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Development of Powered Disk Type Sugar Cane Stubble Saver

Pengembangan Pengepras Tebu Tipe Piringan Berputar

Radite P.A.S¹ dan I Nengah Suastawa²

Abstract

The objective of this research was to design, fabricate and test a prototype of sugar cane stubble saver based on powered disk mechanism. In this research, a heavy duty disk plow or disk harrow was used as a rotating knife to cut the sugarcane stubble. The parabolic disk was chosen because it is proven reliable as soil working tools and it is available in the market as spare part of disk plow or disk harrow unit. The prototype was mounted on the four wheel tractor's three point hitch, and powered by PTO of the tractor. Two kinds of disks were used in these experiments, those were disk with regular edge or plain disk and disk with scalloped edge or scalloped disk. Both disks had diameter of 28 inch. Results of field test showed that powered disk mechanism could satisfy cut sugar cane's stubble. However, scalloped disk type gave smoother stubble cuts compared to that of plain disk. Plain disk type gave broken stubble cut. Higher rotation (1000 rpm) resulted better cuts as compared to lower rotation (500 rpm) both either on plain disk and scalloped disk. The developed prototype could work below the soil surface at depth of 5 to 10 cm. With tilt angle setting 20° and disk angle 45° the width of cut was about 25 cm.

Keywords: sugar cane, stubble shaver, powered disk

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Introduction

The success of stubble shaving is an important field work which determines the success of sugar cane ratoon cultivation. In Indonesia, most of sugar cane plantation does stubble shaving operation manually by farm labor using hoe. Manual stubble shaving operation is inhumane and it is difficult to maintain the quality of work. To finish single hectare of operation farm labor has to walk of about 7.6 km while hoeing on the right side and left side of

sugarcane stubble row. According to an experienced worker, good quality of stubble shaving operation should have "V" like shape. However, manual stubble shaving has shape of "reverse V" or a mountain like shape as shown in Figure 1. As results, sugar cane plants have shallow root developments and thus make it easy to fall when it is grown.

Manual stubble shaving operation had low quality of work, field capacity, relatively costly. In Jatiroto sugar cane plantation at Lumajang, manual stubble shaving needed 20 mandays per hectare. In 2005,



Figure 1. Field condition of sugar cane after harvest (left), and after manually done stubble shaving operation (right)

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labour wages at that region was twenty thousand rupiah per day, or totally cost four hundred thousand rupiahs per hectare.

There was a mechanical stubble shaver named "rota-slasher" which has principle operation like grass mower. This mechanism is proved effective in grass cutting but not successful when it was applied for cutting stubble of sugarcane up to 10 cm depth from soil surface. This equipment had been introduced in several sugarcane plantations in Indonesia, but had not quite successful because of blunted knife problem so cause damage of the sugar cane stubble. Some of the equipments were idle because of they were already worn out.

This research is aimed to develop a sugarcane stubble saver based on powered disk mechanism. In this research, a heavy duty disk plow or disk harrow was used as a rotating knife to cut the sugarcane stubble. The parabolic disk is used as a rotating knife because it is reliable and it is available in the market (in Indonesia) as spare part of disk plow or disk harrow unit.

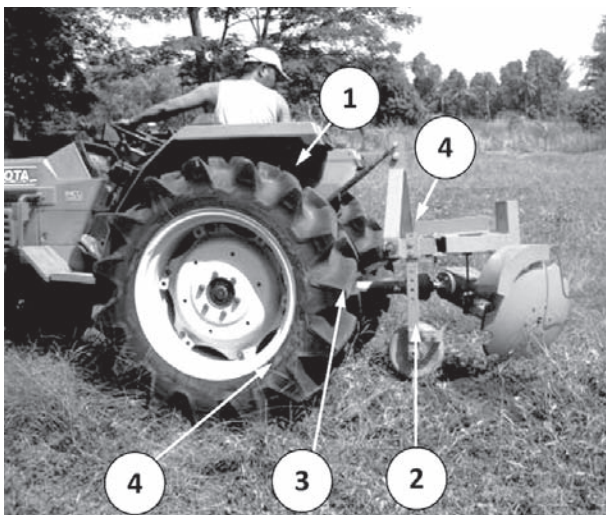


Figure 2. Prototype of PINTAR sugar cane stubble shaver

Rotary cutting mechanism using disk was already been tested in preliminary experiment on sugarcane stem cutting in soil bin (Lisyanto, 2007). The effectiveness of disk in cutting of soil has already proven in the field in plowing and harrowing operation up to 15 - 20 cm depth. Therefore, it should be relatively strong or should be less trouble if it is used in sugarcane stubble shaving operation which only cut the soil up to 10 cm dept of soil.

Materials And Methods

Conceptual Design

The developed sugar cane stubble saver used disk type knife which was rotated by PTO tractor. The depth of cutting was adjusted through tilt angle or vertical angle of the disk. While the widht of cutting was adjusted trough disk angle or horisontal angle of the disk. Therefore the shaft of the disk had vertical and horisontal mis-alignment to the shat of the PTO tractor.

There are many choices of construction to acommodate this shaft mis-alignment problem. In previous research (Lisyanto 2007) the shaft of the disk was driven from back side (behind the disk) using chain and sprocket, and power by electric motor. Since in this prototipe PTO tractor was used as the rotational power, then universal joint and "Tee" type gear box was used to overcome the mis-alignment between the disk's shaft and PTO's shaft because it was simple. Differed with previous design, in this prototipe the disk's shaft was driven from "front side" so that space did not make limitation on design because there was enough space in front of the disk.

Prototipe Development and Testing

Prototipe developement was conducted at Laboratory of Farm Machinery, Departement of Agricultural Engineering, Bogor Agricultural University (IPB). Field tests were conducted at

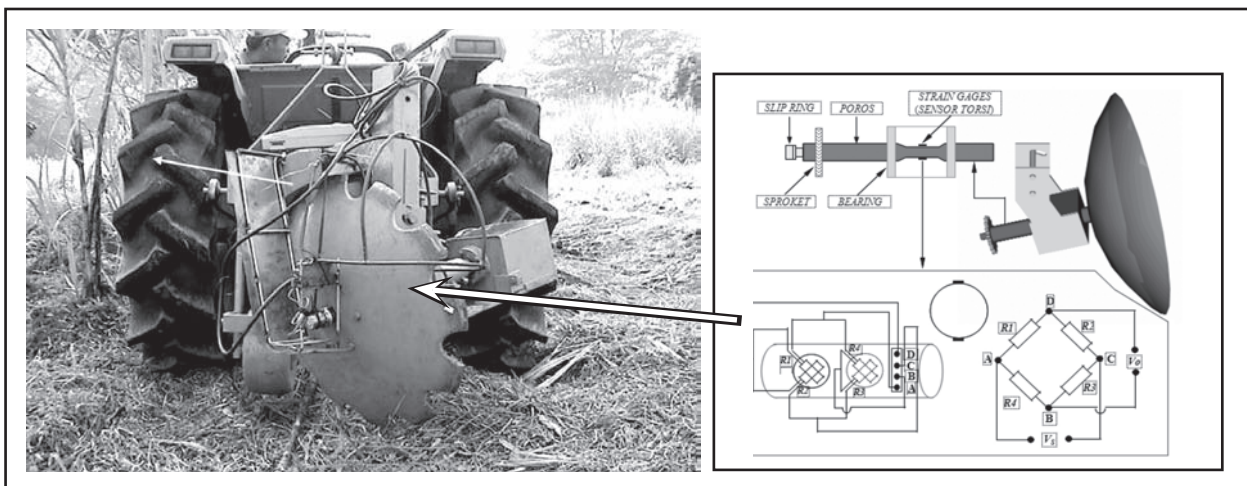


Figure 3. Torque sensor arrangement

Department of Agricultural Engineering Field Experimental Station at Leuwikopo Bogor, and at PT Jatitujuh Sugar Cane Plantation at Majalengka. During field test in Bogor, the prototype was mounted on 34 kW four wheel tractor, while at Majalengka field the prototype was mounted on 84 kW four wheel tractor.

During field test some parameters were observed, such as :

1. Cutting torque, was measure using a torque sensor which was intalled in the shaft of the disk. The sensor was connected to a strain amplifier.
2. Rotational speed of PTO, was measured using a digital tachometer
Field capacity, was measure indirectly by measuring tractor speed (V, in m/s) and width of the implement. Since the prototype was single row, then the widht of implement (L, in m) was equal to the distance between row of the sugar cane. Theoretical field capacity (KLT, in ha/h) was calculate as : $KLT = 0.63 V L$
Actual field capacity was measured by deviding completed area with respect to total time requirement.
3. Quality of work, was measured by relief meter to evaluate the depth of cutting from the soil surface, width of cutting and shape of cuttings.
4. Smoothness of cut, was observed through samples recorded image by digital photo.

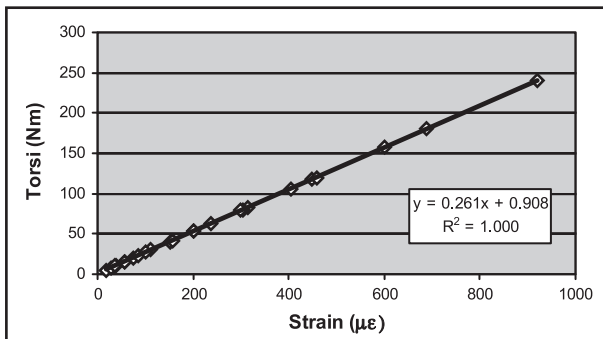


Figure 4. Result of torque sensor calibration



Table 1. Measured Torque at Rotational Speed of 500 rpm

Torque (Nm)	Forward speed (m/s)		
	V=0.275	V=0.281	V=0.273
Minimum	0.26	0.26	1.30
Maximum	48.47	43.52	46.65
average	6.85	9.11	15.04
Standard of deviation	11.92	9.77	12.50

Results And Discussion

The Prototype

The developed stubble saver used a parabolic disk powered from tractor's PTO. The prototype is mounted on tractor's three point hitches. As shows in Figure 2, the developed prototype has 5 main components as follows : 1) frame with three point hitch attachment, 2) disk cutter, 3) gearbox transmission, 4) ground wheel for depth adjustment, and 5) safety protector.

Field test have been carried out at experimental test farm of Department of Agricultural Engineering at Leuwikopo Bogor. Two kinds of operations have been tested, those were cutting of stubble above the soil and cutting of stubble in the soil at 5 to 10 cm. Two kind of rotational speed was tested, those were 500 rpm and 1000 rpm. Traveling speed during field test were 0.7 km/h up to 1.0 km/h.

Torque Sensor

Strain gages were arranged as Wheatstone bridge and was used as the torque sensor. The sensor was installed in the shaft of the rotated disk, as illustrated in Figure 3. Prior to measurement the sensor was calibrated. Results of calibration showed that the sensor had linear respons up to 250 Nm with coefficient of determination $R^2 = 1.0$ as it was presented in Figure 4. The sensor had sensitivity of $0.261 \text{ Nm}/\mu\epsilon$.



Figure 5. Result of Cutting at 1000 rpm (a) and 500 rpm (b) (Feri, 2007)

Table 2. Measured Torque at Rotational Speed of 1000 rpm

Torque (Nm)	Forward speed (m/s)			
	V=0.235 ^{*)}	V=0.224 ^{**)}	V=0.243 ^{*)}	V=0.204 ^{**)}
Minimum	1.30	0.78	0.26	2.87
Maximum	19.28	57.33	41.70	69.84
average	5.37	11.12	7.31	15.69
Standard of deviation	4.36	10.80	7.30	14.54

Note : *) only sugar cane stem **) cutting stem and soil

Table 3. Width of cuttings

No	Width (cm)				
	Row 1	Row 2	Row 3	Row 4	Row 5
1	24.2	22.3	25.0	26.5	25.0
2	25.2	22.0	25.0	25.0	25.3
3	25.3	21.5	24.4	26.0	26.4
Average	24.9	21.9	24.8	25.8	25.6

Table 4. Depth of cuttings

No	Depth (cm)				
	Row 1	Row 2	Row 3	Row 4	Row 5
1	6.9	9.5	12.0	9.1	9.4
2	10.7	9.2	9.8	10.2	10.7
3	10.0	10.5	11.3	7.1	11.4
Average	9.2	9.7	11.0	8.8	10.5

Field Test at Leuwikopo Field

Functional tests were done in Leuwikopo Experimental Field. Tests were conducted with arrangement (through ground wheel) so that the disk only cut the sugar cane stem and in condition where the disk was cutting the soil up to 5 to 10 cm. Tests were conducted at rotational speed of the disk of about 500 rpm and 1000 rpm, while the forward speed of the tractor was in the range of 0.235 to 0.281 m/s. Recorded torques were presented in Table 1 and Table 2.

With sugar cane row distance of about 135 cm (as it was in Jatitujuh sugar cane plantation), the theoretical field capacity was calculated as 0.1 ha/h (as PTO rotational speed was 540 rpm and tractor forward speed was 1.0 km/h), and 0.14 ha/h (as PTO speed was 1000 rpm and tractor forward speed was 0.7 km/h). If the field efficiency is assumed to be 70 %, field capacity could reach 0.5-0.8 ha/day was much more higher as compared to manual stubble shaving operation which needed 20 mandays per

hectar. Result of the test showed that higher speed or disk rotation gave more smooth cuts of stubble compare to slower one. This is understood that higher rotational speed will give less cutting pitch so that cutting mechanism could be done more nicely. Result of cutting was shown in Figure 5.

The profile of furrow was observed before and after test. As shown in Figure 6, relief meter was used to measure the profile, which has total width of 100 cm consists of several sticks spaced by 5 cm apart.

Figure 6 shows the typical shape of profile measurement, before and after stubble shaving operation. As shown the shape was form "V" type as expected. Detail measurement of depth and width of the cuts can be seen in Table 3 and Table 4. At arrangement of 20° tilt angle and 45° disk angle, width of cutting was in the range of 21.9 to 26.5 cm, with average of 24.6 cm. This results was close to design which was set to be 25 cm. Table 4 indicated that depth of cutting was in the range of 6.9-12.0 cm



Figure 6. Relief meter

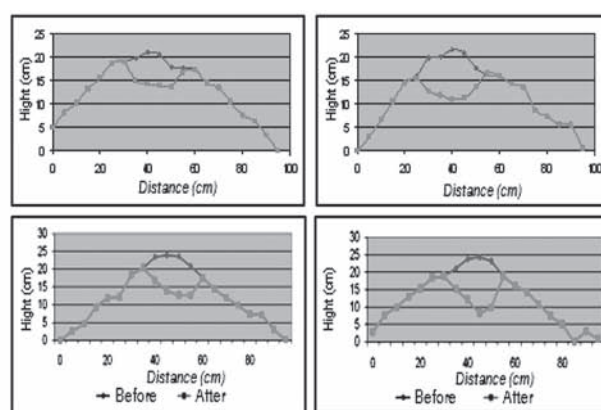


Figure 6. Profile of furrow before and after stubble shaving operation

with average of 9.9 cm, when it was set to be 10 cm. The depth of cutting could be adjusted by ground wheel.

Field Test at Jatitujuh Field

Jatitujuh sugar cane plantation cultivated sugar cane in single row cultivation with row distance of about 135 cm width. The sugar cane furrow had dimension of 15-23 cm height. As it was ratoon field, the peak of the furrow was relatively flat. As it was manually planted, the position of stubbles were not always in the middle of the furrow. Most of sugar cane stalks laid between 8-20 cm from the middle of the furrow.

Tests at Jatitujuh were done at targeted tractor forward speed of about 0.25 m/s. This was done by using gear shift C3. Real forward speed was in the range between 0.216 to 0.251 m/s with average of about 0.238 m/s. While PTO of the tractor was set on 540 rpm, which gave real rotational speed in the range between 560-564 with average of 562 rpm.

Torque was recorded between 11.6 Nm to 32.5 Nm, with average 20.6 Nm. Average number of stem per stubble was 2 pieces with variation between 1 to 8 pieces. During the tests it was observed that transmission system designed in the developed stubble shaver (using single gearbox and single universal joint) could work satisfactorily, able to adapt the problem of non parallel shaft between tractor's PTO shaft and disk cutter's shaft due to the presence of tilt angle and disk angle on disk cutter. Results of tests showed that the value of torque was depend on depth of cutting, number of stem on each stubble of sugar cane, and local condition of soil. Torque increased as depth of cutting was increased, and the increased number of stems per stubble.

Profile of furrow before and after stubble shaving operation was measured using relief meter as previously mentioned. As it was shown in Figure 8, result of field test showed that the developed prototype for sugarcane stubble shaver could operate well and give satisfied cutting shape. It is observed during field experiment that higher rotation of disk cutter give a better result of cutting compares to lower disk cutter rotation speed. It is understood because higher disk cutter rotational speed will have smaller "clip of cut". The result of experiment also shown that the developed prototype could give "V shape" type of cutting path as it is expected.

Depend on the skill of tractor operator, dept of cuttings were varied between 5 to 12.7 cm, with average of 8.2 cm and standard deviation of 2.0 cm. Width of cutting was measured 3 samples each row,

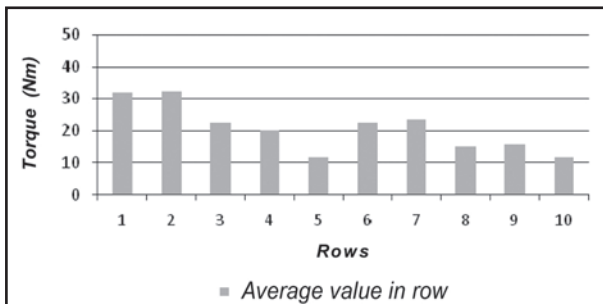


Figure 7. Measured torque at jatitujuh tests

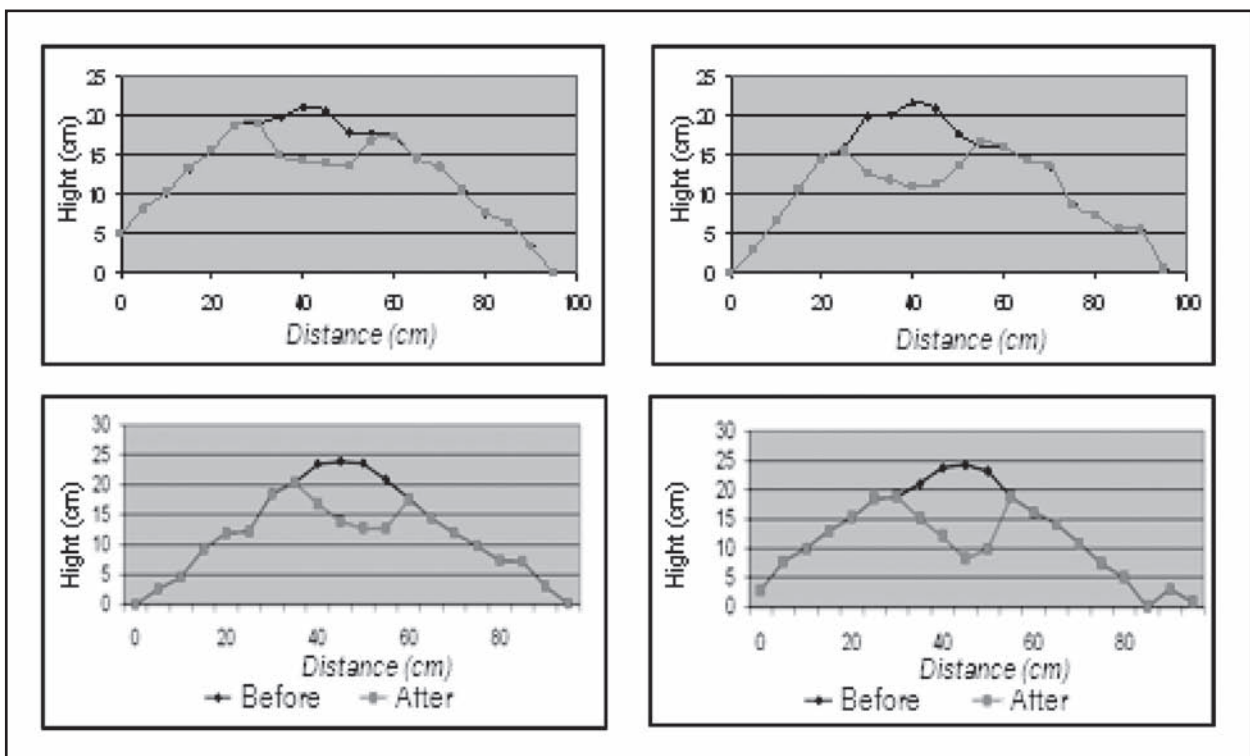


Figure 8. Typical shape of furrow cutting results

and the results were varied between 17.0 to 26 cm with average of 21.7 cm and standard deviation of 2.8 cm. The width of cuttings had already reach the design criteria which close to 25 cm.

However, due to inconsistent condition of sugarcane stubble in the field, some inconveniencies was observed during the test. Width of cutting which was set to be 25 cm was not enough. Therefore, some stubles where stems were spread could not be cut clearly. There was also condition where the root of the stubble was shallow, those made the stubble was removed. Further, depth adjustment was considered important paramater in sugarcane stubble saver design. In the future, powered disk type of sugarcane stubble shaver design should be further developed to become two rows to four rows type for better performance.

Conclusions And Recommendations

1. The developed prototype of sugar cane stubble saver which utilized powered disc mechanism had could functionally work well in the field. The proposed construction had a simple design but could accommodate alignment between PTO shaft and the shaft of the disk. The disk had a range of tilt angle adjustment between 15-25° and a range of disk angle adjustment between 35 – 45°.
2. The powered disk had a potential application for sugar cane stubble saver. Result of field test conducted at IPB's experimental field showed that at test arrangement of 45° in horizontal angle and 25° of tilt angle gave result as expected, where the prototype could worked at average depth of 9.9 cm with standard deviation of 1.4 cm, and had cutting width of 24.6 cm with standard deviation of 1.5 cm.
3. Rotational speed of 1000 rpm gave quality of cuts better than that of 500 rpm. At tractor speed range between 0.7 – 1.0 km/h with a distance between row of about 135 cm, the developed prototype could have a range of field capacity between 0.10-0.14 ha/h or 0.5-0.8 ha/day which was much higher as compared to manual stubble shaving operation which needed 20 mandays per hectare.
4. Torque of cutting increased as cutting depth was increased as well as the increase of the number of sugar cane stem in stubble. Field test at Jatitujuh sugar cane field showed that at rotational speed of 500 rpm torque was in the range of 11.6-32.5 Nm, with average of 20.6 Nm where number of stems in stubble were between 1 and 8 stalks with average of 2 stalks.
5. The developed prototype could gave cutting profile in the form of V type as expected. Depth

of cutting had an average of 8.2 cm with standard deviation of 2.0 cm and had a range between 5.0 – 12.7 cm. While width of cutting had an average of 21.7 cm with standar deviation of 2.8 cm and had a range between 17.0-26.0 cm.

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