The stalk gets cut during the tangential swinging motion of the blade as the cutter rotates. See Fig. 1.1. Cutting blade which utilizes inertia cut has no counter shear for providing support for the material to be cut. The necessary reaction force is instead provided by the inertia of the plant and by the anchoring of the plant in the ground. The cutting process is initiated when the edge of the blade intercepts the stalk and is continued using the rotational motion of the knife. The cutting action is thus started from point and progresses over the entire width of the stem.
Each blade is provided with rake and clearance angles for efficient and free cutting action. A total of 36 numbers of specially designed cutting blades have been mounted on the rotating cutter in a staggered manner along 4 helical supports such that plant does not get missed out for cutting.

After cutting and picking the stalk, the material enters the second phase called the crushing unit. In this unit the hexagonal cutter plates are fitted on main shaft. The rpm of main shaft is selected to be in the range 1100 to 1400 rpm. This range is considered optimum as it provides maximum torque required to convert the cutting residue into powder as well as in the form of chips and fragments. The cutting velocity in this unit lies between 25-61 m/s. The cutter diameter selected was 225mm. The guiding cutters are fitted in a hexagonally shaped casing to match the grooves in the guide for proper cutting and guiding of blades. A perforated screen of sheet metal is added to the casing. Since material cutting and conveying rate increases directly in proportion with the cutting speed, selection of cutter size and passages was important. This was achieved by suitably selecting the dimensions and was governed by the consideration of maximum material conveying capacity in minimum time. Other considerations include reduction in the overall size of the machine, proper balancing and reduced vibrations.

The shredded material is then transferred by a blower to the collection bag attached to the trolley at a height for 1 to 1.2 m. Power requirement and blower size are determined by these factors. For proper handling of material and faster rate of material convening, the velocity is generally in the range 25 to 48 m/s.[10]. The required velocity and material flow rate was achieved using a 10 ton capacity blower. Fig. shows the CAD model of the attachment.[16]

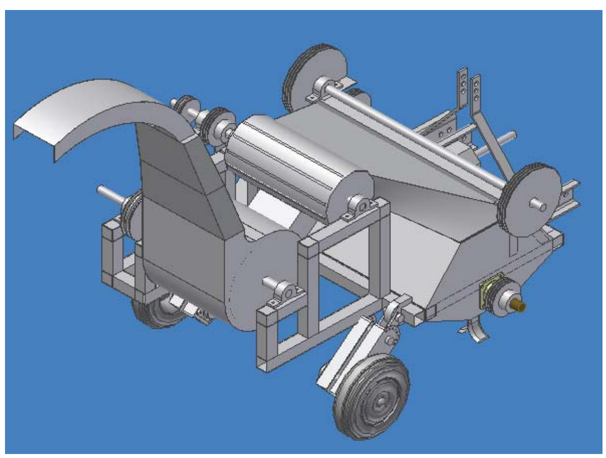

Fig. 3. CAD model of the attachment

On the basis of such considerations, the algorithm uses a different color image multiplied by the weighting coefficients of different ways to solve the visual distortion, and by embedding the watermark, wavelet coefficients of many ways, enhance the robustness of the watermark.

III. FIELD TESTING

The attachment is shown mounted on a tractor in Fig. Field testing of the attachment shows that the stalk is shavedof closely to the ground. Testing was undertaken on different varieties of cotton on plots of standard size so as to determine cutting efficiency. Tests were performed on PKV-HI5, PKV-8, PKV-Rajat and PKV-Suvarna varieties of cotton which are favoured by the farmers for harvesting. The row spacing between plants was as per prescribed cultivation norms for these varieties. The principal parameter studied was the moisture content of the stalk and its influence on cutting efficiency

Table 1. Observations during field trials

Parameters	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7
Theoretical field capacity	0.3939	0.1833	0.1705	0.2209	0.1765	0.1188	0.174
Effective field capacity, ha/h	0.3383	0.1562	0.1445	0.1725	0.1461	0.09514	0.145
Time required for one , ha	2.95	6.4	6.92	5.79	6.84	10.51	6.73
Field efficiency, %	85.88	84.66	84.75	78.80	82.77	80.70	85.29
Av. cutting efficiency, %	94.33	95	97.5	92.85	96.2	93.75	94.30
Av. collection efficiency, %	61.28	62.89	62.59	63.39	60.28	64.63	61.75
Fuel consumption	2.21	2.86	2.50	2.35	2.90	2.68	2.40
l/h	3.74	2.08	1.95	2.31	2.12	2.17	1.88
l/ha	11.03	13.32	13.28	13.37	14.50	22.80	12.65
Cost of harvesting, Rs/h	243.1	135.2	126.75	150	137.8	141.05	122.2
Cost of harvesting, Rs/ha	716.95	865.8	863.2	869.05	942.5	1482	822.25

From table 1 it is observed that the cutting efficiency for the PK- Rajat variety is 97.5% and 93.5% for PKV-Suvarna. The average cutting efficiency of the machine is 94.84%. The behavior and effect of moisture content on the cotton stalk on various field was evaluated.

As seen from Fig. 5 below it is observed that the field efficiency is around 85.88% with 15.28% moisture content while at 32.87 % it reduces to 78.8%. It is observed that the moisture content in the cotton stalk plays a very important role. It was observed that choking in the blowing of stalk increases as moisture content increases. It affects collection efficiency adversely.[12]

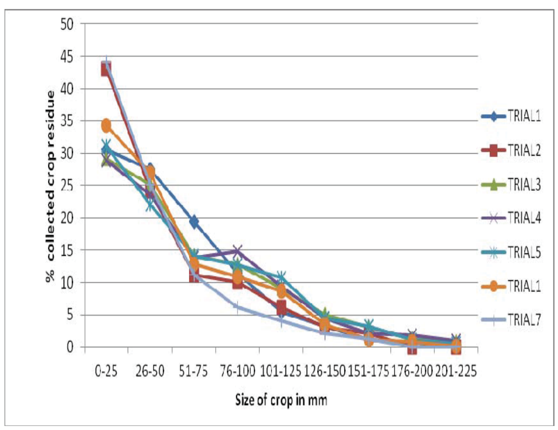

Fig. 4. Distribution of chips collected during test trials

From Table 1, one observes that when the moisture content is more than 15 % a large proportion of the material gets collected in the bag is in the form of small chips ranging between 15 to 50mm. When the moisture content exceeds 30 %, that is the cotton stalk is not completely dry, the variation is between 125mm to 225mm. Collection is thus easier.

IV. PFT TESTING

Prototype field tests were conducted on various fields to evaluate the following parameters. The definitions and procedure used are discussed below.

A. DETERMINATION OF MOISTURE CONTENT

The moisture content in the soil of tuber crop is important for determining the time of harvesting. The tuber crop at the depth of 20 cm in soil was dug out and sample pieces were kept in an oven at 105^0C for 24 h.

B. WIDTH OF OPERATION

Actual width of operation of implement while harvesting was measured at various places in each test plot. Finally average width was calculated for each test plot.

Fig. 5 Field testing with the attachment mounted on tractor

C. SPEED OF OPERATION

Speed of operation was calculated to determine the other performance characteristics like field capacity and field efficiency. During field trial of tuber crop harvester, speed of operation was measured by recording the time required to cover 20 m distance by using stop watch

D. EFFECTIVE FIELD CAPACITY

For calculating effective field capacity, the time taken for actual work and that lost for other activities such as turning, cleaning and adjustment of machine and time spend for machine trouble were taken into consideration.

E. THEORETICAL FIELD CAPACITY

It is the rate of field coverage of the tuber crop harvester, based on 100 per cent of the time at the rated speed and covering 100 per cent of its rated width. It depends upon speed and theoretical width of implement.

F. FIELD EFFICIENCY

Field efficiency is the ratio of the effective field capacity and theoretical field capacity and expressed in percentage**.**

G. FUEL CONSUMPTION

To measure the fuel consumption, first a tuber crop harvester was kept on leveled surface. The fuel tank was filled up to top of the tank before the test started. After the completion of the harvesting operation tractor was parked at the same leveled location again and then tank refilled to original level. Quantity of fuel filled in the tank was measured using a measuring cylinder. The quantity of fuel required to make up the original level was taken as actual fuel consumption.

V. RESULTS

At the time of development of the attachment, the focus was we its utility to cut and disintegrate a particular variety of cotton. [3]It is observed that most of the cotton stalk chips are in the range 25mm to 75mm which makes it is easy to collect and transport the same for product manufacturing to a plant for further processing. It was noted that the cost of manufacturing and operating this tractor attachment are far less than any other conventional machine used for this kind of residue processing.

Tests show that the angle of 105 for cutting blade is most suitable and provides for good chopping. Further, the moisture content should lie between 32 to 36 % for best results. The sample of chopped fragments yielded normal distribution and accounted for a high percentage for 25 to 75 mm length chips..

VI. CONCLUSIONS

From the testing it is conclude that the small tractor attachment presented in this paper is a very convenient and low cost device for farmers to disintegrate the bio-waste generated in cotton harvesting. It can be effectively used on any tractor that has 15 HP capacities and does away the need of using a heavy duty machines traditionally used for this purpose. The attachment is very compact and can handle huge amount of biomass besides advantages in the form of reduced transportation cost and increased capacity per ton.

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