OPTIMISATION OF THE CANE JUICE EXTRACTION
WITH AN OPTIMUM USE OF THE ENERGY:
THE FCB EXTRACTION UNIT

P. Bonin and O. Govaert
Sugar Department, 2 Bd de L'Usine, B.P. 2047 – F 59015 Lille Cedex, FRANCE

ABSTRACT

To reduce the running costs, power demand and also to improve the efficiency of the milling house, FCB has developed an "Extraction Unit", the advantages of which are:

- Reduction of the energy per ton of cane by 14 to 30% compared to conventional 4 roller mill. No energy is spoiled by reabsorption, no friction of the bagasse on the trash plate.
- Extraction over 75% with only two pressure rollers.
- Reduction of the reabsorption factor, the juice being prevented from flowing out with the bagasse.
- Reduction of the number of wear parts, hence the maintenance costs.
- Re-utilisation of the existing drive when an FCB extraction unit replaces an existing mill.

Keywords: Extraction, mill optimisation, energy

INTRODUCTION

The history of milling has shown a continuous increase in the number of rollers fitted on one mill, improving the extraction of course, but also with an increase of the running costs and power demand. One of the major source of energy demand is the trash plate.

Several studies have been carried out about the two roller mills without trash plate, in different configurations, and with various results.

Already, at the end of the last century, our Etbts Cail had developed a tandem with only four two roller mills. The technology at that time did not allow this project to be fully convincing.

From 1990, FCB has developed such a mill, with the objective of

optimising cane juice extraction and use of energy

and keeping in mind the reduction of running costs.

For this, we have to consider four steps of the process:
Cane preparation, so as to open as many cells as possible

Juice extraction (meaning juice in the juice tray), by increasing the efficiency of the first dry extraction

Juice reabsorption, to reduce bagasse re-imbibition and reduce the energy consumption

Bagasse imbibition, by diluting as much as possible the residual juice in bagasse.

The first point is not treated here, since it concerns other equipment, but its influence will be discussed. The second and the third point are partially linked. The grooving must be designed so as to allow the drainage of all the extracted juice. Otherwise, choke and reabsorption occur.

Reabsorption: one major inconvenience of the conventional milling process: reabsorption

If we consider a set of two rollers pressing the bagasse, its efficiency is measured by its extraction:

\[ E_j = 100 \frac{(1 - \frac{k}{C_o}) \cdot d_{je}}{(1 - \frac{f \cdot d_o}{d_f}) \cdot d_{ja}} \]

- \( E_j \): extraction of the mill
- \( d_{je} \): density of the expressed juice
- \( d_{ja} \): density of the juice in entering bagasse
- \( k \): reabsorption factor
- \( C_o \): compression factor \( (C_o = \frac{V_a}{V_E}) \)
- \( V_a \): bagasse volume (fibre + juice) entering the rollers per time unit
- \( V_E \): volume produced by the rollers per time unit
- \( f \): fibre content in bagasse in weight
- \( d_f \): fibre density
- \( d_o \): bagasse density

This shows the well known influence of the reabsorption factor on the extraction: the higher \( k \), the lower the extraction.

The mill settings must allow the drainage of all the extracted juice. Otherwise, there is lubrication of the rollers by the juice and choking (Fig. 1).

Reabsorption is the phenomenon which occurs when the quantity of extracted juice is higher than the drainage capacity of the grooves.

As the bagasse comes towards the outlet of the mill, the juice drainage is more and more difficult as the bagasse reaches a very high density at this level. Liquid pockets are created which tend to burst out towards the lower pressure places. When this liquid is on the top roller side, it is immediately reabsorbed by the outgoing bagasse. All the energy spent to extract this juice is lost.
It is commonly admitted that the reabsorption factor in a conventional four-roller mill is 1.5. The FCB “Extraction Unit” reduces it to 1.1.

Fig. 1: Conventional mill

DESCRIPTION

The design of the “Extraction Unit” is simple: It is fitted with three rollers only, of the same diameter. One is a feeder roller, the other two (top and bottom) are pressure rollers. There is no hydraulic pressure (Fig. 2).

A bagasse duct is fitted at the outlet of the mill. Its purpose is double:
(a) to drive the bagasse to the next intermediate carrier;
(b) to reduce the reabsorption factor.

All equipment is installed in fabricated steel side frames.

The drive is done preferably through the top shaft. The feed roller is driven by the top roller through a set of torch-cut pinions.

The rollers are fully adjustable, but are in a fixed position when operating.

The juice is drained at the junction between the top and bottom rollers. The slight back pressure induced by the Reabsorption Limiting Device allows the cleaning of the grooves and prevents the juice from flowing with the bagasse.

Two units manufactured by FCB using the principle of the extraction unit are operating since their installation. In 1991, one “pre-extractor” was commissioned, and together with the 1070 x 2300 first mill, it increased the extraction and the capacity. The crushing was 387 tch. The extraction in Pol of this combined preextractor-first mill was 74% (19% fibre).

In 1995, a mill based on the same principle was installed in maximum. It was a two 1048 x 2134 roller mill with a feeder roller of the same diameter. Its maximum design capacity is 65 tfh. We do not develop here the special housings used for this mill, since they were a special design which we do not intend to develop further.

The two sets include a “reabsorption limiting device” (RLD).
ACTION

The extraction unit takes advantage of the reabsorption phenomenon.

Action of the grooves

The reabsorption phenomenon has two known components:

1. The extrusion of the product: Slippage of the product at a higher velocity than the rollers when the drainage capacity of the grooves is exceeded. This is reduced in the extraction unit by using a high draining grooving (35°, Messchaert at each tooth, arcing)

2. The drainage of the juice held at the bottom of the grooves, in the same direction as the product. The grooves are never fully filled by the bagasse because of the friction loads, which prevent a deeper penetration of the product.

The action of the RLD

The Extraction Unit uses this second component thanks to the RLD. The drainage of the juice is done in the same direction as the product. It is collected at the outlet of the rollers where it is separated from the bagasse by two scrapers. This separation is made continuous by creating the conditions of a reduced absorption capacity by the bagasse. These conditions are realised by the back pressure device of the RLD (Fig. 3)

SPECIAL POINTS

No lift of the top roller

To avoid having an erratic conduct of the RLD, it has been found that the scrapers needed to be in a constant relative position and it was decided to keep the top roller fixed. At the same time, this is an advantage for the control of the crushing rate.
Tramp iron and stones

As for any mill, the passage of tramp iron or stones must be avoided. A heavy-duty shredder, though it is not its primary target takes care of the stones; a magnet before the extraction unit takes care of the tramp iron. The “preextractor” has been operating for 7 years now without any trouble caused by big foreign objects.

Variations of rate

The system is more sensitive to the high variations of rate. A correct chute cane height control device is necessary. Most of the sugar factories have such a device installed. The best way is to act on the speed of the equipment to insure the minimum level compatible with the extraction target.

Wear and maintenance

To keep up with the process conditions allowing a greater efficiency of the equipment it is necessary to keep the geometrical parameters of the rollers and the RLD:

- grooving profile
- teeth profile of the scrapers of the RLD
- scheduled rebuilding (arching) of the rollers
- cleaning of the Messchaert grooves

The choice of the hard-facing of the teeth of the scrapers, and the easy access to the wear parts allowed by the new concept of the RLD allow a reasonable maintenance planning for the factories running throughout the year (South America, Kenya, ...)

Minimum preparation level.

As for the other types of extraction equipment, the level of extraction is directly related to the cane preparation level:
- 75% Pol extraction needs 80% POC minimum
- 80% Pol extraction needs 90% POC minimum

ADVANTAGES

- Reduction of the energy per ton of cane from 14 to 30% mill. No energy is spoiled by reabsorption, no friction of the bagasse on the trash plate.
- Extraction over 75% with only two pressure rollers.
- Reduction of the reabsorption factor, the juice being prevented from flowing out with the bagasse.
- Less than 48% final bagasse moisture.
- Reduction of the number of wear parts, hence of the maintenance costs.
- Re-utilisation of the existing drive when an FCB extraction unit replaces an existing mill.
Efficiency

The reduction of the reabsorption factor allows better extraction, all other conditions being equal.

Capacity

For the same extraction, the capacity of an Extraction unit is higher than the one of the equivalent conventional mill. By changing the feeding roller by a heavy-duty toothed feeder, the capacity is almost doubled.

Low energy consumption

Linked to the increase of capacity and performance, the energy consumption is greatly reduced. An extraction unit can always be installed in lieu of an existing mill. For units located in the first or second position, it will be necessary to increase the speed, or to reduce the reduction ratio, thus reducing the torque.

Simplicity

The very simple design of the extraction unit makes it easier to set up and to maintain than a conventional mill. The reduced number of rollers, and elimination of the trash-plate reduce greatly the running costs:

- 2 rollers to re-shell instead of 3 or 5.
- 4 bearings (which will wear less because of the lower loads) instead of 6 or 10.
- 2 scrapers, 2 sets of Messchaert knives instead of 1 set of knives, 2 scrapers, 1 trash plate, no hydraulic pressure.

THE RESULTS

Main features of the operating extraction unit

<table>
<thead>
<tr>
<th>Number of pressure rollers</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of feeder rollers</td>
<td>1</td>
</tr>
<tr>
<td>Mean diameter of the rollers (mm)</td>
<td>1070</td>
</tr>
<tr>
<td>Roller width (mm)</td>
<td>2134</td>
</tr>
<tr>
<td>Roller speed (rpm)</td>
<td>5-10</td>
</tr>
<tr>
<td>Designed capacity (tons of cane per hour)</td>
<td>500</td>
</tr>
<tr>
<td>Nominal capacity (tons of cane per hour)</td>
<td>333</td>
</tr>
<tr>
<td>Minimum design capacity (tons of cane per hour)</td>
<td>280</td>
</tr>
<tr>
<td>Target Pol extraction</td>
<td>80%</td>
</tr>
<tr>
<td>Minimum level of preparation required (POC)</td>
<td>90%</td>
</tr>
</tbody>
</table>

Two sets of measurements have been done:

- One after one year operation, i.e. after 1 million tons of cane
- One after one and a half year of operation (1.5 millions tons of cane).

The second set has been done during the peak of the rainy season, which means in the worst possible conditions (muddy cane, non continuous operation of the mills, etc.).
COMMENTS

The results confirm the calculations.

In the above mentioned operating conditions, the average Pol extraction was very good:

70% Pol extraction with a two-roller mill against 65% with a well operated 3-roller mill with heavy-duty feeder roller.

It is important to mention the following:

The plant was running at a very low rate, at the minimum speed of the drive turbine; the cane rate was not controlled, since the feed control device was not operational; the preparation quality was poor: the preparation index was less than 80%.

Due to the weather, the Messchaert grooves were choked with mud; the rollers had reached the end of their life.

The curves show that in spite of these drawbacks, the Pol extraction was measured over 75%.

COMPARISON WITH 6 ROLLER MILLS

The comparison with 6 roller mills (Table 1 and Figure 4) has been established by the Consultant Engineer of our client.

The difference between the POC and the Pol extraction of the first unit shows that the performance of this unit is similar to that of a six-roll mill.

It is important to emphasise that the extraction unit is a one-nip mill, when the other mills are three-nip mills with trash plates, pinions and hydraulic pressure. The advantages are evident.

The following table is for comparison only.

<table>
<thead>
<tr>
<th>Factory</th>
<th>Extraction Unit</th>
<th>POC</th>
<th>Extr. 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factory 1</td>
<td>Extraction Unit</td>
<td>85.00%</td>
<td>75.00%</td>
</tr>
<tr>
<td>Factory 2</td>
<td>6 roller mill</td>
<td>88.00%</td>
<td>80.00%</td>
</tr>
<tr>
<td>Factory 3</td>
<td>6 roller mill</td>
<td>88.30%</td>
<td>74.00%</td>
</tr>
<tr>
<td>Factory 4</td>
<td>6 roller mill</td>
<td>89.70%</td>
<td>70.00%</td>
</tr>
<tr>
<td>Factory 5</td>
<td>Extraction unit</td>
<td>90.00%</td>
<td>74.26%</td>
</tr>
<tr>
<td>Factory 6</td>
<td>6 roller mill</td>
<td>90.80%</td>
<td>82.00%</td>
</tr>
<tr>
<td>Factory 7</td>
<td>6 roller mill</td>
<td>91.20%</td>
<td>81.00%</td>
</tr>
</tbody>
</table>

Fig. 4: Extraction and percent open cells for various mills
OTHER INFORMATION

Life of the scrapers

The first set to be operated lasted 620,000 tons of cane before being completely worn out. It was decided to rebuild the next one at 400,000 tons of cane. At this stage, the wear was minimal and the teeth could easily be rebuilt with powder alloy.

Imbibition

It is obvious that the best position for imbibition addition is at the outlet of the RLD, just before the expansion of the bagasse.

Incident

After three months operation, some of the bolts fixing the RLD at the back of the mill sheared off. This happened at the same time than a foreign object damage one tooth. In fact, these bolts were designed as fuses, and acted as such. There was no damage at all on the mill housings, and the mill resumed operation after replacing the bolts.

Modification on conventional mills

Various retrofit “pre-extractors” have been tried by others on conventional mills but without success. A general view of a complete FCB unit is shown in Figure 5.

Fig. 5 : General view of an FCB extraction unit
## Comparison of performances: conventional mills - FCB Extraction Unit

<table>
<thead>
<tr>
<th></th>
<th>Standard capacity</th>
<th>Optimal capacity</th>
<th>Power used</th>
<th>Power per tch</th>
<th>Power per tfh</th>
<th>Pol extraction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conventional mills</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 rollers M1</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
<tr>
<td>4 rollers M2</td>
<td>147%</td>
<td>164%</td>
<td>102%</td>
<td>70%</td>
<td>70%</td>
<td>110%</td>
</tr>
<tr>
<td>5 rollers M3</td>
<td>147%</td>
<td>200%</td>
<td>119%</td>
<td>81%</td>
<td>81%</td>
<td>110%</td>
</tr>
<tr>
<td></td>
<td>1 big Ø feeder roller + 2 toothed feeder + chute</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 rollers M4</td>
<td>147%</td>
<td>227%</td>
<td>134%</td>
<td>92%</td>
<td>92%</td>
<td>110%</td>
</tr>
<tr>
<td>6 rollers M5</td>
<td>147%</td>
<td>333%</td>
<td>123%</td>
<td>84%</td>
<td>84%</td>
<td>110%</td>
</tr>
<tr>
<td></td>
<td>1 feeder + 2 big Ø feeder rollers + chute</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Extraction Units</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 rollers U1</td>
<td>140%</td>
<td>200%</td>
<td>60%</td>
<td>43%</td>
<td>43%</td>
<td>117%</td>
</tr>
<tr>
<td>5 rollers U2</td>
<td>333%</td>
<td>476%</td>
<td>81%</td>
<td>24%</td>
<td>24%</td>
<td>117%</td>
</tr>
<tr>
<td></td>
<td>1 big Ø feeder roller + 2 toothed feeder + chute</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
OPTIMIZACION DE LA EXTRACTION DE JUGO DE CANA CON USO OPTIMO DE ENERGIA

P. Bonin and O. Govaert
Sugar Department, 2 Bd de L'usine, B.P. 2047 - F 59015 Lille Cedex, FRANCE

RESUMEN

Con el propósito de reducir los costos de operación, la demanda de potencia y al mismo tiempo para mejorar la eficiencia del taller de molienda, la compañía FCB ha desarrollado varios equipos, y entre ellos está la "Unidad de Extracción", la cual posee las siguientes ventajas:

- Reducción de la energía por tonelada de caña extremadamente 30% comparado con molinos convencionales de 4 mazas. La energía no es desperdiciada por reabsorción y el bagazo no ejerce fricción en la cuchilla central.
- La extracción es sobre 75% con sólo dos mazas de presión.
- Reducción del número de partes desgastadas, así la reducción de costos de mantenimiento.
- Re-utilización de el equipo motriz cuando una unidad de extracción de la FCB reemplaza un molino existente.

Palabras Claves: Extracción, optimización del molino, energía.

OPTIMISATION DE L'EXTRACTION DU JUS DE LA CANNE AVEC UN OPTIMUM USAGE DE L'ÉNERGIE: LA UNITÉ DE LA FCB EXTRACTION

P Bonin et O Govaert
Le Département de Sucre, 2 de Bd L'Usine. B.P. 2047 – F 59015
Lille Cedex, France

RÉSUMÉ

Réduire les coûts courants, le demande du pouvoir et aussi FCB a développé une «Unité» de l'Extractions pour améliorer l'efficacité de la maison de métier de meunier, les avantages de qui est:

- Réduction de l'énergie par tonne de canne par 30% comparés à un moulin conventionnel de 4 rouleau. Aucune énergie n'était pas gâté par réabsorption, aucun frottement de la bagasse sur la plaque des ordures.
- Extraction sur 75% avec seulement deux rouleaux de la pression.
- Réduction de facteur de la réabsorption, le jus qui est prévenu de couler dehors avec la bagasse.
- Réduction du nombre de parties de port, ainsi des coûts de l'entretien.
- Ré-utilisation de la promenade existante quand une Unité de FCB extraction remplace un moulin existant.

Mots-clés: Extraction, Optimisation de moulin, énergie.