EXPERIENCES WITH "TWO ROLL" CRUSHING MILLS COMPUTER MODELLING AND EVALUATION

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ABSTRACT

This paper presents a summary of operational results of two milling units configured to work as "two roll" mills. The delivery roll was retired from the last unit of a 4 roll tandem and arrangements were made to keep track of operational performance and energy consumption. The first unit (a two roll crusher) of a tandem with crusher and six mills was fitted with an underfeed roll since April 1996 and the average results are also reported. Finally, experience gained in Finite Element Analysis (FEA) modelling of cheek for failure analysis and improvements has been used for prediction of structural performance when a conventional mill was modified for trials as "two roll" mill.

Keywords: Finite element modelling, crushing, two roll mill

INTRODUCTION

Some of the efforts cane sugar industry is developing toward production cost reduction must include focusing on milling efficiency improvements and maintenance and/or energy savings. Conventional milling is both energy and maintenance intensive and several proposals have been presented in order to reduce those expenses. Technical feasibility of arrangements, different from the typical 6 roll mill of the Australian sugar industry, has been shown (Edwards 1987). Besides the two-roll experimental mill showed quite acceptable extraction performance (Murry 1960).

The two roll mill is an interesting alternative at least for intermediate units in a milling train, provided that an adequate final extraction is obtained.

Experience gained in Failure Analysis and improvement of mill cheeks is now oriented toward prediction of structural performance of a conventional three roll mill, simplified to operate as a two roll mill.

MATERIALS AND METHODS

A small crushing unit (0.76 x 1.22 m) was modified for trials to evaluate operational and energy performances. Delivery roll was suppressed and the remaining rolls were set in order to keep crushing rate, extraction and bagasse moisture. Figure 1 shows drawings of the complete mill and details of the discharge scrapers. A set of pressure, temperature and flow transmitters were used to assess thermodynamic variables. Operational results such as final bagasse moisture and individual mill extraction were taken in a routine basis.
Figure 1. Conventional mill without delivery roller. a) General view, b) Scrapers
A conventional crusher (0.9 x 1.68) was fitted with an underfeed roll (Figure 3) and the unit has been monitored during 2 years for extraction and energy results.

Two different cheek designs have been analysed using FEA. Both are of 2.13 m. rolls, one of cast steel (1.17 x 2.13 m), Design A, and the other of welded construction (1.12 x 2.13 m), Design B. A comparison using strength criteria was done and the weakest one was chosen for experimental stress analysis and the strongest one for modelling the simplified mill.

The loads generated by milling process were calculated using the Australian approach (Murry 1960, 1996), (Russell 1968). Some experiences in measurement of load sharing between feed and delivery rolls have been considered in the analysis (Gómez 1995,1997). The power consumption by underfeed roller was measured using strain gauges and an approximate fraction of total milling power was defined.

A commercial computer code (Algor 1997) has been used for FEA modelling and analysis and some experimental measurements were carried out using strain gauges bonded to several points on the cheek in order to check the model predictions.

**ANALYSIS AND RESULTS**

A summary of performance results of the 0.76 x 1.22 mill without the delivery roll is presented in Figure 2.

![Graph](image)

**Fig. 2:** Some results of mill without delivery roller

The mill had a very short Donelly chute and because of some occasional bridging events the test period was only of ten days between routine maintenance. After that period the mill was set to its normal configuration.
In order to increase the share of the two roll crusher (0.90 X 1.68m) in total extraction at tandem A of Ingenio Manuelita the unit was fitted with underfeed roll as shown in Figure 3. Cane is being prepared by one leveller knife and two conventional knifing machines. Some preparation measurements allow to assess a typical percentage of Open Cells (POC) of 65 % and a Treatment Number of 0.95. The unit average extraction before the upgrade was 40 % compared to a current average of 65%. Energy consumption of that unit is now 66%, in the average, compared to an initial figure of 60% of one of the other 6 mill in the train, see Figure 4.

Fig.3 : Modified two roller crusher
Fig. 4: Results of crusher without and with delivery roller

The more developed method for milling loads calculation has been used and it can be observed that loads are strongly affected by Cf or filling ratio and a prediction does not match too well with some experimental results about how the loads are shared by feed and delivery rolls. For comparison purposes the same approach and the same cane figures were used for stress prediction in both designs.

**Finite Element Analysis** (FEA) results allowed to select the strongest cheek, Design A (Maximum values were 65523 kPa compared to 131046 kPa for Design B). In both case, maximum stresses were located at delivery side, see Figures 5 and 6.
Figure 5. Predicted stresses for design A, normal configuration.
   a) General view. b) Delivery side.
FEA results for simplified mill showed a maximum of 75869 kPa somewhat higher than the conventional loading and located at feed side, see Figure 7.

Fig. 7: Predicted stresses for design A without delivery roller.
   a) General view, b) Feed side, highest loaded points
Experimental Stress Analysis Previous FEA models of the frame were used to locate strain gauges see Figure 8. One axial strain gauge was used to measure tension stresses on the upper delivery region, external face of non-drive side, a second axial gauge was used to estimate the arm bolt preloading of the delivery side arm bolt. A rosette type gauge was placed near to the support plate of the top roll, see Figure 9.

Fig.8: Frame, design B, exploded view
Strain Gauge results The strain gauge in the arm bolt measured a preload stress of 113.7 MPa (16,500 psi) equivalent to a clamping force of 1240.3 kN (278,850 lb). During crushing, a value of 137.5 Mpa (19,950 psi) was measured, equivalent to a load of 1499.6 kN (337,155 lb).
The difference in these two values can be used to estimate the horizontal force due to the delivery roll. The frame arm can be solved as an articulated hinge. The following diagram shows the model to be solved, see Figure 10.

Fig.10: Horizontal forces calculation from arm bolt stresses

Pe can be calculated from the strain difference during crushing and the equivalent stiffness of the joint. Rdx estimated by this method is equivalent to 1534.85 kN (342,799.5 lb) compared to a calculated value of 1,689 kN (379,733 lb). This estimation can be done in all four-arm bolts in order to measure horizontal reactions on the feed and delivery rolls; such method may be used to obtain frame loads.

Recorded values for the strain gauges are shown in Table 1. Values are averages from 36 values for each strain gauge recorded in a 45 minute period.

### Table 1: Strain gauge measurements

<table>
<thead>
<tr>
<th>Strain Gauge 1</th>
<th>Strain Gauge 2</th>
<th>Rosette 3 I</th>
<th>Rosette 3 II</th>
<th>Rosette 3 III</th>
</tr>
</thead>
<tbody>
<tr>
<td>119</td>
<td>665</td>
<td>-18</td>
<td>61</td>
<td>194</td>
</tr>
</tbody>
</table>

Strain gauge 1 model results indicate tension for all three FEA models. Rosette gauge No. 1 recorded compression values. The 2D model and the 3D load case 2 models predict a compression strain value much higher than the actually recorded. This indicates that the loads probably are distributed towards the inner portion of the support plate. The third rosette gauge recorded a tension strain value higher than the value predicted by the FEA models, see Table 2.

### Table 2: 2D and 3D model results vs. Strain gauge results

<table>
<thead>
<tr>
<th>Date</th>
<th>Strain Gauge 1</th>
<th>Rosette 3 I</th>
<th>Rosette 3 II</th>
<th>Rosette 3 III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurements</td>
<td>119.0</td>
<td>-18.0</td>
<td>61.0</td>
<td>194.0</td>
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<tr>
<td>2D model</td>
<td>88.0</td>
<td>-99.0</td>
<td>-7.0</td>
<td>93.0</td>
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<tr>
<td>3D model load case 1</td>
<td>65.0</td>
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<td>104.5</td>
<td>105.4</td>
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<tr>
<td>3D model load case 2</td>
<td>115.6</td>
<td>-127.2</td>
<td>-3.5</td>
<td>139.0</td>
</tr>
</tbody>
</table>
CONCLUSIONS

FEA is a powerful design tool and can be used to support new mill design proposals. A typical failure analysis approach compared two different cheek designs and showed how the absence of preloading of through bolting makes a hinged design weaker. FEA showed that modified mill proposal could be tried without strong increases in stresses on the structural parts of the mill.

By means of simple experiences linked to more fundamental analysis, it has been possible to reinforce the general idea about "Two Roll" mill potential in energy and maintenance savings without significant impact on operational results.

More applied research will be needed to convince mill engineers about "Two Roll" mill advantages. More comprehensive and prolonged trials are suggested in order to assess the cost-benefit approach.

REFERENCES


Murry, C.R.(1960)."A theoretical and experimental investigation into the mechanics of crushing prepared sugar cane, University of Queensland, PhD Thesis.


EXPERIENCIAS CON MOLINOS TRITURADORES DE DOS RODILLOS: MODELAR Y EVALUACIÓN

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RESUMEN

Este estudio presenta un resumen de resultados operacionales de dos unidades de molienda configuradas para trabajar como molinos de "dos rodillos" El rodillo de maza bagazera fue removido de la última unidad de un tren de 4 molinos y se hicieron arreglos para medir el comportamiento operacional y el consumo de energía. La primera unidad (un triturador de dos rodillos) de un tren con un triturador y seis molinos fue adaptado con un rodillo de alimentación de cuarta maza desde Abril del 1996 y el resultado promedio también se reportó. Finalmente, experiencia ganada en un modelo de la virgen en FEA para probar análisis de fallo y mejoras ha sido usado para predicción de comportamiento estructural cuando un molino convencional fue modificado como un molino de dos rodillos" para propósito de pruebas.

Palabras Claves: Modelo de elemento finito, Triturador, Molino de dos rodillos.

MODÉLISATION PAR ORDINATEUR D'UN MOULIN AVEC DEUX CYLINDRES

E Oliveros et al

RESUMÉ

On présente les résultats obtenus avec deux moulins configurés pour travailler avec deux cylindres. On a enlevé un cylindre du dernier moulin et on a noté la performance et la consommation d'énergie. La première unité (crusher deux cylindres) d'un tandem avec crusher et six moulins a été étudié et les résultats sont donnés. Finalement on commente sur la modélisation FEA pour détecter des fissures et pour prédire la performance, dans un moulin modifié pour opérer avec deux cylindres.