IMPROVING THE QUALITY OF C SUGAR MAGMA FOR USE AS SEED CRYSTAL MATERIAL

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Abstract

The sugar crystals produced by continuous C massecuite centrifugals typically comprise large numbers of crystal chips and broken grain, as well as the main crystal population. Consequently, the C sugar magma produced from this material is of poor quality for use as crystal seed for subsequent crystal growth, unless washing is undertaken firstly to dissolve and remove the chips and small crystals. Generally mills undertake this magma preparation step in batch pans, but the washing step is one of the most difficult to control on the pan stage due to the rapid crystal dissolution that occurs. A magma preparation system has been developed that involves the continuous flow of magma through a mixer where controlled dissolution is undertaken, and then through a specially designed cooling crystalliser where the dissolved sucrose is recrystallised onto the remaining crystals. Condong Mill has operated the SRI designed magma preparation system since 1995, with good results. The prepared magma, which is stored in a buffer tank prior to use in a batch pan for seed development, typically is of 25% crystal content, has a mean size of 0.25 mm, and contains very few small crystals. No washing of the prepared magma is undertaken in the batch pan prior to the commencement of crystal growth. The main benefits to Condong Mill from implementing the system have been a boost of about 9% to the production capacity of the pan stage and improved quality of the sugar produced by the factory. The paper describes the design of the system and the control functions, together with the results from Condong Mill. The application of the system to other raw sugar factory arrangements, e.g. as the seed supply to continuous pans, is also discussed.

Introduction

The production of shipment massecuites with consistent crystal mean size and narrow size distribution allows the centrifuging and drying operations to be tightly controlled and the polarisation, moisture and temperature of the shipment sugar to be maintained at the target specifications.

The critical first step in ensuring the shipment massecuites are of consistent mean size and spread is to provide seed massecuite of consistent quality with respect to numbers, mean size and coefficient of variation.

For most flowschemes, the magma of sugar crystals which is used to produce the shipment massecuites is produced in continuous centrifugals where crystal breakage inevitably occurs. Various procedures are employed to reduce the extent of breakage and/or remove the majority of the small crystal fragments from the magma. These procedures include:

- Dissolution and recrystallisation in a batch pan to ‘prepare’ the magma. Typically, during the ‘washing’ step of C sugar magma in the Australian three massecuite boiling scheme, the crystal content of the magma is reduced from 50%, initially to as low as 10% to 15%, and the mean size is reduced by 0.1 mm (Broadfoot et al., 1994). The usual procedure of washing magma in batch pans is often quite variable, largely because the dissolution step is rapid and any variation in control or judgement by the operator results in large variations in the numbers of crystals provided for high grade seed development. This washing procedure is unproductive in the use of expensive pan equipment.
- Use of wide-casing centrifugals to reduce the extent of breakage of the parent crystals. However, it is usual that some magma preparation by washing is still required.
Use of anti-breakage baffles and other devices in the casing of the centrifugals. These devices tend to be of variable and generally limited benefit. Magma preparation by washing is still normally required.

Generation of an undersaturated sugar solution for the preparation and storage of the magma before it is used in batch or continuous pans. This procedure can successfully remove the majority of crystal chips but suffers from variability in crystal numbers supplied to the pans, due to the very low crystal content of the supplied magma, and variability due to undersaturation by dilution. Stobie et al. (2004) recently employed the dissolution process in the pipe flow supplying the magma to the first cell of a continuous high grade seed pan.

Each of the above procedures is considered to be deficient in consistency with respect to crystal numbers per unit mass, mean size and coefficient of variation of the crystals. The supplied magma should also be of sufficiently high crystal content that the batch or continuous pan to which the magma is supplied can be placed immediately onto crystal growth, i.e. operated at high productivity.

The SRI developed magma preparation system achieves these objectives. The system involves the continuous flow of magma through a mixer where controlled dissolution is undertaken and then through a specially designed continuous flow cooling crystalliser where the dissolved sucrose is crystallised back onto the remaining crystals. Condong Mill has operated the SRI magma preparation system since 1995, with good results. The installation, typical results and main benefits to Condong Mill from implementing the system are described.

The installation of the magma preparation system at Condong Mill

Figure 1 shows the schematic arrangement for the magma preparation system, the instrumentation and control loops, as installed at Condong Mill. Figure 2 shows a photograph of the mixer and cooling crystalliser.

Fig. 1—General arrangement for the magma preparation system at Condong Mill.
Condong Mill crushes cane at 185 t/h and the high grade massecuite production rate is 48 t/h. The magma preparation system processes an average 2.4 t/h which is sufficient for the total high grade massecuite production and is about 45% of the factory's C sugar magma production rate at the centrifugals. The surplus magma is remelted and sent to the liquor tank. The extent of crystal breakage in the C sugar magma is fairly typical for the Australian industry.

Mixer unit

The magma mixer consists of a horizontal vessel of semi-circular cross-section, having a hold-up volume of magma of 0.46 m³ and mean residence time for magma of 16 minutes for the design rate of 2.4 t/h. Baffles are installed perpendicular to the longitudinal axis of the mixer to retard the flow of magma from the inlet to the exit.

Magma flows continuously into one end of the unit and is heated from about 60°C to about 88–90°C using direct steam injection. The temperature of the magma and the quantity of dilution hot water are regulated to give the desired amount of dissolution. The washed magma then overflows from the other end of the mixer to the cooling crystalliser.

Cooling crystalliser

The cooling crystalliser is a horizontal cylindrical vessel with a magma volume of 1.6 m³. The crystalliser contains bundles of tubes through which cooling water is pumped. The mean residence time for
magma in the crystalliser is about 58 minutes at the design rate of 2.4 t/h. The design incorporates several features to ensure adequate cooling (temperature drop of 20 to 30°C) is achieved without the formation of false grain.

An overflow chute is provided on the side of the crystalliser at the exit end to allow the prepared magma to flow directly into the magma receiver, from where magma is transferred to the batch magma pan.

**Control instrumentation**

The measuring instrumentation and control loops for the system are shown in Figure 1. The major control loops are:

- Regulation of magma flowrate to the mixer. An ultrasonic level sensor on the mixer outflow controls the speed of the positive displacement pump which transfers the magma to the mixer.
- Regulation of the magma brix in the mixer. The water flow to the inlet end of the mixer is regulated by the signal from a WPR RF transducer located in the base of the mixer.
- Regulation of the magma temperature in the mixer. The steam flowrate to the distributor within the mixer is regulated by the signal from the RTD temperature sensor.
- Regulation of the temperature of the cooling water supply to the crystalliser and control of the magma temperature at the exit of the crystalliser. The temperature of the magma exiting the crystalliser is controlled by cascade control to regulate the set point of the water temperature control loop. The water flowrate to the crystalliser is manually set.

**Results and performance of the magma preparation system**

Since commissioning in 1995, the SRI magma preparation system has supplied the total magma requirements of the factory for shipment sugar production. The following performance data were obtained during evaluation trials.

Typically, the magma supplied to the mixer is at 55°C, is heated to 89 to 90°C in the mixer and exits the cooling crystalliser at 63 to 67°C. The magma is of high purity, typically between 90 and 93. General operational data are:

- Dry substance of magma supplied to the mixer: 88
- Crystal content of magma supplied to the mixer: 40 to 45% (on magma)
- Dry substance of magma exiting the mixer: 84 to 85
- Crystal content of magma exiting the mixer: 15% (on magma)
- Crystal content of magma exiting the crystalliser: 22 to 27% (on magma)
- Mean size of crystals exiting the crystalliser: 0.25 mm
- Colour increase in the magma through the total system: 2% (approximately)

As a guide, the mean size of the crystals exiting the cooling crystalliser is similar to the mean size of the parent crystals in the magma supplied to the mixer. The prepared magma is ready for immediate crystal growth in the vacuum pans.

Figure 3 shows photomicrographs of the crystal samples taken for one series of trials, for crystals at the entry to the mixer, at the exit of the mixer, and at the exit of the crystalliser. This sequence of samples is typical of the improvement in crystal quality achieved by the system.

The extent of improvement is dependent on the spread of sizes of the crystals in the supplied magma and the separation of size between the 'chips' and the parent crystals. The importance of this is no different from that when the washing procedure is undertaken in batch pans.

**Operation and performance of the dissolution mixer**

The temperature of the magma in the mixer is tightly controlled (typically ± 0.5°C) by the feedback control loop which regulates the steam injection flow. Condong Mill no longer uses the brix control on the mixer as adequate control of the brix of the magma pumped to the mixer is achieved.

The results of a lithium tracer test for magma flow in the mixer are given in Figure 4. The distribution of times is similar to that for three well-mixed cells in series. There is no evidence of shortcircuiting or slow moving material.
Inlet magma as supplied from the C fugals

At the end of the dissolution step

After cooling crystallisation

Fig. 3—Photomicrographs of the crystal samples taken for one series of trials.
An important parameter of the residence time distribution for the mixer is the fraction of the incoming magma stream that resides in the unit for short residence times and would thus not experience adequate time for dissolution. A residence time of less than seven minutes is considered likely to result in the retention of significant numbers of 'chip remnants' within that portion of the magma stream.

Analysis of the residence time distribution data indicates that 17% of the incoming magma stream resides in the mixer for less than seven minutes. This figure is considered to be acceptable but would be reduced in future installations through design modifications.

**Operation and performance of the cooling crystalliser**

The cascade control of the magma temperature at the exit of the crystalliser, through manipulation of the cooling water temperature, is very effective. Lower and upper limits for the cooling water temperature are set at 40 and 60°C. Immediately after cleaning the tubes of the crystalliser, the water temperature operates at a set point of at, or near, 60°C and, as crusting occurs, the set point is gradually reduced till the minimum set point of 40°C is reached.

Nucleation does not occur in the cooling crystalliser. The increase in the cooling water temperature through the crystalliser, by between 8 and 20°C (depending on the water flowrate), reduces the temperature difference between the magma and the surface of the tubes, and so reduces the likelihood of nucleation.

During operation of the cooling crystalliser, crust gradually develops on the cooling tubes and this is removed by passing hot water through the tubes. This procedure is normally undertaken every five to six days. Owing to the short time for this procedure (typically 30 minutes) the quality of the prepared magma held in the buffer tank is degraded by only a minor amount. The factory undertakes a maintenance stop every 10 to 12 days, when both the mixer and crystalliser are emptied and cleaned.

The key to minimising the rate of crust formation is to reduce the temperature differential between the cooling water and the magma. In this regard, the cascade control of the magma temperature at the exit of the crystalliser, by manipulating the cooling water temperature, has been very effective.

The results of the lithium tracer test on the crystalliser are given in Figure 5. The mean residence time agrees exactly with the design nominal residence time of 58 minutes. The distribution of times approximates closely to that for four well mixed cells in series.

There is no evidence of shortcircuiting of material or the presence of stagnant regions. Shortcircuiting of magma would likely cause nucleation owing to excessively fast cooling of those 'pockets' of magma with short residence times. The proportion of the magma flow which resides in the crystalliser for times shorter than 20 minutes is calculated from the residence time distribution to be 5%.
The residence time of 20 minutes is taken as an appropriate target, based on the propensity for nucleation to occur within the system. Overall the residence time distribution for the crystalliser is a good result, as it is important that a narrow spread of residence times is achieved.

Supervision of the system

Very little supervision of the plant is required as the process control loops on the mixer and crystalliser maintain effective operation at the nominated set points. The supply of a consistent (heavy) brix of magma is very beneficial. The fugal operators must divert low brix material (e.g. as produced during hosing out of the fugals) to the remelt system.

Even when the magma flow to the system is stopped completely e.g., during cleaning of the fugals, the magma in both the mixer and crystalliser hold at safe conditions and no intervention is required by the operators.

Condong Mill installed a TV camera above the magma preparation system so that the visual condition of the magma exiting the mixer can be viewed from the pan stage. This image provides a good indication of the brix of the magma. On average, the pan stage operators take a magma sample (at the exit of the crystalliser) for checking on a slide under a microscope, every couple of hours.

Benefits to the pan and fugal station operations at Condong Mill

The implementation of the magma preparation system at Condong Mill has provided benefits to:
- the production capacity of the pan stage;
- improvements to the quality of the shipment sugar; and
- reduction in pan stage supervision for the operators.

Change in high grade massecuite production capacity

A significant benefit to Condong Mill has been obtained through a change to the high grade boiling schedule on the pan stage. This change has been possible through the use of a much smaller charge of magma (i.e. prepared magma) and the elimination of the magma washing step in a batch pan. For the new schedule, the high grade massecuite production rate for the stage has been increased by 9% as the result of reducing the production load on the rate limiting pan.

No washing or change in vacuum on the magma pan is used, with the charge of prepared magma being brought to the boil and placed directly onto liquor feed.

The magma usage rate for shipment sugar production has reduced from 3.8 t/h, when magma washing was undertaken in a batch pan, to 2.4 t/h for the present arrangement with prepared magma being
used. This reduction is attributed directly to the gentler, more controllable dissolution procedure in the continuous flow mixer, compared with the harsh conditions during the wash-up in batch magma pans. An increased proportion of the parent crystals are retained in the continuous flow system.

**Improvement in shipment sugar quality at Condong Mill**

The consensus of mill production staff is that the mean aperture of the shipment sugar has been more consistently at the target size of 0.85 mm since the installation of the magma preparation system. This is attributed to improved consistency in the numbers of crystals supplied in the charge quantity of magma taken for each round of shipment massecuite production.

Improved consistency in producing sugar at the target polarisation of 99.3 has also been achieved as the result of the improved consistency of the crystal mean size.

No evidence of an increase of the sugar colour (as colour%impurities) due to the usage of prepared magma was determined from trials conducted before and after commissioning of the system. This is expected as the colour increase of the magma itself averaged only 2%, and the magma crystal is only about \( \frac{1}{40} \)th of the crystal mass of shipment sugar.

**Reduction in pan stage supervision**

The elimination of the magma washing step in a batch pan has removed one of the time consuming operations that required close attention by the pan stage operators. This reduction in workload is important as the same operators also supervise the evaporator station.

**Implementation of the magma preparation system**

**Quality of the magma at the centrifugals**

The quality of the magma produced at the continuous centrifugals has a significant influence on the quality of the prepared magma that can be produced. Ideally the magma as supplied to the mixer:

- is of consistently high brix (e.g. 89 dry substance or higher);
- comprises crystals with a distinct difference in size between the parent crystals and the fine chips which are to be dissolved. The extent of crystal breakage must be contained, and so it is important to keep the anti-breakage baffles clear of any crystal build-up. This is no different from current operation with magma washing in batch pans.

**Guidelines for implementation**

The designs for the mixer and cooling crystalliser at Condong Mill have proven to be very effective and only minor modifications are recommended for future installations. The two vessels should be sized to provide a minimum residence time of:

- 15 minutes for the mixer;
- 60 minutes for the cooling crystalliser.

With vessels providing these residence times the system is able to accommodate throughput rates double that of the design rate for short periods of time, without major impact on the magma quality. This largely results because the magma at the outflow end of the mixer is close to saturation. Thus, large changes to flowrate do not alter the process conditions at the outflow of the mixer to any major extent.

Several variations on the arrangement installed at Condong Mill are feasible. For example, the system (mixer and crystalliser) could be installed adjacent to the centrifugal station and the prepared magma pumped to the receiver located on the pan stage.

**Applications of the SRI magma preparation system**

No subsequent installations for the SRI magma preparation systems have been made since the first system was installed at Condong Mill. The lack of adoption of the technology is attributed to the very poor economic climate for capital investment, and minimal expansion of crushing capacity, in Australian mills in the subsequent years.

Applications of the technology for supplying prepared magma to batch and continuous pans are discussed.

**Use of the prepared magma in batch pans**

The system effectively removes 20 minutes (minimum) of unproductive time for the magma washing step in the batch pan. An increase in the production capability for the whole high grade pan stage would be achieved for factories where the current magma pan is the rate limiting pan.

The use of the magma preparation system may allow changes to be made to the duties of individual pans and changes to the schedules. Depending on the specific circumstances, this may provide a substantial increase in the high grade massecuite production capability for the stage.
For a factory undertaking an expansion program to increase crushing rate, the increase in pan stage capacity provided by the implementation of the magma preparation system may avoid or defer capital investment in new pans.

**Use of the prepared magma in continuous pans**

Potential applications include the supply of prepared seed material to the A and B continuous pans in the CBA boiling scheme, and to a continuous high grade seed pan in the three massecuite boiling scheme as used by Australian factories. The system replaces the need for a batch magma preparation pan and provides a consistent, good quality magma which is suitable for immediate growth in the first cell of a continuous pan.

Compared with operation of continuous pans where magma washing is undertaken in the first one or two cells, the use of the magma preparation system maximises the productive capacity of the continuous pan. Importantly also, a substantial improvement in the consistency of the mean size of the product massecuite and a narrower spread of sizes would result. This latter benefit is directly attributable to the maintenance of a low coefficient of variation of the crystals in the early cells of the continuous pan when a prepared magma (ready for immediate crystal growth) is supplied to the first cell of the pan (Broadfoot, 1992).

**Conclusions**

The experience at Condong Mill is that the SRI magma preparation system provides consistency in crystal numbers which is superior to that achieved by operators preparing magma by washing in a batch pan.

The main benefits of the system are enhanced productivity for the batch or continuous pan receiving the prepared magma, and a consistently improved quality of the shipment massecuite produced from this magma.

The prepared magma is ready for immediate crystal growth and is suitable for providing a charge to batch pans or as seed massecuite to the first cell of continuous pans.

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**REFERENCES**


I fabrica resultados de la principal de cristales. En consecuencia, el beneficio para la fibra. Esta ponencia describe el del magma preparado en el uso en un tacho de carga para con muy buenos resultados. El magma preparado, que se almacena en restantes. La de una mezcladora donde comprometen grandes cantidades de cristal fraccionado y de grano roto, los PALABRAS virutas enfriamiento especialmente disefiado, donde la sacarosa disuelta se vuelve a cristalizar controlar en la se ha desarrollado un sistema de siguiendo de cristales, a no ser que se MEJORA EN LA CALIDAD DEL MAGMA DE AZÚCAR C PARA SU USO COMO MATERIAL DE SIEMBRA DE CRISTALES
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PALABRAS CLAVE: Magma del Azúcar, Disolución, Cristalización, Cristales Rotos.

Resumen
Los CRISTALES de azúcar producidos por las centrífugas de masacocida C de manera típica comprometen grandes cantidades de cristales fraccionados y de grano roto, así como la población principal de cristales. En consecuencia, el magma de azúcar C que se produce a partir de este material tiene una pobre calidad para su uso como siembra de cristales para el crecimiento subsiguiente de cristales, a no ser que se realice un lavado previo para disolver y remover las virutas y los cristales pequeños. En general, los molinos realizan este paso de preparación del magma en los tachos de bache, pero este paso de lavado es uno de los más difíciles de controlar en la etapa de los tachos, debido a la rápida disolución de cristales que tiene lugar. Se ha desarrollado un sistema de preparación de magma que implica el flujo continuo del magma a través de una mezcladora donde se lleva a cabo una disolución controlada, y luego a través de un cristalizador de enfriamiento especialmente diseñado, donde la sacarosa disuelta se vuelve a cristalizar sobre los cristales restantes. La fábrica Condon ha operado el sistema diseñado de preparación de magma SRI desde 1995, con muy buenos resultados. El magma preparado, que se almacena en un tanque amortiguador antes de su uso en un tacho de carga para desarrollo del sembrado, en general tiene un contenido del 25% de cristales, con un tamaño medio de 0.25 mm, y contiene muy pocos cristales pequeños. No se realiza ningún lavado del magma preparado en el tacho de carga antes de dar comienzo al desarrollo de cristales. Los principales beneficios para la Fábrica Condon al implementar este sistema, han sido una alza de alrededor del 9% de la capacidad de producción de la etapa de tachos y una mejora en la calidad del azúcar producida por la fábrica. Esta ponencia describe el diseño del sistema y las funciones de control, conjuntamente con los resultados de la Fábrica Condon. Se discute asimismo la aplicación del sistema a otros arreglos de la fábrica de azúcar, por ejemplo, como suministro de semilla para los tachos continuos.