

Improved crystallisation in cane sugar mills with updated strategies and equipment*

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Abstract

Changing market conditions are forcing cane sugar factories to find ways of improving the quality of the produced sugar, increasing the sugar output, and, if the location permits, developing alternative uses of the bagasse besides sugar production. Numerous process details from crystallisation, which are commonly applied in beet sugar factories, but not yet considered to be state of the art in the cane sugar industry, have in recent years been implemented in cane sugar factories. The achieved improvements affect different performance parameters. Progressive automation of the crystallisation process combined with the production of seed massecuite by cooling crystallisation yields a controlled crystal quality. Continuous crystallisation of bold A sugar in a vertical continuous pan (VKT) was verified while working at very low temperature differences. Process automation together with far-sighted operation of the process produces A massecuite of a consistent quality. The use of 4th vapour for continuous crystallisation of A product contributes significantly to steam savings in the sugar production process. The yield improvement obtained by continuous cooling crystallisation of C product directly depends on the outlet temperature reached. The oscillating vertical cooling crystalliser (OVC) system achieves low molasses purities thanks to a final temperature of 40°C and the low percentage of fine crystals. With these measures for sugar house operation, the challenging demands for controlled sugar quality, efficient steam utilisation and higher sugar output can be met at the same time.

Keywords: Crystallisation, automatic pan operation, continuous crystallisation, A product, C product, crystalliser, seeding

Introduction

While sugar production in the cane sugar industry was largely the same for decades, market developments have now provided an impetus for change. In particular for large production units, adapting to new production conditions proves to be profitable in the long run. There are three major requirements that present-day sugar production has to meet:

1. Higher sugar quality: With a wider range of information, competition on the local sugar market is becoming more transparent, making it easier to translate higher sugar quality into higher revenues. Key account customers, in addition, have their own standards and often ask for qualities that match those achieved in the beet sugar industry.
2. Reduced process steam consumption in sugar production: With the efficient use of bagasse, sugar production is no longer the

only potential source of earnings. Excess bagasse is normally burnt in co-generation plants and excess power is fed into the local power grid. A more recent application, currently on a small scale, has been the sale of bagasse for use by third parties. For cost reasons, using additional fossil fuels as a source of energy for sugar production must strictly be avoided.

3. Maximised sugar output: The cane sugar industry has to face new challenges in the form of low sugar prices and a cutback in local subsidies. A possible option in this situation is to provide for optimal molasses exhaustion in order to maximise crystalline sugar output. This only makes economic sense if the sugar contained in the molasses cannot be put to other more profitable uses, e.g. in the production of ethanol. The primary criterion for sugar house operation is the quality of the product sugar. To some extent, this applies to

the production of raw sugar from sugarcane, but certainly to the production of plantation-white sugar and refined sugar. Maximising sugar output and minimising molasses purity have been defined as additional targets. With steam savings throughout the sugar process as yet another target, cane sugar factories are now focusing also on steam consumption in the sugar house.

Numerous process details from crystallisation, which are commonly applied in beet sugar factories but not yet considered to be state of the art in the cane sugar industry, have in recent years also been implemented in cane sugar factories. This offers cane sugar factories new ways of reacting to a changed market situation (Lehnberger 2015). Here, we describe some of these processes.

Exhaustion of C product with continuous crystallisation in an oscillating vertical cooling crystalliser (OVC)

One of the primary objectives of almost every sugar factory is to ensure that the molasses is exhausted as much as possible. Since any sugar that is additionally centrifuged from the C massecuite can be sold as extra crystalline sugar, all efforts aimed at increasing the C product yield can count as additional sugar production. Based on the mass of dry substance, any additional output of crystalline sugar will reduce the amount of molasses produced.

Cooling of C massecuite to raise the crystal yield is a measure that has been known for some time and is widely used. As a rule of thumb, lowering the temperature by 4 to 5°C will reduce the purity of the mother liquor by one purity point. For the beet sugar industry, these conditions have been analysed in detail (Wagnerowski *et al.* 1962; Ekelhof 1997; McGillivray *et al.* 2003), leading to the development of continuous cooling crystallisers several decades ago. With long retention times, which can be up to 36 h (Südzucker 1994) and sometimes more, and uniform temperature difference between massecuite and cooling water, these crystallisers produce a low outlet temperature. The maximum viscosity of massecuite that cooling crystallisers and centrifugals can still handle represents the technical limit to this process.

Although OVC continuous cooling crystallisers are proven

performers in the beet sugar industry, the jump to applications in cane sugar factories was hesitantly. The main reason for this reservation was the doubt that these crystallisers would yield the same technological results in cane as in beet sugar factories. The experience gathered from operation of 10 of these crystallisers installed in cane sugar factories show comparable technological results.

One such OVC crystalliser has been in operation in the Puga sugar factory in Mexico for 5 years. It has a capacity of 900 t and a cooling area of 1,000 m², and, at a height of 33.5 m, it is one of the tallest pieces of equipment in that factory (Figure 1). With the OVC, 33 t/h of C massecuite is steadily cooled by about 1°C per hour from about 65°C to 40°C (Anon. 2012). This gradual cooling with constant temperature difference between massecuite and cooling water ensures that supersaturation in the OVC is always kept within a range in which only existing crystals grow but no new nuclei are formed.

Figure 1: OVC at Puga, Mexico



A crucial factor is that the temperature is lowered consistently in the entire mass flow of massecuite, which the OVC achieves with a typical 10°C difference between massecuite and cooling water. In the OVC, the cooling surfaces oscillate up and down in the massecuite volume, producing uniform heat transfer conditions everywhere in the system. Because of the elements mounted inside the OVC, the material behaves under plug flow conditions. This prevents local supersaturation peaks. This prevents the formation of fine crystals, which cannot be separated in continuous centrifugals and would therefore increase the molasses purity.

With the oscillating system of the cooling coils, which has a stroke of 1 m, no agitator is necessary. The hydraulic unit to

move the coils by hydraulic pistons imposes a power demand of less than 20 kW in the above mentioned installation.

OVCs installed in cane sugar factories have helped to reduce the molasses purity by an average 4 to 5 percentage points in comparison to horizontal crystallisers. From an original temperature of 55°C down to a temperature of 40°C, the mother liquor purity reduction accounts for three purity percentage points, as in the beet sugar industry. Furthermore, improved separation in the centrifugals due to reduced fine crystal content reduces the purity by another one to two percentage points compared with the original setup.

Controlled crystallisation, along with the prevention of the formation of fine crystals while cooling the C massecuite and a low final massecuite temperature, are the preconditions for achieving the improvements in molasses purity. These have been demonstrated in cane sugar factories in Mexico, India, Senegal and El Salvador.

Continuous boiling of plantation white sugar in a vertical continuous pan (VKT)

When the exhaust steam required for sugar production in cane sugar factories is to be reduced, this inevitably means that the concepts for the sugar house have to be changed, as the sugar house is the largest single consumer of vapour from the evaporation station. The options that are available for reducing steam requirements in the sugar house and the utilisation of low-pressure vapour have been discussed on various other occasions. These concepts are state of the art in beet sugar factories, but have not been extensively applied in the cane sugar industry yet.

The Indian Cane Power Ltd. (ICPL) sugar factory in India has installed a vertical continuous pan of the type VKT for A massecuite (Figure 2). In the 2015 season, the factory started to produce part of their plantation-white sugar in the VKT. The steam is primarily 4th vapour from the five effect evaporation plant at a saturation temperature between 76 and 81°C. Details of the installation and achieved operating data are listed in Table 1.

Figure 2: VKT with 4 chambers for A massecuite at ICPL, India

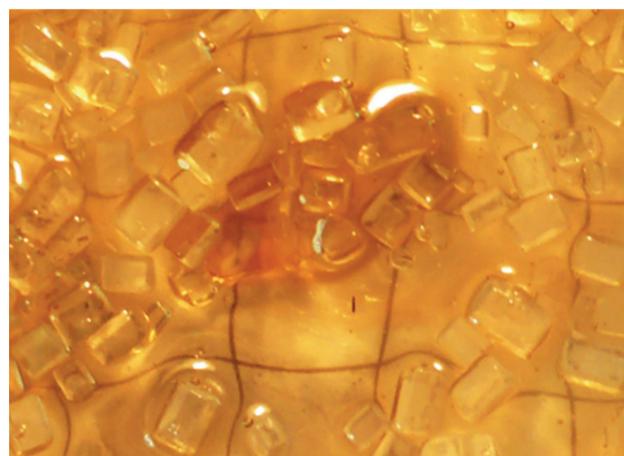


VKT design	4 superimposed chambers diameter 5,600 mm with stirrer
Heating chamber	636 m ² heating surface each chamber
Massecuite	78 t capacity each chamber, total 312 t
A massecuite crystallisation	Operation in season 2015/16
Feed (syrup)	30 - 55 m ³ /h, 62 - 68 Bx, 85% purity
Seed from batch pans	30 - 40 t/h, crystal size (MA) up to 1.5 mm, 91% purity
Massecuite	60 - 80 t/h, crystal size (MA) up to 2 mm
Vapour in vapour chest	160 - 190 mbar abs. (55 - 59°C saturated)
Steam in calandria	400 - 500 mbar abs. (76 - 81°C saturated)
Temperature difference between steam and massecuite	10 - 14°C
Condensate flow	14 - 18 m ³ /h

The produced crystals are bold crystals with a mean diameter of up to 2 mm (Figure 3). With a massecuite production rate in the range from 60 to 80 t/h the crystals remain 4-5 h in the continuous pan for crystallisation. The water evaporation rate is low in order to limit crystallisation rate, which allows the heating steam pressure to be on a very low level. In this case, the driving temperature difference is only 10°C. The powerful agitators in the VKT's chambers ensure stable operation also under these conditions with low water evaporation rates. Local supersaturation peaks that would lead to the formation of undesired fine crystals are prevented by thorough mixing.

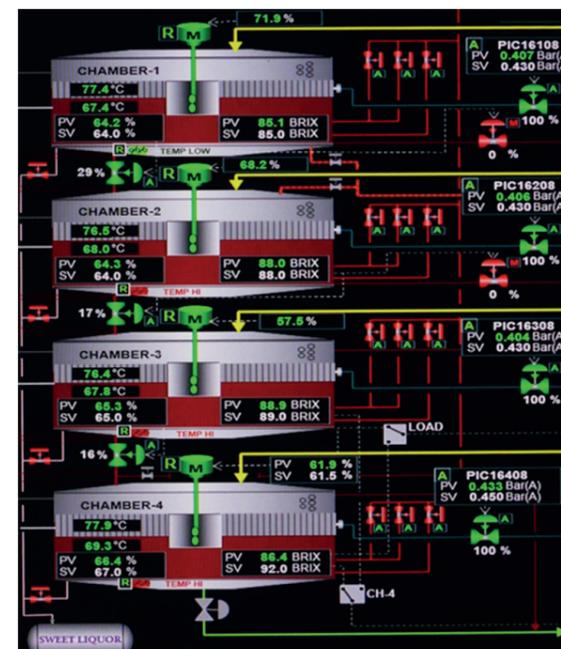
Continuous crystallisation needs a control to produce constant operating results for throughput and crystal quality. The VKT is, therefore, completely controlled from a control centre. The control set points for the different chambers are set in an overview screen (Figure 4). As the operators became skilled with the requirements for stable operation of the VKT, the

Figure 3: Crystals from the 4th chamber, background grid spaces 5 mm.



formation of false grain was eventually avoided. This continuous operation at low temperature differences minimises the amount of steam required for the VKT and leads to a low specific steam consumption of the factory.

Figure 4: VKT operating with approximately 405 mbar abs. heating steam pressure and 68°C massecuite temperature



Crystal seed preparation for refined and raw sugar by cooling of syrup

Controlled crystal growth is the real challenge in crystallisation. In beet as well as in cane sugar production, pan seeding and footing is an established method that helps considerably to reduce the risk of secondary nucleation. Particularly at the beginning of the pan boiling, when the crystals are still very small and have a low volume concentration in the vacuum pan, undesired secondary nucleation can take place and is regularly observed in practice.

One approach towards improved control of crystallisation that has proved successful in beet sugar factories is cooling crystallisation of syrup or remelt for producing sugar crystals with a size of typically 100 µm. This provides for excellent control of crystal growth from the slurry up to a stable intermediate size.

Such a fully automated crystal seed plant has been installed in a cane sugar factory at the Santa Matilde sugar mill in Honduras (Figure 5). The automated batchwise production of seed massecuite uses a 6.8 m³ tank with agitator and integrated cooling coils. A typical cycle time of about 6 h includes the steps of filling, concentration, cooling, discharge and steaming out. Final seed massecuite is discharged to an agitated strike receiver from where the vacuum pans take out their required quantity of crystal seed.

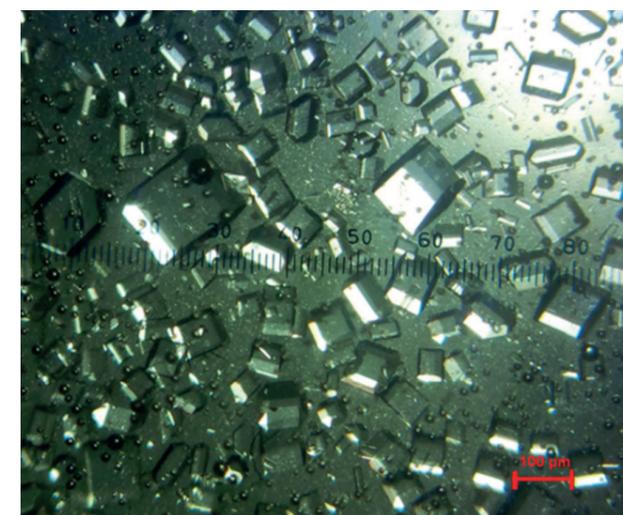
In the agitated tank with cooling coils, concentrated feed solution is gradually cooled and seeded under slight supersaturation conditions with sugar that has been ground for 4 h in a ball mill to form slurry. As cooling slowly continues, the slurry

particles grow and form well-sized crystals. When the massecuite has been cooled to a temperature of 35°C, it should have a crystal content of about 20%. The mean crystal size can be adjusted between 80 µm and 140 µm, depending on the amount of slurry added. This confirms the d³ rule, which states that the number of crystals remains constant in the course of the crystallisation process, so only the seeded crystals contribute to forming the product. Microscopic analysis shows that crystal size distribution is quite narrow and that there are no agglomerates (Figure 6). Both factors are critical for good crystal quality at low energy requirements during the following stages of sugar crystallisation.

Figure 5: Cooling crystalliser with 6.8 m³ capacity at Santa Matilde, Honduras for crystal seed preparation



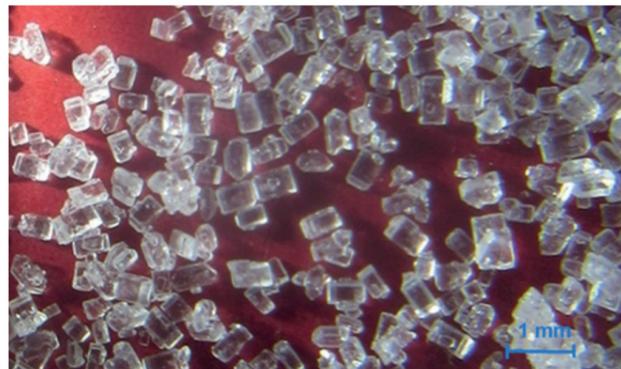
Figure 6: Crystals in seed massecuite, prepared from slurry by cooling of syrup. Crystal size approx. 100 µm



At first, the Santa Matilde sugar mill used the seed massecuite for refined sugar crystallisation. While the crystal seed plant was being installed, the vacuum pans of the refined sugar crystallisation system were fully automated, too. The increase in throughput and the higher refined sugar quality (Figure 7) that were thus achieved were exciting according to Hauck *et al.* (2015):

- Application of the seed massecuite has distinctly enhanced the efficiency of the vacuum pans, because the process requires neither a grain formation phase nor the regular 'washing of the crystals'. The throughput in the refined sugar station has increased from 7,000 bags per day to 11,500 bags per day.
- The variation parameter for crystal size distribution (CV) has improved from 44% to 28%. As a result, the centrifugals need less water to achieve the same sugar colour. This has helped to further improve the yield achieved with refined sugar crystallisation.
- The percentage of fine sugar crystals is now very low (about 4% are smaller than 0.3 mm at a mean aperture of 0.67 mm) compared to manual operation. The sugar dryer performance is improved and the sugar no longer cakes in the bags.

Figure 7: Crystals from the refined sugar production, sample taken after the centrifugals. Crystal size approx. 0.7 mm



This implementation in a cane sugar factory proves clearly the benefit of paying attention to the crystal grow from seeding to final product. In order to fully utilise the potential of the production concept transferred from beet to cane sugar industry, the pans as well as the crystalliser have been automated. The reliably sequenced operation of the vacuum pans now provides for a stable production capacity and product quality.

Conclusions

Changing market conditions are forcing cane sugar factories to find ways of improving the quality of the produced sugar, increasing the sugar output, and, if the location permits, developing alternative uses of the bagasse beside sugar production.

Numerous process details from crystallisation, which are commonly applied in beet sugar factories, but not yet considered to be state of the art in the cane sugar industry, have in recent years been implemented in cane sugar factories. The achieved improvements affect different performance parameters. Experience by operating the named crystallisation equipment continuous cooling crystalliser for C-product, continuous vacuum

pan for A-product and crystal seed preparation by cooling from syrup shows the proper transfer of technology from beet to cane sugar industry.

The improvement in yield that can be achieved with continuous cooling crystallisation of C massecuite is directly dependent on the final temperature after cooling. Along with gentle supersaturation during cooling the formation of fine crystals is prevented and separation in centrifugal is improved too. The OVC crystalliser allows final temperatures down to 40°C.

Continuous crystallisation of coarse A-sugar in a vertical continuous pan (VKT) was verified while working at very low temperature differences. The use of 4th vapour for continuous crystallisation of A product contributes significantly to steam savings in the sugar production process.

Improved control of crystallisation particularly at the beginning of the pan boiling is secured with seed preparation by cooling of syrup. This approach to get rid of undesired secondary nucleation has now proved successful in cane sugar factories too. Progressive automation of the entire crystallisation process combined with the production of seed massecuite by cooling crystallisation yields a controlled crystal quality.

Although these well-known crystallisation techniques are commonly used in beet sugar factories, they are not widely applied in cane sugar factories. With these measures for sugar house operation, the challenging demands for controlled sugar quality, efficient steam utilisation and higher sugar output can be met at the same time in cane sugar factories.

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