EXPERIENCES WITH A HIGH GRADE CONTINUOUS CENTRIFUGAL AT DARNALL

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Abstract

A high grade continuous centrifugal (supplied by Broadbent) was commissioned at Darnall in 1996. Considerable effort has gone into evaluating the performance of this machine and some modifications have been carried out. Results of tests and experiences of operating the continuous centrifugal are reviewed. VHP sugar is produced at massecuite throughputs of up to 25 ton/h. Moisture content and purity rise are higher than those achieved with the existing Batch centrifugals. Lump formation and crystal breakage have not been evident.

Introduction

Darnall sugar mill received a high grade continuous centrifugal HGC1100 for trial purposes in 1996 from Thomas Broadbent and Sons Ltd. This centrifugal has since been purchased and operates as a production machine. The HGC1100 centrifugal has a basket angle of 25° and a separating effect ranging from 300g at 700 rpm to 960 g at 1 250 rpm. The variable speed drive motor for the basket is side mounted and the feed inlet is centred at the top of the casing. Wash water is applied by means of horizontal concentric rings at four points in the machine.

Relative positions of the wash rings are shown in Figure 1. They are labelled lubrication, bottom, middle and top wash rings. The flow rate to each wash position can be set individually on the flow meter. Steam at low pressures is supplied to the feed cone.

The specifications for which the HGC1100 centrifugal was designed to achieve are:

Massecuite Rate	:	35 ton/hr
Dried Sugar Pol	:	> 99,3 %
Sugar Colour	:	< 1 350 ICUMSA
Dried Sugar Moisture	:	< 0,15 %
Fines	:	minimum
Lumps	:	minimum
Purity rise	:	< 2 units.

Over 150 tests have been carried out to optimise the performance of this continuous centrifugal, during which time a number of problems were encountered and some modifications necessitated. These experiences and the results obtained so far are discussed in this paper.

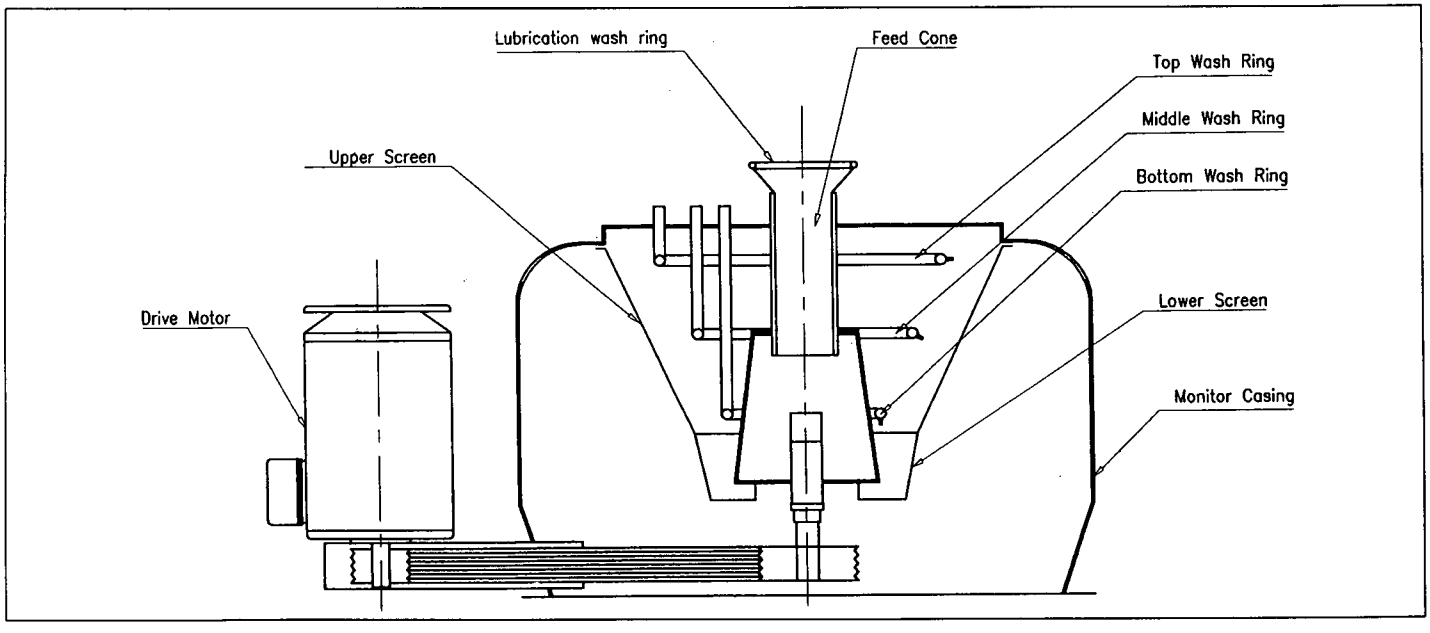

Figure 1. Sectional arrangement of high grade continuous centrifugal.

Modifications since commissioning

Several retrofit changes have been made to the peripheral equipment of the high grade machine, most of which were related to the wash water system. A booster pump was installed on the wash water supply line because water flowrates higher than 20 L/min could not be attained. Later on very high water rates were required to achieve acceptable sugar pol levels. As a result purity rise values were extremely high, ranging from 6 to 10 units. It was discovered that the screens were torn at the level of the wash rings. This was either caused by water jets from the nozzles or particulate matter in the wash water; wash water being supplied from the sweetwater tank. The spray nozzles were found to be blocked by scale, rust and other debris. Consequently, a bag filter made of cloth was fitted downstream of the booster pump.

The concentric wash ring at the middle position was replaced with a vertical pipe which gave better results at low water rates (<20 L/min) than the wash ring. The top wash was discontinued as it was found to produce high moisture in the product sugar, without a significant increase of sugar pol. Water from the top wash was also carried over with the sugar.

Turbine flow meters were found to be unreliable. They were blocked by particulates in the water, and operators would hit them with blunt objects to make them functional. These flow meters were replaced with magnetic flow meters, which do not have moving parts or impellers. Recently the flat 'vee jet' nozzles were replaced with cone nozzles which are low impact sprays. When the high grade continuous centrifugal was commissioned, the accelerator cup was completely covered with a nickel chrome screen. This resulted in vibration, after which the screen was replaced with an unperforated steel sheeting. This has recently been partly (50%) replaced with screen, without incurring the vibration penalty.

Operating experience

The high grade continuous centrifugal has proved to be mechanically reliable, operates smoothly without vibration. It has a simple layout and minimum peripheral equipment; it has no massecuite or sugar mingler. The continuous machine does not produce lumps in the product sugar. This is a significant benefit of the Broadbent machine over the other designs which require a blender to remove lumps. In their articles, Wong Sak Hoi and de Rosnay (1996) and Milner and Houston (1997) evaluate high continuous centrifugals that do not work satisfactorily unless blenders are functional. However, the monitor casing of the Broadbent machine needs to be washed on a weekly basis, or small lumps of approximately 6 mm will begin to dislodge from the high moisture sugar build-up on the casing. The colour of the wet sugar from the continuous machine looks higher than that from the batch machines because the continuous machine sugar is wetter. Generally, dried sugar from the continuous machine meets the 1 350 ICUMSA colour specification when the VHP pol specification is attained. The centrifugal is satisfactorily run by the operating staff on shift, and it takes about five minutes to bring on-line. It handles massecuite with false grain reasonably well. This was expected as the sugar flow on the screen is dynamically regenerating, which allows massecuites with high CV values to be cured (Milner and Houston, 1997).

Screen life was two to three weeks of continuous operation in the first two seasons. It was noticeable that the worn screens were heavily dented, possibly by debris from the horizontal crystallisers. Darnall has 16 A-massecuite horizontal crystallisers, with a total of 200 m^2 of open surface area. This presents an opportunity for debris to fall into the crystallisers and mix with A-massecuite. However, in the current season screens have lasted as long as six weeks before a change was necessary. This was achieved by ensuring good housekeeping of the crystallisers during off-crop and season. It takes six hours to change screens because the feed arrangement and wash water pipes limit access, and have to be removed. This is a major constraint in being able to do a comparison between two types of screens over a short term basis.

Performance evaluation

Massecuite throughput and sugar quality

Massecuite throughput was calculated by using a least squares procedure which minimises the effect of random errors of measurements, as discussed by Hubbard and Love (1998). Known variables were the flow rates of molasses and wash water, and results of analyses of sugar, massecuite and molasses samples. Molasses flow rates were measured with a bucket-and-timer method; wash water rates were set at the flow meters and all analyses were carried out using standard procedures. Tests were carried out with varying massecuite rates, wash water rates and steam settings to determine the capacity of the machine. The main findings can be summarised as follows:

- Massecuite quality has a large influence on the sugar quality that is produced and the throughput achievable.
- High wash rates give a better quality of sugar, at the expense of purity rise and molasses brix.
- Throughput and sugar quality increase with machine speed up to a point where molasses carry over occurs.
- Sugar quality increases with the steam supply to the feed cone, but purity rise and sugar moisture also increase.
- Massecuite throughput is limited by the VHP specification of 99,3% pol for the quality of sugar that is produced, this is illustrated in Figure 2.

In Figure 2, sugar quality is indicated by corrected sugar pol %, as discussed in the Appendix I.

A massecuite throughput of 30 ton/h was reached when maximum wash water rates (76,3 L/min) were set; the purity rise was 5 units across the continuous machine. At moderate wash water rates (33,7 L/min) massecuite throughputs of 25 ton/h were attained with a purity rise of 4 units. The effect of hot massecuites on throughput and sugar quality was investigated during boil-off when massecuite temperatures were in the 62 to 65°C range. Results in Table 1 indicate that sugar quality did not improve when hot massecuites were used, which was contrary to expectations. This could be attributed

to the quality of the boil-off massecuites. During the two weeks of hot massecuite trials corresponding results from the batch machines also gave corrected pols below 99,3%; and the weekly average pol values for VHP sugar made at Darnall were 99,19 and 99,10%. Consequently, trials with hot massecuite did not show an improvement in throughput of the continuous centrifugal.

Purity rise

Average purity rise figures in Table 1 are significantly lower in the case of hot massecuites (2,29 units) than that of cold massecuites (4,15 units). (Note that tests with maximum wash water settings were an extreme case and therefore are excluded from the discussion on purity rises.) Purity rises for hot massecuites (2,29 units) also compared reasonably well with values for batch machines (2,13 units). Although the sugar quality for hot massecuites was low, the reasons were not under-washing or unrepresentative massecuite throughputs. Settings for bottom:middle:lubrication washes were 6:24:3 L/min for cold massecuites and 20:20:5 L/min for hot massecuites, and 80% of throughput rates for hot massecuites were in the 22 to 27 ton/h range where 99,3% pol has been achieved with cold massecuite.

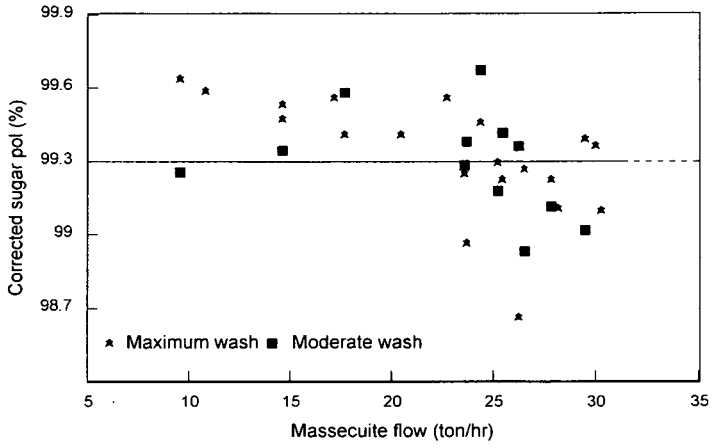

Figure 2. Relationship between massecuite throughput and corrected sugar pol.

Table 1. Overall summary of test work results.

No. of data points	Tests	Centrifugal type	Massecuite temperature	Wash water rates		Corrected sugar pol (%)	Wet sugar moisture (%)	Purity rise units (%)	Massecuite throughput (ton/hr)
21	A	Continuous	Cold (48-45)°C	Maximum (76 L/min)	Average Std. Dev.	99,32 0,23	1,27 0,26	5,05 2,21	23,18 6,92
13	B	Continuous	Cold (48-45)°C	Moderate (34 L/min)	Average Std. Dev.	99,24 0,27	1,12 0,24	4,15 1,03	23,24 7,79
9	C	Continuous	Hot (65-62)°C	Moderate (45 L/min)	Average Std. Dev.	98,91 0,28	1,14 0,56	2,29 1,12	25,22 3,51
10	D	Batch	Hot (65-62)°C	–	Average Std. Dev.	99,16 0,13	0,41 0,20	2,13 1,14	–

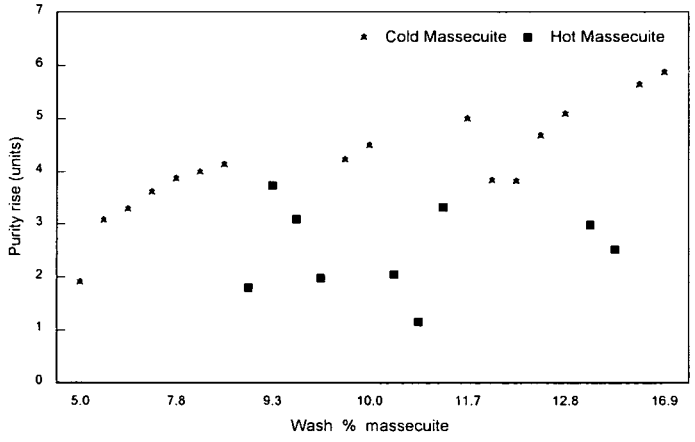

Figure 3. Purity rise as a function of wash % massecuite.

Figure 3 shows the relationship between the purity rise and the wash water % massecuite for hot and cold massecuites for the continuous machine. This plot shows that cold massecuites have higher purity rise figures which also tend to increase with wash % massecuite. This was expected, as it confirms that increasing wash rates lead to higher levels of purity rise. The plot for hot massecuite is somewhat scattered. but purity rise values did not seem to increase as water % massecuite increases. This may be unrepresentative because hot massecuite trials were carried out with poor quality (boil-off) massecuites. High wash water rates can increase the capacity of the continuous machine up to 30 ton/h of massecuite, as shown in Figure 2. However, the resulting high levels of purity rise will lead to reduced exhaustion on the A station and increased massecuite loading at the A and B stations. Low brixes in molasses, caused by over-washing, may also require an increased evaporative capacity. A trend in the relationship between purity rise and massecuite throughput is shown in Figure 4, where massecuite throughput is indicated as Amperes drawn by the basket drive motor.

Purity rise and sugar pol decrease as massecuite throughput increases if the wash water rate is kept constant. Figure 4 compares two types of screens: a nickel chrome screen and a stainless steel screen. Results of trials with stainless steel

screens were inconclusive because these screens were torn within two days of operation. This was because the edges of the screens were not reinforced with a blind strip; the stainless steel screens for the trial had been cut to fit the centrifugal with a pair of scissors.

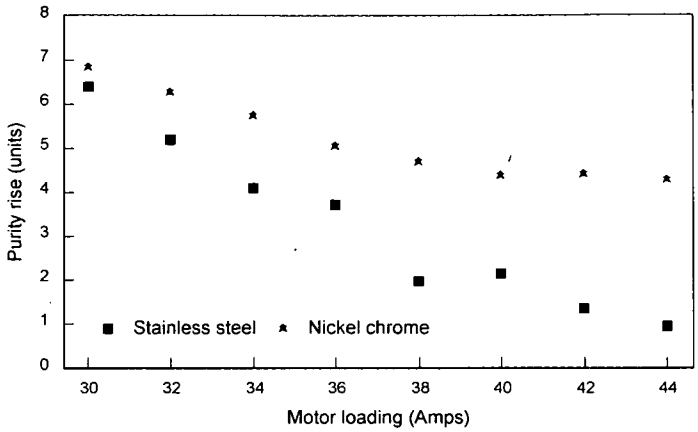

Figure 4. Relationship between purity rise and massecuite throughput at constant wash water rate of 45 L/min and decreasing sugar pol.

Moisture

The continuous centrifugal produced a higher moisture content in its wet sugar than the batch centrifugals. As shown in Table 1, the average moisture content of wet sugar from the continuous centrifugal is 1,12%. This is 0,7 to 0,9 units higher than the average values for the batch machines; when moderate wash rates were used in the continuous centrifugal. This means that a larger drying capacity would be required if A continuous machines were installed instead of batch machines and this needs to be built in as part of the capital costs. In the case of a sugar mill with a back end refinery, the sugar produced from the continuous machine can be directly melted and thus avoid the drier capacity penalty. The temperature of sugar at the drier inlet was 4°C higher (at 55°C) for the sugar from the continuous machine than that of the sugar from the batch machines during hot massecuite tests. Modelling work and operating experience in Australia (Greig and Belloti, 1996), have shown that hotter (62-70°C) and wetter (0,8-1,3%) sugar at the drier inlet will not sacrifice drying performance; this has not been observed at Darnall.

Crystal breakage

Crystal breakage in the continuous machine was assessed by comparing dimensions obtained from crystal size distribution (CSD) analysis of wet sugar samples against those from the batch machines. Wet sugar was sampled over five days, three samples per day, from each machine. Averages of the results are given in Table 2.

Table 2 shows that dimensions of crystals from the continuous machine are similar to those for crystals from the batch machines. Individual CSD plots for each day also supported this. On the basis of this side by side analysis, no evidence of crystal breakage has been found. MA/CV results of product sugar will give more conclusive results about crystal breakage in the continuous centrifugal. These trials are difficult to run because the continuous machine is installed as a production machine and cannot be run alone without disrupting sugar production.

Table 2. Results of crystal size distribution for wet sugar samples.

Measurement	Batch centrifugals	Continuous centrifugal
Length (microns)	607	643
Width (microns)	378	405

Future developments

A number of aspects of the high grade continuous machine still need to be investigated. Maximum wash rates need to be applied when hot massecuites (good quality) are available to investigate the benefits on purity rise figures. Some centrifugal manufacturers specify the minimum temperature of the feed massecuite to be 65°C (Milner and Houston, 1997). Massecuite viscosity can also be reduced by using a high steam supply pressure and by heating the wash water to 100°C. Screens with different open areas, materials and hole geometry need to be investigated. Back blending with molasses/syrup has been claimed to reduce purity rise levels. The basket speed needs to be optimised with respect to sugar quality, subject to crystal breakage being not excessive.

A comparison of the performances of the continuous machine and the new range of large batch machines would be a valuable exercise. It is envisaged that some of these developments will contribute to achieving increased massecuite throughput, in the 30 to 35 ton/h range.

Conclusions

The high grade continuous centrifugal at Darnall has proven its capability to produce VHP raw sugar quality without reliability problems, lump formation or crystal breakage. Its massecuite throughput is 25 ton/h for VHP sugar, has a purity rise of 4 units and a moisture content of 1,12% on the wet sugar. Hot massecuites have shown a potential to reduce the purity rise to 2,3 units. More development work is required to raise throughput level closer to the design rate of 35 ton/h.

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APPENDIX I
Calculation of corrected sugar pol

The continuous machine at Darnall is installed as a production machine, its wet sugar is combined with that from the batch machines in a screw conveyor before the sugar drier. Therefore, under normal operating conditions it is not possible to obtained a dried sugar sample made up of sugar solely from the continuous machine. By calculating dry solids in the wet sugar sample and assuming a moisture content of 0,1% in the dried sugar, it is possible to approximate the equivalent value of pol %. This is the pol % value that would have been attained if the continuous sugar sample (or batch sugar sample) was dried separately to a moisture content of 0,1%. An empirical relationship is used to convert the brix value into a dry solids value (Hoekstra, 1998) according to:

$$Dry\ solids\ (DS) = Brix\ x\ (1 - 0{,}00066\ x\ non\text{-}Pol)$$

The corrected pol % value is therefore;

$$Pol(dried) = 99{,}9\ x\ \frac{Pol(wet)}{DS}$$

$$= Corrected\ Pol$$

Dry solids is used instead of brix, due to the error associated with the optical nature of brix measurement.