
MILLING AND DIFFUSION EXTRACTION—THEORY AND PRACTICE

By

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Abstract

AN ENGINEERING Workshop was held from 21 to 24 November 2006 in Veracruz, Mexico. Forty delegates from 12 countries attended the workshop on theory and practice of milling and diffusion extraction. This report provides a general overview of activities undertaken during that workshop which consisted of five technical sessions over two days with presentations and discussions plus two days of field and factory visits. Topics covered during the technical sessions included: power transmissions, cane preparation, diffusers, mills, and a comparison of milling and diffusion.

Introduction

Under the auspices of the Engineering Section of ISSCT, the Mexican Association of Sugar Cane Technologists (ATAM) and the University of Veracruz, a workshop on 'Milling and Diffusion Extraction – Theory and Practice' was held in Unidad de Servicios Bibliotecarios e Informaticos USBI in Veracruz, Mexico from 21 to 24 November 2006.

The workshop consisted of two days of technical presentations and discussions and two days of visits. A total of 20 presentations were made during the workshop by the 40 registrants from 12 countries. As is usual with ISSCT workshops, no formal papers from the participants and no proceedings of the workshop were produced, so as to encourage informal exchanges of ideas and discussions. All the presentations were compiled on a CD, which was available to all the participants

Objectives

The main objectives of the workshop were:

- To interchange knowledge and understanding from extraction engineers from around the world and to encourage communication and collaboration.
- To discuss, compare and review all aspects of design, operation, maintenance and control of milling and diffusion extraction processes.
- To identify the future directions of extraction processes and the development and/or research required to achieve these outcomes.

Opening session

The welcome address was delivered by Mr Manuel Enriquez Poy, vice president of ATAM and the coordinator of the workshop, who explained the details of the organisation of the event. Juliusz Lewinski, chairman of the engineering and energy section of ISSCT, explained the objectives of the ISSCT workshop and its mechanics. The formal inauguration of the workshop was done by Mr Roberto Bravo from the University of Veracruz who confirmed the support of his institution for the sugar industry in Mexico and for the workshop, wishing to all the participants the best results from the meetings. The opening session concluded with the presentation of Mr Manuel Enriquez Poy about the sugarcane agro-industry in Mexico including the geographical distribution of the sugar mills and principal parameters and statistics of their sugar production.

Technical presentations

The conference included five technical sessions. The chairman of each section gave an overview of the topic to lead into a discussion of that topic. Additional technical presentations were also given.

Power transmission

Overview of current and future options (Juliusz Lewinski)

Different options for modernising mill drives including the upgrading of the existing transmissions were analysed, listing the advantages and disadvantages of each option. Special focus was made on the individual drives including the combination of the existing transmission with an additional individual drive on the cane roller – the option which has become very popular world wide. The most common recent options of individual transmissions, electromechanical variable frequency transmissions and electro-hydraulic drives were described.

Some considerations in the selection of mill drives (Adolfo Gomez)

The presentation showed the advantages of the electromechanical mill drive in comparison with the conventional drive (with turbine) based on the measurements made by the author. The electromechanical mill drive gives many advantages:

- better torque and speed control
- higher efficiency
- higher speed range
- higher torque range
- easier monitoring
- lower maintenance cost.

Hydraulic drives in milling applications (Bo Ljung)

Variable frequency electromechanical drives were compared with electro-hydraulic drives considering the torque – speed relationship and the efficiency.

The main conclusions were as follows:

- In the case of torque – speed relationship, electro-hydraulic drives show a clear advantage.
- Electromechanical and electro-hydraulic drives show no major difference in efficiency in comparable applications.
- It is relatively easy to measure the efficiency of a hydraulic drive but difficult for an electromechanical (VFD) drive.
- Service factor and additional power losses have to be taken into account when calculating efficiency.
- If a tailbar coupling and crown gears are used, further power losses in the range of 10% are added.

Experience in the use of electric drives for mills (Carlos Martinez and Ivan Ramos)

The criteria for selection of the type of mill drive and its elements were discussed. The authors claimed that the variable frequency electromechanical drive is of higher efficiency than the electro-hydraulic drive.

Fundamental considerations for the upgrading of speed reducers (Isaias Regalado)

The objectives of the presentation were:

- Listing of the possibilities to improve the power capacity (upgrade) of mechanical transmissions.
- To propose a logical procedure for an adequate upgrading.

It was concluded that the strength and durability of a transmission may be improved by:

- changing the tooth/gears geometry
- changing the material property
- improving the manufacturing quality.

Cane preparation

Overview – historical evaluation and future perspectives (Paulo Delfini)

This presentation led to a discussion about the value of achieving high preparation in the shredder. Brazilian shredders typically achieve a preparation index (similar to pol in open cells) of 80% to 85%, generally through a set of knives and a light duty shredder. This approach results in lower power consumption in the shredder. Because mills open up cells as well as express juice, the preparation index is around 99% by the end of the milling train whether fine preparation or coarse preparation is achieved in the shredder. Finer preparation is needed for diffusion, however.

The counter argument was that, by having low preparation, opportunity for higher extraction in the first few mills was lost and that that extraction could not be completely recovered by the end of the milling train.

The author's view was that consideration needs to be given to the value of the reduced power consumption in the shredder against the lost sugar income from lower preparation.

Cane separation review (Helmut Bourzutschky)

This presentation reviewed cane separation technology where cane billets are split in two, the pith removed and the pith and rind sections processed separately. Examples of the uses of the separate components were given. The juice can be extracted from the pith using a double screw press where up to 95% extraction can be achieved in a single extraction operation. The remaining pith fibre can be added to flour to increase its fibre content. The rind can be used to make charcoal or paper products.

A pilot plant was set up some years ago to process 3 t/h and further investigations are now taking place. It is believed the technology is applicable up to about 50 t/h.

New techniques for preparation and milling of sugarcane: impact over the bagasse cellulose production (Manuel Enriquez Poy)

Until recently, six paper plants were operating at raw sugar factories in Mexico. To provide sufficient fibre for the paper plants, oil was used to supplement bagasse for steam generation.

In recent times, improvements in cane preparation and milling have increased extraction but have caused deterioration in the fibre quality for paper making. In addition, rises in the price of oil have made bagasse more attractive for steam and power generation. There is presently only one factory still producing paper in Mexico.

If Mexico intends to insure the future of its paper industry, it will need to put greater focus on the production of bagasse with suitable fibre quality, possibly at the expense of extraction. The high price that the factories pay for oil for fuel also requires that the energy efficiency of the process is examined to increase the use of renewable fuels. The combinations of sugarcane, ethanol and cogeneration; or sugar cane, ethanol, cellulose and cogeneration need to be explored. The solution is a formidable sugarcane technologist challenge.

Measurement of cane preparation (Peter Rein)

This presentation described the various methods of cane preparation measurement and also how cane preparation methods differed in different countries. While both South Africa and Australia use a similar method, the preparation index method in South Africa tumbles prepared cane for 30 minutes while the pol in open cells method in Australia tumbles prepared cane for 10 minutes. The preparation index method gives a higher result than the pol in open cells method because of this longer tumbling time.

Efficient cane preparation (Steve Inskip)

In-line shredders have now advanced to the stage where knives can be eliminated, even when processing whole-stick cane. Overall power consumption is less with a single shredder than with a typical installation with two sets of knives and a shredder.

The comment was made that cane preparation in a single stage results in fibres of longer length and that the longer length fibre was an advantage in both milling and diffusion.

Diffusers***Overview: Historical development and future evolution (Peter Rein)***

This presentation gave an overview of the history and types of diffusers and gave some practical information about their operation and maintenance.

High temperatures of 80°C to 85°C are recommended to prevent microbiological activity and to promote good extraction.

The main purpose of lifting screws is to disturb the bed after the addition of press water from the dewatering mill. The press water contains sufficient fines to form an impermeable layer and the screws disturb that layer. The screws also have a useful function in levelling the bed.

Dewatering the diffuser bagasse remains a problem. It is very common for there to be two dewatering mills following a diffuser. The main function of the first mill is to remove the majority of the water. The second mill then aims to reduce the moisture content to a satisfactory level. The pressure feeder in a six-roll mill performs a similar function to the first dewatering mill and so, where a six-roll mill is used, a single dewatering mill should be sufficient. A low-cost dewatering device has been developed in Brazil which is believed to be a light-duty two-roll mill.

With a diffuser, much more of the dirt remains with the bagasse. This extra dirt does not cause erosion problems in the boilers, provided gas velocities remain low. Recycling clarifier mud to the diffuser is now common practice and does not affect percolation, extraction or losses. The mud is generally returned before the first lifting screws.

Not all factories add lime to the diffuser. The only purpose for adding lime is to control corrosion. Sucrose inversion is not a problem at high temperature provided the pH does not get below 5.

Further energy savings by optimised diffuser concept (Burkhard Bartels)

This presentation discussed a method for improving the steam economy of a diffuser. The concept is to add extra stages to the start of a diffuser and use mixed juice to heat scalding juice. Scalding juice is the largest consumer of steam in a diffuser and uses high pressure vapour. By using the hot mixed juice to preheat the scalding juice, the scalding juice steam consumption can be reduced. While the mixed juice still needs to be reheated in the primary heaters, lower pressure vapour can be used for this application. The steam saving was reported to be about 4.8% on cane.

The Bosch Projects chainless diffuser at UCL (Ivan Voigt)

Bosch Projects have invented and patented a chainless mechanism for moving bagasse through a diffuser. The chainless mechanism was installed in 2006 at UCL Mill in South Africa at a price about 75% of a replacement set of chains.

The concept involves moving sections of floor a distance of 1 m before retracting the floor sections (at different times). The sections are moved with hydraulic cylinders.

From the one season of operation, wear of the wear strips under the moving floor was minimal (about 1 mm).

This type of floor mechanism removes a significant restriction on the width of a diffuser. With this floor mechanism, there is no need for the headshaft and tailshaft, items that have traditionally limited the width (and hence capacity) of a diffuser. The floor mechanism also

removes the need to keep the underside of the diffuser clear for the chain. Consequently, structural supports can be placed under the diffuser to reduce the size of the structural members.

The Riviere juice extractor (Paulo Delfini)

Copersucar in Brazil has an exclusive licence from the Riviere estate to use the patented Riviere juice extractor. CTC, formerly part of Copersucar, has developed a pilot plant and developed the concept to the stage it is ready for commercial demonstration. As yet, no factories have volunteered the money necessary for this next stage.

The extraction concept involves flooding bagasse from below, adding low brix imbibition juice above and then draining the juice from below. The higher brix juice is drained away leaving the low brix juice to displace the high brix juice in the bagasse. The percolation rate has been measured to be 30 to 40 times higher than in a diffuser.

The process is rapid (about one to two minutes). CTC's pilot plant contains three Riviere units in series. With a dewatering mill at the end of the extractor, extraction of 93.5% is expected. With a first mill as well, extraction of 95% is expected.

The limitation in this concept is that the process relies on the shredder (and first mill if used) for cell breakage. Unlike diffusion, time and temperature are not available to diffuse juice from closed cells. The total cost of a Riviere juice extractor tandem is estimated at about the same price as a single milling unit.

Mills

Basic configurations and options. Overview (Geoff Kent)

The author gave a presentation to lead discussion into low-cost mill designs, mill maintenance practices and mill control.

The FCB three-roll mill has started to be introduced into the industry this year after little activity for many years. Seven installations are planned this year. The FCB mill is configured like a pressure feeder and has a reabsorption-limiting device attached to achieve satisfactory performance.

The reabsorption-limiting device is like a pressure feeder chute but is hydraulically loaded on the delivery end to vary the divergence of the chute. The reabsorption-limiting concept involves compressing the bagasse in the axial direction to restrict re-entry of juice into the bagasse mat.

There was some interest expressed in Bundaberg Foundry's two-roll (BHEM) mill but little performance information was available.

There have been no further sales of the STG two-roll mill since two sales to Vietnam some years ago.

The low pressure extraction concept has been applied by several factories in India in recent years. This concept uses pairs of fairly crude, flat, perforated rolls to apply a light squeeze to the bagasse.

A series of eight pairs of rolls with imbibition added before each pair significantly reduces the capital cost and power consumption of a milling tandem. The concept has so far been restricted to low rates.

Predicting mill speed (Geoff Kent)

The author explained the importance of predicting mill speed to the mill setting process. Different models of mill feeding were discussed and compared with experimental measurements. A new model to predict mill speed based on physical laws rather than empirical model was developed.

Compare and contrast milling and diffusion

A comparison of milling and diffusion (Peter Rein)

Since the introduction of diffusers into South Africa, average extraction has increased and is now consistently between 97.5% and 98.0%.

South Africa has a lot of information regarding the relative costs and performance associated with diffusion compared to milling and has published information regarding the relative performance in Maidstone factory where both a milling tandem and a diffuser were operating.

Efforts in steam usage reduction have now resulted in steam usage values similar to milling if vapour 2 or vapour 3 is used for heating in the diffuser.

Starch and gum levels in raw sugar are lower with a diffuser although colour is higher.

Because of the filtering ability of the bagasse bed in a diffuser and because mud is recycled to the diffuser eliminating the need for fibre for filtration, some factories have been able to remove their rotary juice screen.

Microbiological losses are expected to be higher in a milling train due to the lower temperatures of operation. Lactic acid measurements in juice are recommended to gain an understanding of these microbiological losses.

Ten new diffusers are planned for Brazil this year, doubling the number in Brazil.

Comparison of diffusion and milling at a cane sugar plant (Mullapudi Narendranath)

The experience at the Andhra Sugars factories is also that diffusion has much lower costs than milling. Capital and maintenance costs are lower. More electricity generation can be achieved.

The diffuser is more flexible in crushing rate than a milling train. Crushing rates of 20% to 100% of its rated capacity are possible.

Steam and power balance in diffuser and mill based cane sugar factories producing white sugar (Boris Morgenroth)

This presentation describes the results of a study to examine milling and diffusion options for cogeneration at a factory configuration equivalent to a planned Pakistan plant. At the conditions studied, a diffuser option produced 9% to 11% more electricity than the milling option.

A Comparison of Sugarcane Juice Quality from a Mill and a Diffuser (Peter Rein)

Audubon Sugar Institute has compared juice quality from the milling tandem and the diffuser at Enterprise factory in Louisiana. Based on the results, no difference in sugar recovery was expected. Colour levels were higher in the diffuser juice and starch and dextran levels were higher in the mill juice.

Site visits

A strike by workers at Mexican sugar factories prevented the planned visits to Tres Valles Mill and San José de Abajo Mill. Instead a visit to the 3M factory in Cordoba was arranged.

3M factory

Manufacturera 3M is a large casting, machining and fabrication plant in Cordoba, Veracruz. The factory manufactures most roll shells for Mexico and is capable of manufacturing all roll sizes up to nine feet in length. The factory is capable of manufacturing a large variety of sugar mill equipment. A pan and an evaporator were also being manufactured at the time of the visit.

Central Motzorongo Mill

Central Motzorongo Mill is located in the state of Veracruz. The factory processes 10 000 t/d of cane and the cane equivalent of 13 000 t/d of liquor. The factory receives liquor from the neighbouring mill.

The factory has a wide range of feeding tables to account for different cane transport vehicles. Cane preparation is achieved by several sets of knives and a shredder. The factory has six four-roll mills. The first and final mills are driven by four Haggblunds MB1600 drives (two on the top roll and one each on the feed and delivery rolls). The intermediate mills are all driven by steam turbines. Chute level is controlled in the first mill by varying the rate through the feeding station. There are no other automatic controls. Load control is achieved through the top roll hydraulics.

Every mill roll is hardfaced using the Brazilian picot method.

The mill couplings are rope couplings of South African design. Each mill has this design of coupling.

The factory produces 2000 t each year of compost of a mixture of filter mud (85%) and bagasse (15%). The compost is placed in rows 3 m wide and 1.5 m high and left to compost over 14 weeks. The factory uses 5 ha of land for this operation. The resulting compost is sold for about US\$50 to US\$55 a tonne, mainly to local cane farmers.

Conclusions

The workshop was attended by a good cross-section of factory personnel, equipment suppliers and researchers from around the world. From the attendees, an impression of trends in extraction technology was gained.

Cane preparation is trending towards a single cane preparation device.

Little development is occurring for traditional six-roll and four-roll mills. Trends in milling are towards low-cost mills. The FCB three-roll mill has quite suddenly gained popularity and promises quite good capacity and adequate performance.

While milling trends are towards lower capital units with reduced performance, diffusion trends are towards higher capacity units with increased performance. Diffusers have been shown to have lower capital costs, lower maintenance costs and can now achieve lower steam consumption than milling tandems, allowing greater electricity generation.

Power consumption is becoming a significant issue for factories around the world. Low efficiency steam drives are being replaced by electro-mechanical and electro-hydraulic drives, powered by higher efficiency steam turbo-alternators.

Final comments

- There has been very little formal study about the design, construction and maintenance of the equipment used in sugar industry made by the research institutes.
- The newest technology for the sugar industry was presented mainly by the equipment manufacturers, which mainly talk about the advantages of their equipment and disadvantages of the competition.
- There is a need to promote the detailed study of the performance of the equipment for the sugar industry made by the research institutes as well as the research and engineering departments of the manufacturers.
- There is a need to find an answer to the question 'Why, if diffusion gives so many advantages in comparison with milling, are milling tandems still used in new sugar factories'.

The members of the section decided to dedicate the next workshop to the subject: 'Design, manufacturing and maintenance of the mechanical equipment in sugar mills'. The country to organise it could be Brazil.

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THEORIE ET PRATIQUE DU BROYAGE AUX MOULINS ET DE LA DIFFUSION

Par

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MOTS CLÉS: Atelier ISSCT, Moulins, Diffusion, Canne a Sucre, Sucre.

Résume

LA SECTION « Engineering » a organise un atelier a Veracruz, Mexique, du 21 au 24 novembre 2006. Quarante délègues venant de 12 pays différents ont été présents pour cet atelier sur le broyage aux moulins et sur la diffusion. Ce compte rendu présente les activités de l'atelier, discutées pendant cinq sessions techniques avec des présentations et des visites aux champs et aux sucreries. Parmi les items discute on note la préparation des cannes, l'énergie, les diffuseurs, les moulins, et une comparaison moulins / diffusion.

EXTRACCIÓN POR MOLIENDA Y DIFUSIÓN-TEORÍA Y PRÁCTICA

Por

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PALABRAS CLAVE: Taller ISSCT, Molienda, Difusión, Caña, Azúcar.

Resumen

UN TALLER de Ingeniería se llevó a cabo desde el 21 hasta el 24 de Noviembre 2006 en Veracruz, México. Cuarenta delegados de 12 países asistieron al evento sobre teoría y práctica de la extracción por molienda y difusión. Este reporte presenta una visión general de las actividades desarrolladas durante el taller, que consistió de cinco sesiones durante dos días, más dos días de visitas a campo y fábrica. Los tópicos cubiertos durante las sesiones técnicas incluyeron: transmisión de potencia, preparación de caña, difusores, molinos y una comparación entre molienda y difusión.