ANALYSIS OF THE CUTTING PROCESS IN THE CHOPPER OF KTP — 1 SUGARCANE HARVESTERS

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ABSTRACT

The sugarcane chopper is one of the most important working parts of sugarcane harvesting machines.

The study of the cutting process in the chopper permits one to know the influence of every factor playing a role in it, and allows one to establish the parameters that characterize the best functioning of the drums which make up this chopper.

By the application of ultrarapid filming techniques and tensometric measurements it is possible to obtain data that will contribute to explain the functioning of the chopper parts which, at first sight and using conventional methods of measurement, is not possible due to the revolution frequency (300 rpm) of the drums that make up the chopper.

The influence of drum and knife geometry in the cutting and stalk throwing processes by the chopper are pointed out in this paper.

The data furnished by this work may be of help for an accurate determination of the chopper functioning characteristics, and may contribute to develop existing design criteria so as to make possible the modernization of the apparatus.

INTRODUCTION

Among the working parts of the harvesting machine, the chopper is particularly important. The chopping of stalks and leaves in pieces of a given length (250-400 mm) makes possible the separation of leaves from stalks by means of an air current, a more rational use of transportation means during the harvesting process, and the optimization of the harvested mass processing by the sugar mill.

Mass chopping is one of the most power consuming operations among those carried out by the harvester.

Although choppers are widely used in sugarcane harvesters, the factors in-
fluencing the chopping process of the vegetable mass are unknown up to the pre-
ent, independently of the geometric and kinematic parameters that play a part in
the cutting process and which undoubtedly influence the quantitative and energetic
indicators of chopper performance.

This analysis of the chopper cutting process of the KTP-1 sugarcane harvester
is designed to clear up some unknown facts in relation to the work and functions
carried out by these components of the chopper, thus contributing to bring up to
date the work of this part as a point of reference for its modernization in future
harvester prototypes.

THEORETICAL CONSIDERATIONS

While the drums of the chopper are working, the upper and lower knives
(Fig. 1) of the drums rotate at velocity \( w \) and they grab stalk layers. They compress
and draw the stalk layer towards them, penetrate the layer and then constitute
a cutting pair which chops the layer.

\[ x^2 + \left( y - \frac{S}{2} \right)^2 = R^2 \]

\textbf{FIGURE 1.} Diagram for the analysis of chopper performance.

Once the cutting process is over, the knives continue to rotate and perform
an action of throwing the cut pieces of stalks onto a conveyor. The absolute
trajectory of the movement of the cutting-edge in coordinates \( x-y \) may be
represented by circumference equations:

for the upper knife
for the lower knife

\[ x^2 + [y + (R - \frac{S}{2})]^2 = R^2 \]

where

- \( R \) = drum radius up to the extreme of the knife cutting edge
- \( S \) = overlapping of knife cutting edges

Knife cutting edge peripheral velocity \( V \) may be resolved in \( V_x \) and \( V_y \)

thus:

\[ V_y = V \text{ per } \sin \psi \quad ; \quad V_x = V \text{ per } \cos \psi \]

where

\( \psi \) = the rotation angle of the upper and lower knives from the moment of contact of their cutting edges with the material to be cut up to the moment of coincidence with axis \( y \). Component \( V_y \) represents the vertical displacement velocity of the knife outer edge, while the component \( V_x \) represents the attracting velocity of stalks by the knives or the displacement velocity of stalks in the direction of axis \( x \) without considering their sliding. The importance of determining the values of angle \( \psi \) can be inferred from these formulas in order to know the relation existing between \( V_x \) and \( V_y \).

**FIGURE 2.** Diagram of the experimental installation
MATERIALS AND METHODS

To study the cutting process of the mass of stalks of cane leaves, a two-drum chopper installation was used whose diagram is shown in Fig. 2. This installation consisted of a slat conveyor 1 which had the possibility of varying the feeding angle of stalks of a two-drum chopper 2; of independent driving mechanisms 3, and of chassis 4.

Stalks with leaves attached were carried by a conveyor driven by an electric motor through a reducer which was also driven by another electric motor. The installation was prepared for measuring the rotational movement of the chopper.

For the cinematographic investigations of the cutting process, windows were opened on the lateral walls of the installation, through which the cutting process was observed.

For these ultrarapid filmings a German “Practika” camera was used.

Table 1 shows the parameters that characterized the experimental conditions.

<table>
<thead>
<tr>
<th>No.</th>
<th>Parameter denomination</th>
<th>Established dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Feeding capacity, kg/sec.</td>
<td>10</td>
</tr>
<tr>
<td>2.</td>
<td>Feeding velocity of the mass, m/sec.</td>
<td>1</td>
</tr>
<tr>
<td>3.</td>
<td>Feeding angle of the conveyor, grades</td>
<td>0</td>
</tr>
<tr>
<td>4.</td>
<td>Rotation frequency of the chopper, RPM</td>
<td>300</td>
</tr>
<tr>
<td>5.</td>
<td>Free spaces between the knives, mm</td>
<td>1</td>
</tr>
<tr>
<td>6.</td>
<td>Recovering of the knives, mm</td>
<td>10</td>
</tr>
<tr>
<td>7.</td>
<td>Sharpening of the knives, μk</td>
<td>100</td>
</tr>
<tr>
<td>8.</td>
<td>Sharpening angle of the knives β, grades</td>
<td>20</td>
</tr>
</tbody>
</table>

Experiments were made on variety My 53 174 which in preliminary investigations proved to be more resistant to the cutting process (Silveira²).

Tests were carried out three times.

Tensometric measurement of the cutting process

With the objective of establishing the indicators of energy requirements of the chopper cutting process, tensometric measurements of the process were made. Considering the specific work of each drum, the upper one and the lower one were measured independently.

For measuring the rotation moment (Me) a tensometric pulley made
for this purpose was placed at the entrance of the lower drum. Extensometers were fixed on the pulley according to a Wheatstone bridge connection. The rotational moment \( (M_z) \) of the upper drum was determined by extensometers attached to the shaft. The signals from the extensometers were caught by annular and terminal collectors. A Soviet amplifier 8AH4—7M was used for the amplification of electronic impulses.

The number of revolutions of the shafts was measured with an electric induction tachometer. An oscillograph H-700 was used to record all measured parameters on a special paper and thus oscillograms were obtained. A planimeter was also used.

The tensomerting process was coordinated with ultrarapid filming.

Ultrarapid filmings

At the beginning, the velocity of the filming process was determined considering the rotation frequency of the drums in the chopper. Then, the frequency and the filming time of the cinematographic camera was calculated. The camera was placed in front of one of the lateral windows of the installation. This window was covered with transparent acrylic material.

The lighting of the objective was determined with the help of a photometer, taking into consideration the sensitivity of the film used. The last determination of the light intensity was made after some test filmings.

The filming velocity ranged between 100 and 300 pictures/second. When the filming of the objective was finished quantitative and qualitative analyses of the film process were carried out on a montage table.

RESULTS

The work movement of the cutting edge of the two-drum chopper knives represented a curvilinear surface with the shape of a trochoid loop.

During the cutting process, the knives not only penetrated the material but they also attracted it towards them. The penetration angle of the knives cutting edge varies in relation to the cutting surface, thus causing a compression of the material by the two faces of the knives cutting edge. Part of the power was consumed in this way.

The results of the analysis of the fast filmed pictures showed that the chopper had the following characteristic fundamental phases of interaction with the mass of leaves and stalks:

1. Grabbing and formation of a layer in the mass
2. Cutting process in the mass
3. Throwing of the chopped mass

These three phases were highly significant for the fulfillment of the chopper.
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FIGURES 3-a, 3-b and 3-c. Grabbing and formation of a layer in the mass.

FIGURES 3-d, 3-e and 3-f. The cutting process.

FIGURES 3-g, 3-h and 3-i. The cutting process.

FIGURES 3-j, 3-k and 3-l.
FIGURES 3-m, 3-n and 3-o. Pith particles being detached from the cut stalks.

TABLE 2. Values of the circumference arches described by the border of the knives (in grades) and the velocities $V_x$ and $V_y$ (in m/sec.)

<table>
<thead>
<tr>
<th>Velocities $(m/sec)$</th>
<th>Holding angle and formation angle of the layer $\alpha_3 - \alpha_2$ grades</th>
<th>Direct cutting angle $\alpha_2 - \alpha_1$ grades</th>
<th>Throwing angle $\alpha_4 - \alpha_3$ grades</th>
<th>Total working angle of the chopper $\alpha_4 - \alpha_1$ grades</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha_1 = 46^\circ$</td>
<td>$V_{x1} = 3.46$ $V_{y1} = 3.56$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha_2 = 66^\circ$</td>
<td>$V_{x2} = 4.56$ $V_{y2} = 2.00$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\alpha_3 = 81.5^\circ$</td>
<td>$V_{x3} = 4.96$ $V_{y3} = 0.73$</td>
<td>$20^\circ$</td>
<td>$15.5^\circ$</td>
<td>$32.5^\circ$</td>
</tr>
<tr>
<td>$\alpha_4 = 114^\circ$</td>
<td>$V_{x4} = 4.56$ $V_{y4} = 2.00$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE 3. Used power in the drum transmission of the chopper

<table>
<thead>
<tr>
<th>Total power $Ne$, kw</th>
<th>Upper drum $Nz$</th>
<th>Lower drum $Ne - Nz$</th>
<th>Relation $Nz/Ne - Nz$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Kw$</td>
<td>%</td>
<td>$Kw$</td>
<td>%</td>
</tr>
<tr>
<td>11.4</td>
<td>6.91</td>
<td>60.6</td>
<td>4.48</td>
</tr>
<tr>
<td>9.9</td>
<td>6.28</td>
<td>63.4</td>
<td>3.61</td>
</tr>
<tr>
<td>10.95</td>
<td>5.53</td>
<td>59.5</td>
<td>5.42</td>
</tr>
<tr>
<td>13.23</td>
<td>6.68</td>
<td>50.5</td>
<td>6.55</td>
</tr>
<tr>
<td>12.42</td>
<td>6.59</td>
<td>53.04</td>
<td>3.86</td>
</tr>
<tr>
<td>8.14</td>
<td>4.48</td>
<td>55.06</td>
<td>3.86</td>
</tr>
<tr>
<td>6.92</td>
<td>3.53</td>
<td>51.0</td>
<td>3.39</td>
</tr>
<tr>
<td>12.22</td>
<td>7.25</td>
<td>59.38</td>
<td>4.96</td>
</tr>
<tr>
<td>12.42</td>
<td>7.25</td>
<td>58.4</td>
<td>5.16</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fig. 3 shows the filmed pictures. It may be seen that the knives of the upper and lower drums, while rotating, grabbed the stalk mass (Fig. 3-a), then the mass was compressed by the knives and drawn towards them (Fig. 3-b).

In the layer formation process (Fig 3-c) the upper knife acted more intensively upon the mass. The figure shows the beginning of the cutting process (Fig. 3-d), and its end (Fig. 3-h). In this phase, the knives get into the stalk layer at the same time (Figs. 3-d, e, f, g) and when they meet the cutting pair which cuts the stalk layer is constituted (Fig. 3-h).

The pictures show that the upper knife played a more active role during the cutting process than the lower one.

After the cutting process was completed, the throwing process of the cut mass of stalks and leaves onto the conveyor began (Fig. 3-i). After the cutting process, the lower cut plane of the chopped stalk fell and lay on the lower knife face. From that moment, the throwing action of the chopper was carried out only by the lower knife up to the last moment of the throwing (Fig. 3-k) when the contact between the knife and the material was lost.

In the course of the cutting process pith particles were detached from the stalk, thus causing juice losses. This phenomenon is shown in Fig. 3-l, m, and o.

The results of the filmed pictures are shown in Table 2. The circular arc described by the border of the knife cutting edge (α2 - α1) corresponded to the grab and stalk layer formation phase and was 23% of the total working arc; (α3 - α2) corresponded to the direct cutting phase and was 30% of the total arc, and (α4 - α3) corresponded to the throwing phase and was 47%.

The analysis of the oscillograms obtained led to the conclusion that the power used for driving the upper drum was more than the power used for driving the lower drum (see Table 3). This meant that the knives cutting edges of the upper drum had a greater activity for penetrating the mass of stalks and leaves. Therefore, the internal action of the cutting edges of the upper drum brought about a reduction in the drum cutting capacities during a short period of exploitation.

**CONCLUSIONS AND RECOMMENDATIONS**

1. The arc of the circle described by the border of the knife cutting edge in the grab and stalk layer formation phase was 23% of the total working arc; 30% during the direct cut phase and 47% during the phase of chopped mass throwing.

2. The power used for driving the upper drum of the radial-type chopper was 28% higher than the power used for driving the lower drum.

3. Losses occurring in the chopper during the cutting process might be con-
siderable in relation to the amount of stalk particles detached. Hence, it is recommended that this phenomenon be further investigated.

4. The results of this work could be used as initial data for future investigations on drum knives wear and durability, and also a design criteria for new and more efficient choppers.

REFERENCES


ANALISIS DEL PROCESO DE CORTE DEL TROZADOR DE LAS COSECHADORAS DE CAÑA KTP – 1
Juan Silveira Remus

RESUMEN

El trozador de caña es una de las piezas de mayor importancia en el proceso tecnológico de las maquinas cosechadoras de caña de azucar.

El estudio del proceso de corte del trozador da a conocer la influencia de cada uno de los factores que toman parte en el proceso, y permite establecer los parametros que caracterizan el mejor funcionamiento de los cilindros de que se compone el trozador.

El uso de técnicas de filmacion ultrarapidas y medidas tensometricas permite obtener informacion contributiva a la explicacion de funcionamiento del trozador, lo cual no seria posible a primera vista y usando metodos de medida convencionales debido a la velocidad (300 rpm) de los cilindros que componen el trozador.

Hacemos notar en este estudio la influencia geometrica del cilindro y la cuchilla en los procesos de corte y tiro del tallo por el trozador.

Los datos suministrados por este estudio pueden ayudar a determinar con exactitud las características de funcionamiento del trozador y pudieron contribuir al mejoramiento de las normas de diseño existentes haciendo asi posible la modernizacion de este aditamento.