PERFORMANCE OF A LAST MILL WITH ASSIST DRIVE

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ABSTRACT

With the adoption of a combined drive (turbine & hydraulic motors) for a four roll mill it has been possible to experiment in the search of better performance in individual extraction and final bagasse moisture and also to assess the power split and total energy consumption. This Paper looks at general performance of a final mill that was fitted with an "assist drive" in order to diminish the power handled by the turbine gearing when crushing rate grows.

Keywords: Sugar cane, crushing mills, hydraulic drives, power consumption, Colombia.

INTRODUCTION

The conventional three roll mill with an underfeed roll is the typical unit of a Colombian milling tandem. Every mill of this kind has a fixed ratio between top and underfeed rolls and the drive, either turbine or hydraulic motor, uses the crown gears to split the power to feed and delivery rolls. The engineering project of a sugar mill for solving problems at enclosed gearboxes using the "assist drive" generated the need for experimenting to look for optimal conditions for individual extraction and final bagasse moisture, taking advantage of the flexibility of the new system.

The results reported below correspond to an intermediate stage of the project where both feed and delivery rolls of mill No. 6 were driven by individual hydraulic motors leaving top and underfeed rolls to the existing turbine. After this experimental stage, only one motor is going to be kept at that mill and the other will be installed at mill No. 1. One of the objectives of the experiments was also to show, using operational and energy results, which roll at mill No. 6 will keep its individual hydraulic drive.


Hydraulic drives have been in use at crushing mills in the Colombian sugar industry since 1987 mostly acting through the final gears. So far, 10 units are being driven by hydraulics at that location (indirect drive) and one uses two motors at each side of the top roll shaft (direct drive). Two more mill units (2.13 m) are close to be commissioned with a hydraulic motor located at the feed roll shaft after the results of the project this Paper is about showed that is the best location.
MATERIALS AND METHODS

A conventional four roll mill (1.16x2.13 m) was modified to include individual hydrostatic motors (MB 1600) for feed and delivery rolls. Top and underfeed were driven by the existing turbine. Each hydraulic motor has an installed power unit of 350 kW, a specific torque of 1600 N-m / Bar and a maximum working pressure of 350 Bars. Figure 1.

![2.13 Mill with hydraulic motors at feed and delivery rollers](image)

Ingenio Providencia has an average crushing rate of 7800 tons of cane per day with average fibre of 13.5%. Cane is being prepared at about 72% open cell with a leveller knife and two “swing back” machines knifing over the carrier in the same direction of cane flow. Mill No 6 is fitted with chute height control by changing turbine speed and hydraulic motors control was designed to keep feed roll / top and delivery / top roll rpm ratios.

The monitored variables were the following:
- Top roll lift (using LVDT)
- Final bagasse moisture (on line, NIR)
- Working pressure at feed and delivery hydraulic motors.
- Power consumption (electrical) of hydraulic units.
- Tail bar torque (SRI’s Torque Monitoring System).
- Turbine chest pressure.
- RPM at each roll shaft.
- Crushing rate (using on-line mass balance).

The following operational variables were taken as being dependent:
- Final bagasse moisture.
- Individual mill extraction
- Total power consumption.
- Ratio between power consumption of feed and delivery rolls
- Reabsorption coefficient.
- Filling ratio.

As a first approach a factorial experimental design (3^2) was chosen using rotational frequency ratios (Feed/ top and Delivery/top rpm ratios) (Table 1, stage 1) and the factors and levels were chosen according to previous experiences (Muñoz et al 1995) (Abon 1987). Figure 2 shows a review of this references together with initial approach. Each set of conditions was run during 6 hours and three groups of samples (Mill No. 5 and mill No. 6 bagasses, juices etc.) were taken every two hours. Bagasse analysis was carried out following Method No 5 of the Australian Standard Laboratory Manual.
Table 1: Experimental Designs RPM RATIOS

<table>
<thead>
<tr>
<th>Condition</th>
<th>RPM feed roll</th>
<th>RPM delivery roll</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RPM top roll</td>
<td>RPM top roll</td>
</tr>
<tr>
<td>Stage 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>2</td>
<td>0.8</td>
<td>1.0</td>
</tr>
<tr>
<td>3</td>
<td>0.8</td>
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</tr>
<tr>
<td>4</td>
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<td>0.8</td>
</tr>
<tr>
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<td>1.0</td>
<td>1.2</td>
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<tr>
<td>7</td>
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<tr>
<td>8</td>
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<td>1.0</td>
</tr>
<tr>
<td>9</td>
<td>1.2</td>
<td>1.2</td>
</tr>
<tr>
<td>Stage 2</td>
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<td></td>
</tr>
<tr>
<td>A</td>
<td>0.9</td>
<td>0.85</td>
</tr>
<tr>
<td>B</td>
<td>0.9</td>
<td>1.05</td>
</tr>
<tr>
<td>C</td>
<td>1.1</td>
<td>1.05</td>
</tr>
<tr>
<td>D</td>
<td>1.1</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Fig. 2: Conditions evaluated by different authors: Ratios Feed/top, Delivery/top
Using response surface a new set ($2^2$) of conditions were chosen (Table 1, Stage 2) and every condition was kept during an eight hour period sampling every two hours. The two best conditions (B and C) were repeated, each one for a full crushing day. Finally to the best condition (C) another control loop was applied to keep a selected working pressure set point by means of small adjustments in feed roll rpm.

**ANALYSIS OF RESULTS**

A commercial code (MatLab 1996) was applied to experimental results. At the first stage of the tests important differences were found from the three-dimensional representation of results (See Figure 3), and it was noticed that the best extraction figures were obtained with a feed roll running faster than the top one while the delivery roll was running slower. From Figure 3, best ratios for mill extraction were 1-1.2 and 1-1 (top/feed and top/delivery speeds respectively). Surprisingly, from the same plot, it was found that the lowest extraction values correspond to ratios 1-1 and 1-1, those typically obtained in conventional three roll mills. The results of the first stage led to a second experimental design where the best ratios for mill extraction were 1-1.1 and 1-1.05 respectively. A small increase in either the feed and/or the delivery speed roll allow to obtain an increase of the mill extraction (See Figure 4).

![Fig.3](image1.png)  ![Fig.4](image2.png)

**Fig.3** : Effect of roller speed ratios on the individual last mill sucrose extraction.  
**Fig.4** : Effect of roller speed ratios on the individual last mill sucrose extraction during second stage of the tests.

The moisture of the final bagasse is a main parameter at any sugar factory due to the strong effect on efficient steam generation. Bagasse moisture during the tests was the parameter that showed better repeatability in addition to noticeable differences among every tested condition.

Through the tests the highest values of bagasse moisture were obtained when minimum delivery roll speed was set (1-0.8 top/delivery), while the lowest values were obtained when maximum delivery roll speed was (1-1.2 top/delivery). This marked difference showed that the speed of the delivery roll have the main effect on the moisture of the bagasse (See Figure 5), while the speed of the feed roll have lesser effect, but it could be noticed that moisture decreases slightly when the feed roll frequency is higher.
Reduction of final bagasse moisture rendered a gain of 460 KJ/Kg fuel caloric value and gave a more stable steam generation process.

Overall power consumption at the last mill was calculated from power requirements on the steam turbine, measured at tail bar plus power spent by hydraulic motors measured by pressure transmitters at inlet ports. It was also considered the total steam flow needed to drive the whole system, using turbine steam flow and electric power consumption of hydraulic units converted to steam by means of specific consumption of turbines at power plant. These values were measured or calculated and added on-line to make simple comparison of different conditions.

Test results showed how roll speed ratios have a great influence on the mill power consumption (See Figure 6). The highest values were obtained when maximum delivery speed ratio was 1.2 (delivery/top) and lowest values were obtained when delivery speed ratio was minimum (0.8 delivery/top). The great difference shows that delivery roll speed affects power consumption in a stronger way compared to feed roll speed. However, the increase on the speed of the feed roll also brings a lesser but still important increase on mill power consumption. In a general way, crushing power increases as speeds of either the feed and/or delivery rolls go up.

Fig.5 : Effect of roller speed ratios on the moisture of final bagasse.

Fig.6 : Effect of roller speed ratios on the milling power required.
As average values for the C condition, feed roll power consumption was 32.36% of total power, delivery roll 30% and the turbine was delivering 37.64%. Previous experiences at Colombian factories trying to establish how the mechanical power is distributed among the different components of a conventional three roll mill had showed that most of the time the delivery roll need more power than that of the feed roll (Gómez et al 1995) (Montoya et al 1997). From tests conducted on this final mill it was found that power consumption is affected strongly by rpm ratios in such a way that, for example, when the feed and delivery rolls were faster than top roll they needed the most of total power and the turbine seemed to work almost free, and when the feed and delivery rolls were slower than top roll, the turbine presented the highest values of power demand during the tests period. That performance matches with previous research results about power consumption for each roll being directly proportional to their velocity (Abon, 1985).

A comparison of the ratio between feed and delivery roll power requirements during the tests is presented in Figure 7 where a comparison is also being made with previously published values (Muñoz, Abon).

![Figure 7](image)

**Fig. 7**: Comparison of the ratio of feed and delivery consumed power against results obtained previously by other authors.

![Figure 8](image)

**Fig. 8**: Performance of individual mill power demand through one hour of continuous milling.
Finally, with best ratios an increase on last mill extraction of 15% was achieved and a maximum on global extraction increase of 0.47% was made possible.

CONCLUSIONS

- The flexibility of the individual drives to operate on a wide range of speed, combined with use of experimental techniques allowed the identification of near optimum operating conditions for milling efficiency.
- Differences of roll surface speeds generate an increase of the total power consumption and depending on the specific steam consumption at the turbines driving the alternators, steam consumption could be increased.
- Speed ratios between rolls have strong effects on the power consumption and its distribution among the rolls. In general, mechanical power requirements increase as the speed ratios are higher.
- Better extraction, moisture and energy results have been obtained with rolls running at different RPM and consequently peripheral speeds so it is suggested to get deeper into more applied and fundamental research looking for new designs and operational improvements in milling technology.

REFERENCES


COMPORTAMIENTO DEL ULTIMO MOLINO CON MOVIMIENTO ASISTIDO

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RESUMEN

Con la adopción de un movimiento combinado (turbina y motores hidráulicos) para un molino de cuatro rodillos, a sido posible experimentar en la búsqueda de mejor operación de extracción individual y humedad final del bagazo, y también, para valorar la división de potencia y energía total de consumo. Este estudio examina el comportamiento general de un molino final que fue adaptado con un "movimiento asistido" en orden a disminuir la potencia consumida por el engranaje de la turbina, cuando la molienda aumenta.

Palabras Claves: Azúcar de caña, molinos de molienda, movimiento hidráulico, consumo de potencia, Colombia.

LA PERFORMANCE DU DERNIER MOULIN

AL Vivas et al

RESUMÉ

Les moulins avec quatre cylindres peuvent être conduits par des transmissions combinées (turbine/moteur hydraulique). On a expérimenté pour trouver des meilleures performances en terme d'extraction et d'humidité de bagasse. On aussi considère l'énergie. Ce papier donne des résultats sur la performance d'un dernier moulin avec transmission assistée pour réduire l'énergie.