DEVELOPMENT OF THE BUNDABERG TWO-ROLL MILL

By

D.B. BATSTONE¹, R.J. HATT², B.D. EVANS² and G.E. MITCHELL¹

¹Bundaberg Sugar Ltd, Brisbane, Australia
²Bundaberg Foundry Engineers Ltd, Bundaberg, Australia

Abstract

The development of the Bundaberg High Extraction Mill (BHEM) from a small-scale prototype is described. A commercial-scale prototype has completed four seasons as the second mill in the tandem at the Bingera sugar factory (3.5 Mt cane crushed). Three other units make up the Tableland syrup factory tandem and have crushed 1.2 Mt of cane to the end of the 2000 season. The BHEM is a patented¹ configuration of two rolls with axes of rotation on a horizontal plane. The cane or bagasse to be crushed is presented vertically from a chute above the rolls. The juice drains equally from both rolls and flows down in the same direction as the rolls. Development progressed through three stages: small-scale experimental unit, working prototype at Bingera, Tableland Mill tandem. The two-roll mill research, development and extension effort was embedded in a project to establish sugar milling facilities in a new, highly productive cane growing area. The priority was to reduce the capital, operating and maintenance costs of milling. As a sub-component of a commercial project, the BHEM development process benefited from a clear objective, tight deadlines and timely funding.

Two-roll crushing of sugarcane

The Tableland factory west of Cairns in North Queensland, Australia, was conceived as a relatively small, low-cost operation supplying syrup to the established sugarcane factories on the coast. The challenge was to build a new factory for considerably less than the cost of expanding established factories. Alternatives to effective but expensive conventional six-roll mills had to be considered.

If reabsorption were no worse, two rolls would extract the same quantity of juice as a conventional mill, if the density of fibre in the delivery nip was the same in both cases (Murry, 1998). According to volumetric theory, rolls of conventional length but larger diameter should be able to achieve typical delivery-nip fibre densities in one pass. However, free drainage of juice from the one feed zone and nip of a two-roll mill is essential to compensate for the multiple zones of pre-compaction and juice drainage in a six-roll mill.

BHEMs were conceived as operating with nip compactions (fibre densities) similar to those of the final nip of conventional mills. The alternative ‘Low Pressure Extraction’ approach of Leibig (1987) was acknowledged but not adopted. Xu Si-Xin and Gu Yu-Keng (1996) published results for a further variation that had a large bottom roll, and a moderately loaded top roll in an inclined housing. Feeding was assisted by a lightly constructed underfeed roll. The arguments for low-pressure milling are unconvincing when matched against theory and practice that confirm extraction increases as density of the fibre in the delivery nip increases and the need to design crushing rolls for inevitable high-load events.

BHEM design was influenced by previous experience of one of the authors (Batstone) with multi-twin roll mills linked by pressure chutes. Reid and Tait (2000) have described the evolution of two-roll mills of this type. The difficulty of mixing imbibition liquid with bagasse in the closed chutes became a critical problem on larger capacity equipment. Closed chutes also prevent bypassing of any one pair of rolls that might have a mechanical problem. The free fall of bagasse into and from rolls that are horizontally opposed overcomes both problems.

BHEM configuration

Figure 1 illustrates the small scale experimental BHEM and commercial scale prototype BHEM used during the development phases of the mill. The configuration of rolls, feed chute, discharge chute and juice collection trays are shown along with some basic specifications.

Small-scale testing

The small-scale experimental unit in Figure 1 has the same roll diameter and width as an experimental unit at the University of Queensland that was used for many years to investigate the mechanics of crushing sugarcane. The extraction performance of this unit is very well documented in a series of PhD theses, especially Murry (1960). The objective of small-scale testing was to evaluate extraction performance at a modest cost before a decision was made to build a commercial-scale prototype.

The results in Figure 2 for prepared cane were very reassuring. Roll speed had much less effect on juice extraction for the vertical feed BHEM unit than the horizontal feed University rolls. Feeding to the BHEM unit was unassisted. The University rolls were fitted with a servo-controlled ram that presented a pre-compressed block of feed to the rolls.

KEYWORDS: Crushing, Sugarcane, Reabsorption, Extraction, Drainage, Milling.

¹US Patent No 6,039,276. Applications in all major countries.
Free drainage of juice, in the same direction as the rolls is suggested to be the main reason for higher extraction. Lower average reabsorption factors at similar compactions compared to the University results provided further evidence of superior juice drainage.

The results of small-scale testing during the 1996 season were sufficiently encouraging to justify building a commercial-scale prototype for testing prior to installation in the proposed Tableland factory due to be commissioned in the 1998 season. Figure 3 illustrates the test arrangement at Bingera factory.

**Commercial-scale testing**

The commercial-scale unit was designed to crush the then maximum anticipated rate for the Tableland factory of 180 t cane/h. The nominal rate for Bingera is 400 t cane/h. Therefore, provision was made for varying the feed to the prototype. Any bagasse not passing through the prototype would bypass to the next mill in the tandem. The arrangement allowed testing at extreme rates, with varying amounts of imbibition and different modes of application. A comparison could also be made with data from
previous season operation of a conventional six-roll mill replaced by the prototype.

Comparative bagasse moisture results as a function of compaction are illustrated in Figure 4. The six-roll data came from the 1996 season and the two-roll data from 1997.

The enhanced drainage performance is again apparent. Figure 5 illustrates the suggested differences in drainage from BHEM compared to a conventional six-roll mill.

The end of August 1997 had been set as a deadline for a go/no-go decision on using the new two-roll crusher for the Tableland project. The pressure on the design, manufacturing, installation, commissioning and testing teams was intense as crushing commenced in early June. The same pressure was applied for manufacture and installation of three units for the start of mechanical testing in April 1998 at the new Tableland mill. A decision was made to retain the commercial prototype at Bingera and operate Tableland with a three mill tandem to provide more opportunity for systematic investigation of the promising new crusher.

Table 1 summarises the nature and extent of testing, evaluation, investigation and analysis.

The factory test work followed procedures in general accordance with Method 5 of Volume 2 of the Laboratory Manual for Australian Sugar Mills (BSES, 1991). The procedures reduce the variability of results from sampling and analysis of prepared cane, bagasse and juice and the natural variability of the cane supply and factory operations. Figure 6 illustrates one series of tests in which mill performance was measured at different speeds. Each test was paired in that the sampling and measurements were done on cane from the same block on the same day for the two speeds. The 24 hour harvesting and supply of cane direct from field to the tipping station at the mill satisfies the need to use identifiable parcels of cane (in excess of 20 t) for mill testing. Collection of test data was enhanced by the factory control system which has been set up with comprehensive sensors and data logging facilities as part of the distributed control system.

Extensive testing and data logging has provided a sound working knowledge of BHEM operational characteristics.

BHEM characteristics

Capacity-extraction

Assuming drive torque is not limited and roll surfaces are suitably rough, crushing rate is ultimately limited by drainage capacity as all the juice is expressed at one nip. As the total mass rate of fibre and juice presented to the mill increases, the percentage of juice extracted gradually falls. The paired trials in Figure 6 illustrate this characteristic. Extraction is generally higher than conventional mills operating at the same nip compaction due to lower reabsorption.

Operation-setting

With one floating, hydraulically-loaded roll, a BHEM tandem is essentially self setting over a wide range of crushing and imbibition rates. A turn-down ratio of more than 50% is possible at the Tableland Mill. More significantly, a BHEM tandem has a high turn-up ratio as crushing rate may be increased to the
Juice pools causing reabsorption via grooves

Fig. 5—Drainage from BHEM rolls and a conventional six-roll mill.

Table 1—Development activities.

<table>
<thead>
<tr>
<th>Resource</th>
<th>Period</th>
<th>Activities</th>
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<tbody>
<tr>
<td>Small-scale experimental</td>
<td>1996–1999</td>
<td>• Extraction performance</td>
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<td>• Feed performance</td>
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<td>• Scale-up parameters</td>
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<td>Commercial prototype at Bingera</td>
<td>1997–2000</td>
<td>• Comparative performance</td>
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<td>• Capacity limits</td>
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<td>• Torque relationships</td>
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<td>• Component wear investigations</td>
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<td></td>
<td></td>
<td>• Feeding performance relationships</td>
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<tr>
<td>Tableland tandem</td>
<td>1998–2000</td>
<td>• Milling relationships e.g. cane and fibre rate, speed, compaction, pol in open cells, torque, extraction, bagasse moisture, reabsorption, crushing factor, imbibition coefficient</td>
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<tr>
<td></td>
<td></td>
<td>• Imbibition effects</td>
</tr>
<tr>
<td>Computer analysis and simulation</td>
<td>1997–1998</td>
<td>• Finite element analysis (FEA) of bagasse and juice flows</td>
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<td>• Design FEA</td>
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<td>• Performance modelling</td>
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<tr>
<td>Laboratory</td>
<td>1998–2000</td>
<td>• Permeability and shear strength measurement to develop a relationship with feed performance (Williams, et al (2001))</td>
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<td>• Groove packing tests</td>
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Fig. 6—Tableland Mill: 1999 paired trials.
limit of the available drive power, if a fall-off in extraction can be tolerated. BHEM units have been shown to handle dry feed well. This reduces the need for sophisticated control of maceration and makes them suited for duty as auxiliary dewatering mills. As might be expected with only two rolls, the operation of a BHEM is very simple compared to a six-roll mill. The principal requirement is feeding without gaps. The same is true of conventional three, four and six-roll mills but as there is only one nip and therefore no inter-nip accumulation in a two-roll mill, the adverse effects of any 'holes' in the feed are greater.

**Energy consumption**

BHEM roll load-torque characteristics are similar to well-established relationships for roll pairs. With only one pair of rolls and associated scrapers, no turn plate and no pressure chute, BHEM energy consumption is significantly lower than conventional mills.

**Conclusions**

Reduced capital expenditure was a key requirement for financial viability of the Tableland project.

BHEM development has been one of the innovative components of the Tableland mill that has achieved a 40% reduction compared to the typical investment in factory expansion in Australia. Benefits are also being gained in lower operating and maintenance expenses. Embedding the BHEM development project in a commercial project provided resources that are rarely available for research and development. Deadlines and milestones were real and resulted in an exceptional intensity of effort by Bundaberg Sugar Ltd and Bundaberg Foundry Engineers Ltd staff.

**Acknowledgments**

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**REFERENCES**


DESARROLLO DEL MOLINO BUNDABERG DE DOS MAZAS

D.B. BATSONE¹, R.J. HATT², B.D. EVANS² y G.E. MITCHELL¹
¹Bundaberg Sugar Ltd, Brisbane, Australia
²Bundaberg Foundry Engineers Ltd, Bundaberg, Australia

Resumen

Se describe el desarrollo del Molino de Alta Extracción Bundaberg (BHEM) partiendo de un pequeño prototipo a escala. Un prototipo a escala comercial ya ha completado cuatro zafras como segundo molino del tándem del Ingenio Bingera (3.5 Mt caña molida). Otras tres unidades conforman el tándem de la fábrica de sirope Tableland y completaron una molienda de 1.2 Mt de caña al final de la zafra del 2000.

El BHME es una configuración patentada de dos mazas con ejes de rotación alineados sobre un plano horizontal. La caña o el bagazo entra al molino verticalmente a través de un chute ubicado sobre las mazas. El jugo es drenado igualmente por ambas mazas y fluye a ambos lados en dirección de las mismas.

El desarrollo se efectuó en tres etapas:
1. Unidad experimental a pequeña escala.
2. Prototipo trabajando en Bingera.
3. Tándem de molinos en Tableland.

La investigación, desarrollo y extensión del diseño estuvieron comprendidos en un proyecto que busca establecer fábricas azucareras en una nueva zona de cultivo de caña altamente productiva. La prioridad fue reducir los costos de capital, operación y mantenimiento asociados al proceso de molienda. Como sub-componente de un proyecto comercial, el proceso de desarrollo del BHEM se benefició de un objetivo bien definido, un cronograma ajustado y oportuna financiación.

Palabras claves: Molienda, caña de azúcar, reabsorción, extracción, drenaje.