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Design and Construction of an Improved Animal Drawn Corn Harvester

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Abstract. Previous attempts in animal draft harvesting corn had short comings: insufficient power and speed generated to facilitate cutting the stalk; poor maneuverability of cart; poor draw bar design causing crop damage as it passed under yoke; and cart had difficulty in moving over rough terrain due to low ground clearance. This research was to improve on existing means of harvesting corn using animal draft power, focusing on an existing harvester at Makerere University Agricultural Research Institute Kabanyolo in Uganda. Design objectives were: improve cutting efficiency of cutting mechanism; improve ground clearance of cart; improve cart's rigidity; reduce damage to unharvested crops due to poor draw bar design; improve maneuverability and traction transmission of cart; and improve safety of cart for operator. Additional focus was on an efficient and versatile animal drawn corn harvester that could be used during the off season as a normal transportation cart for other farm activities. Results indicate the cart's ability to cut corn stalks at an average of 60 cm above the ground, with an average corn dia of 3 cm. The cart, if operated under 2.5 Km/h, should harvest 1 ha in about 5 h compared to the 4 days it takes 4 humans to harvest the same area. The project yielded positive results and presents a potential in the use of animal draft power for the harvesting of corn and other large stalked grains like sorghum and millet, at the same time providing an economical mode of carrying out harvesting and transportation on farms.

Keywords. Corn harvester, animal draft, design, animal drawn

DESIGN AND CONSTRUCTION OF AN IMPROVED ANIMAL DRAWN CORN HARVESTER

Abstract

Corn remains an important element in the daily life of Ugandans as emphasized by the fact that between 1980 and 2000, annual production rose from 602 000 to 1,096,000 metric tonnes. Despite high levels of production, there has been little done about the introduction of cost effective harvesting equipment to reduce drudgery. This can be deduced from the fact that in 1990 Uganda had 4500 tractors and 15 harvesters which number has basically remained the same to date in spite of the doubling in levels of production. Currently, most corn farmers depend on manual tools such as the machette and simple knives for harvesting. There are efforts by the government of Uganda to improve the mechanisation status of the farmers. Animal draft power that reduces drudgery, increases output and at the same time remains economically affordable to the average farmer is a potential intervention in line with government efforts.

Previous attempts in animal draft harvesting corn had the following short comings: (1 insufficient power and speed generated to facilitate cutting the corn; (2 poor maneuverability of cart; (3 poor draw bar design causing damage to crop as it passed under yoke; and (4 the cart had difficulty in moving over rough terrain due to low ground clearance.

The purpose of this project was to improve on the existing means of harvesting corn using animal draft power. The focus was on an existing animal drawn corn harvester at Makerere University Agricultural Research Institute Kabanyolo (MUARIK). The design project objectives were: (1 improve cutting efficiency of the cutting mechanism; (2 improve ground clearance of cart; (3 improve cart's rigidity; (4 reduce damage to unharvested crops due to poor draw bar design; (5 improve maneuverability and traction transmission of cart; and (6 improve safety of the cart to the operator. Additional focus was on the introduction of an efficient and versatile animal drawn corn harvester that can be used during the off season as a normal transportation cart for other farm activities like transportation of produce and supplies.

The results obtained indicate the cart's ability to cut corn stalks at an average of 60 cm off the ground, with an average corn diameter of 3 cm. The cart, if operated under an average speed of 2.5 $Kmhr^{-1}$, should harvest 1 hectare in just about 5 hours compared to the 4 days that it would take 4 humans to harvest the same area. The project yielded positive results and presents a potential in the use of animal draft power for the harvesting of corn and other large stalked grains like sorghum and millet, at the same time providing an economical mode of carrying out harvesting and transportation on farms.

Introduction

Corn remains an important element in the daily life of Ugandans as emphasized by the fact that between 1980 and 2000, annual production rose from 602 000 to 1,096,000 metric tonnes. Despite high levels of production, there has been little done about the introduction of cost effective harvesting equipment to reduce drudgery. This can be deduced from the fact that in 1990 Uganda had 4500 tractors and 15 harvesters which number has basically remained the same to date in spite of the doubling in levels of production. Currently, most corn farmers depend on manual tools such as the machette and simple knives for harvesting. There are efforts by the government of Uganda to improve the mechanisation status of the farmers. Animal draft power that reduces drudgery, increases output and at the same time remains economically affordable to the average farmer is a potential intervention in line with government efforts.

Previous attempts in animal draft harvesting corn had the following shortcomings:
- ✓ insufficient power and speed generated to cut the corn stem;
- ✓ poor manoeuvrability of the harvester-cart;
- ✓ poor draw bar design causing damage to crop as it passed under yoke; and
- ✓ the cart had difficulty in moving over rough terrain due to low ground clearance.

The purpose of this project was to improve on the existing means of harvesting corn using animal draft power. The focus was on an existing animal drawn corn harvester at Makerere University Agricultural Research Institute Kabanyolo (MUARIK). The project objectives were:

- ✓ to improve the cart's rigidity and ground clearance, and the harvester cutting efficiency;
- ✓ to improve manoeuvrability and traction efficiency of the cart;
- ✓ to reduce damage to unharvested crops; and
- ✓ to improve safety of the cart to the operator.

Additional focus was put on the introduction of an efficient and versatile animal drawn corn harvester that can be used during the off season as a normal transportation cart for other farm activities like transportation of produce, farm supplies and water.

Animal Drawn Corn Harvesters

In Africa the use of animal powered harvesters have been unsuccessful. According to Starkey & Kaumbutho (ed) (1994), the high cost, which was unlikely to be justified from the profits of one small farm (1-5 ha), coupled with heavy weight, requiring high draft and the high power and speed requirements to effect cutting, are the main reasons for lack of adoption of the animal drawn corn harvesters.

According to Johnson & Lamp (1966) the impact force and speed necessary to cut a typical fixed maize stalk of 30.48 mm diameter at 30-60 % mc (dry) lies in the range of 344 - 442 N at 1.9 – 3.96 m/s speed. The cutting force required is directly proportional to the diameter of the stalk. Although the woody part occupies about 30% of the total cross section of the stalk its resistance accounts for close to 87% of the cutting force. When using a counter shear mechanism, the cutting force required to cut corn stalk varies with the part of the stalk

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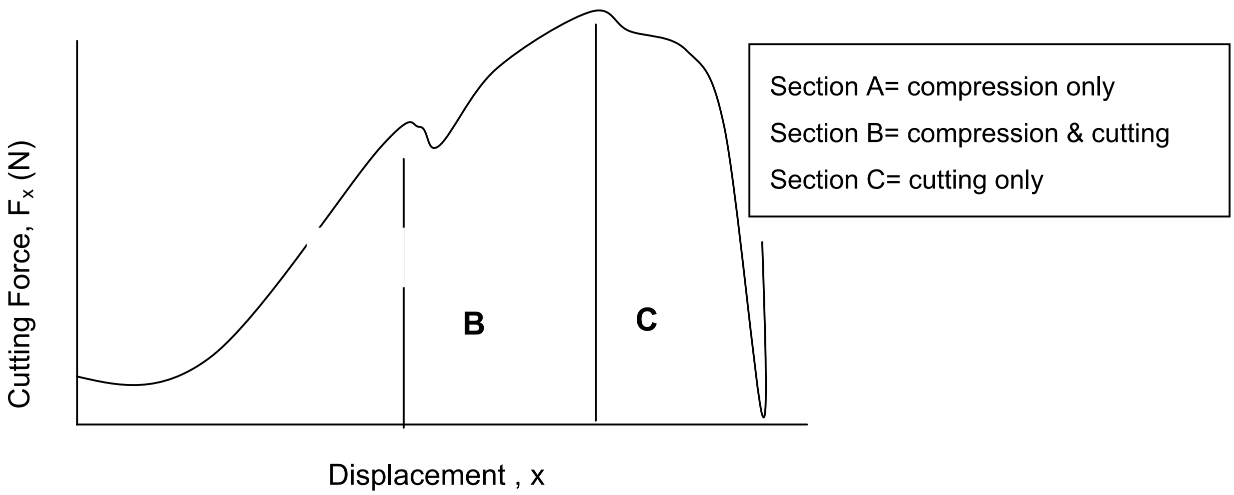

Figure 1. Knife force - displacement curve for a straight cut against a counter-shear.

In section A, only compression of the stalk occurs, as the knife-edge tends to grasp the stalk. After initial stalk failure, cutting progresses but with further compression of the stalk, as in section B. In section C, the stalk is fully compressed and cutting continues and then the force drops rapidly as the knife crosses the stalk. The energy per cut is equal to the area under the force-displacement diagram (see Fig.1).

Development of Animal Drawn Corn Harvesters in Uganda

Oxen are the main animals used for providing draft and many of the rainfed grains like maize, sorghum and millet have large stems that require high cutting forces such that large draft power would be needed and high travel speeds required. The first design of an animal drawn corn harvester at Makerere University Agricultural research Institute (MUARIK) consisted of a 500 kilogramme capacity wooden box and a “V” shaped knife shear cutting mechanism (Odida, 1995). Its operation was such that as animals drew the cart forward, the operator sitting on the cart would grasp or support the corn stalks just before the knife shears the stalk. The operator would then throw the cut corn into the cart. The major problem of this prototype was the poor ergonomics design, poor stability of the cart in the uneven field terrain, and undue vertical loading on the animals at the yoke-bearing surface.

Okiror (1998) and Musinguzi (1999) changed the harvester cutting mechanism by Odida (1995) to impact cutting using horizontal rotating plates coupled to the harvester drive wheels through a bevel gear system. The operation of these prototypes were similar to the earlier prototype by Odida (1995) such that as the cart was drawn forward the operator would grasp or support the corn stalks just before the knife cut off the stalk and then throw the cut corn into the cart. A single caster wheel was also introduced to improve stability, manoeuvrability and to reduce pressure on the animals at the yoke-bearing surface.

The above-mentioned design had the following shortcomings:

1. Although the impact force from the rotating blade would have been adequate for cutting maize stalks, the timing of the blades to cut the maize stalks was not easily accomplished. This was mainly due to the fact that the animals cannot move at a constant speed. Furthermore, wheel slip and the bouncing of the harvester wheels due to the unevenness of the field made the knives rotation uneven.
2. The body was bulky.
3. The caster wheels would not move continuously due to the uneven terrain of the field.
4. The cutting mechanism was at the centre of the cart such that the corn to be cut had to pass under the yoke. This led to damage of the crop.

METHODOLOGY

Considering the shortcoming of the previous designs' cutting mechanisms, a cutter bar shearing mechanism was postulated. The cutting mechanism was changed from the rotary impact cutting to reciprocating cutter bar, shear cutting. Since the speed of the animals cannot be easily regulated, the cutter bar design was based on the crop spacing of 60 centimetre inter-row and 40 centimetre inter-crop of common Kawanda Composite A&B Kenya hybrid maize commonly grown by farmers.

Most farmers who use draft animal power use two oxen. Assuming oxen of 500 kg, each, moving at an average speed of 0.694m/s, the tractive power from the oxen was about 677 Watts. In one minute, the animals traversed 41.4 metres, cutting 104 crops, along a row.

A double chain drive (as shown in Fig. 2., below) with a ratio of 55/15 per drive with a final crank speed of 223 revolutions per minute was used. The power of the chain drive was calculated as 676 Watts. Two traction wheels were used to provide the rotation to the chain drive. Since incorporation of a third wheel interferes with movement of the cart in the field, no additional support wheels were incorporated on the cart.

The force on the shaft due to chain pull was 3459 N. Considering the reversible bending stresses subjected to the shaft the minimum safest diameter of the shaft was given as 45 mm, after standardization. Similarly, the spindle diameter was obtained as 32 mm, while the crank -shaft was obtained as 25 mm, after standardization.

A crank –lever mechanism, onto which a cutter bar was attached to cut the corn stalks was used. Kinematic analysis of the pitman in single-plane motion, spatial motion being neglected, gave a 45 mm square section, considering AISI 1040 mild steel. The chain-cutter mechanism was placed in guards to ensure safety. The cutting mechanism was assembled as shown in Fig. 2, below.

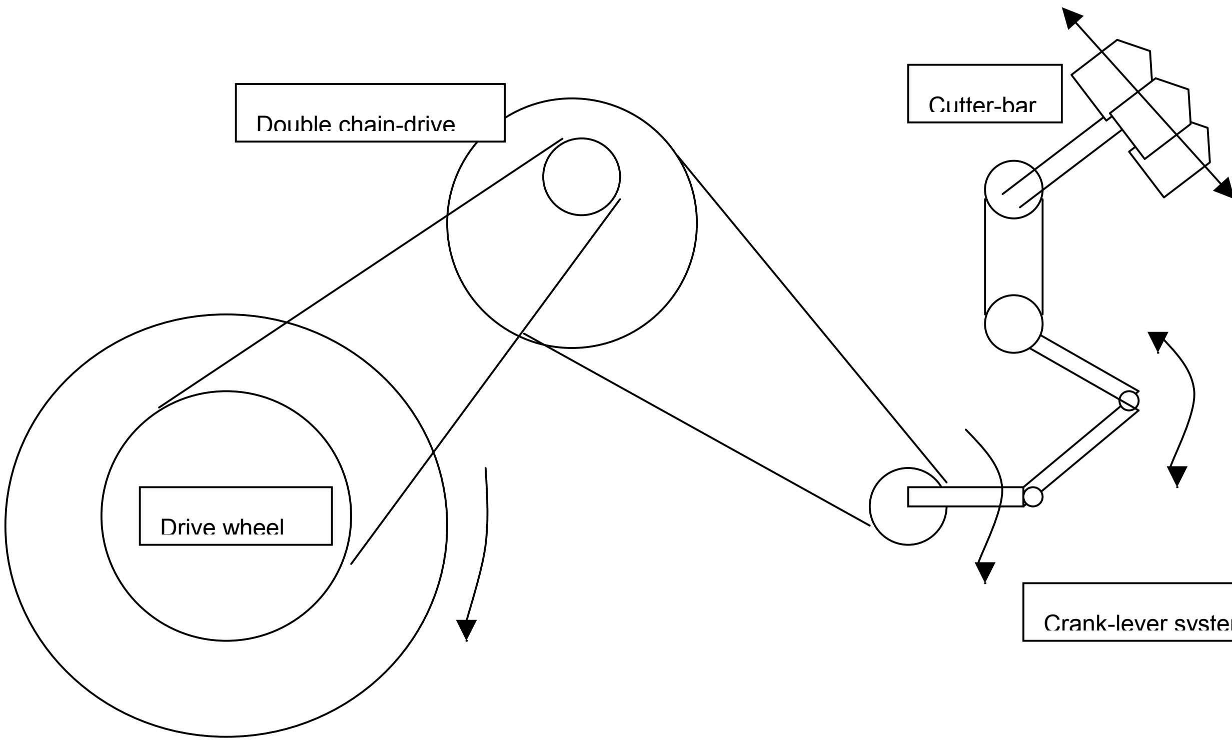

Figure 2. A crank-lever mechanism coupled to a double chain-drive (not to scale).

In order to reduce on the crop damage the cutting mechanism was offset so that the animals pass on the harvested land. Two drawbar positions on the cart, one in the centre; to be used when the cart is in the transportation mode; and another offset; used when the implement is cutting. A "Z" shaped bar was used so that the cutting blades are maintained at 600 mm off the ground. Tractive efficiency of the harvester was improved by providing more wheel lags onto the harvester wheels.

Results and Discussion

The results showed that the corn harvester cut corn stalks at a fairly uniform height of 600 mm. Corn stalks with a diameter of 50 mm and below were cut with ease, whereas thicker stalks than 50 mm jammed the cutting mechanism. At an average speed of 2.5 $Kmhr^{-1}$, one hectare was harvested in 6 hours as compared to the 4 days that it would take 4 humans to harvest the same area. No appreciable damage to crops was exhibited. However, a large turning circle that is required presented a large loss to the implements field efficiency. This will be even more serious since the implement is targeting relatively small farms (1-3ha).

In the prototype, the cranking mechanism and the cutter generated a relatively high level of noise, especially at the two dead-centres. This was an indication that the crank-lever mechanism was not dynamically balanced. Although the movement of the reciprocating cutter is not expected to be uniform, there is potential to reduce the noise generated by improving the crank-lever mechanism.

Since the operator has to pick the cut corn as well as guiding the animals, he is likely to tire and loose concentration very fast. The operation can be improved by using two operators, the ox-man and another operator to catch and load the cut corn. This however introduces an addition load to the animals as well as another cost of labour. Automatic conveyance system could be incorporated if its cost can offset the cost of an extra operator. The limiting parameter would be the power derived from the animals.

Although the study considered a pair of a combined liveweight of of traction animals of about 1000 kg, most draft animals in tropical countries about 150- 250 kg liveweight. Considering that the animals will deliver a draft of 10% of the liveweight of the draft animals, the animals used by farmers will generate less than 50% the power used in the study. Therefore higher traction, transmission and mechanical efficiencies should be targeted to ensure that the difference in the draft potential of the animals is offset.

Conclusion and Recommendations

The prototype presents a potential in the use of animal draft power for the harvesting of corn and other large stalked grains like sorghum and millet, at the same time providing an economical mode of carrying out harvesting and transportation on farms. Cutting timing is very critical in this prototype. Generalization of the findings of the study indicates potential advantages of the cutter-bar mechanism over the cutting modes of the previous prototypes. However, further refinement of the cutting mechanism is required to ensure that large stalks can be cut and less noise is generated. The possibility of incorporating an automatic conveying system onto the prototype should also be explored by future research on the corn harvester.

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