ABSTRACT

Just as any other techno-economical process, the centrifugation of various sugar massecuites in the beet and cane sugar industries is under the permanent compulsion to rationalize, to save energy and to improve the quality of the processed products. During the past years a number of advanced technology on the continuous centrifugals of different designs have been developed and operated throughout the sugar industries worldwide. The development in this specific field has focussed on the provision of high capacity continuous centrifugals for the application on all sugar massecuites in raw sugar factories and refineries; targeting the key issues of high sugar qualities at minimization of molasses or run-off purities and power consumption. Low installation, operation and maintenance costs have been important design criteria. Design criteria, design details and operational results are presented in this paper outlining the pros and cons between the application of continuous centrifugals and batch centrifugals within the field of its application over the full range of sugar massecuites in the beet and cane sugar industries.

INTRODUCTION

The production of sugar is under the permanent compulsion of innovation, rationalization, product quality improvement, energy and manpower saving. The advancement in centrifugation of any kind of sugar massecuite, whether it is batch or continuous, is largely dependent on the effectiveness of sugar crystallization. A perfect crystallization process is a fundamental requirement for optimal sugar fusing. The most significant goals for sugar crystallization and centrifugation are:

- Higher sugar yields and better qualities.
- Minimum sugar production costs.
- Shortest possible production time from sugar crystallization to sugar storage.
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- Electrical energy, water and steam savings.
- Minimum investment, operation and maintenance costs.
- Meaningful monitoring and automation.

WORLDWIDE APPLIED CONTINUOUS CENTRIFUGAL DESIGNS

Continuous centrifugals of different designs such as pusher type and conical centrifugals in horizontal and vertical shaft operation with side and central feed distribution systems and self discharge have been performing successfully for more than 30 years throughout the cane and beet sugar industries worldwide.

The initial demand for continuous centrifugals resulted from the necessary improvement of exhaustibility of low grade massecuites in the beet and cane sugar industries.

Over the years of steady development and continuous research the basic concept of continuous low grade massecuite curing has been shifting gradually towards the processing of middle and high grade massecuites in raw sugar factories and refineries. This has led to the development of an automatically controlled magmatizing and remelting continuous centrifugal.

Further advancement resulted in the double spinning continuous centrifugals involving two or three conical baskets integrated in one centrifugal housing.

It is necessary to distinguish between single and double curing continuous machines:

Single curing continuous centrifugals

FIGURE 1. Typical continuous centrifugal with dry substance discharge (BMA K 2900).
An example of a single curing machine is shown in Figure 1. Similar basic concepts are applied by several international centrifugal manufacturers. Special features of this particular machine are:

- Special three step massecuite acceleration device.
- Balanced tension V-belt drive, i.e. applying a special coupling between V-belt drive system and basket drive shaft.

Alternative designs are shown in Figures 2 and 3.

**FIGURE 2.** Continuous centrifugal, pendulum type, with dry substance discharge (SL 1400).

**FIGURE 3.** Hybrid continuous centrifugal for high grade m/c.
In Figure 3 the term hybrid fugal refers to a centrifugal which has been converted from a batch to a continuous mode of operation (Smith and Howard).

**Double spinning continuous centrifugals**

Concepts of double spinning continuous centrifugals for the processing of all grades of massecuites applying vertical drive shaft operation are illustrated in Figures 4 to 6. The key objective of such double continuous designs is the combination of the following process steps in a single centrifuge:

- Initial fugalling of massecuite in the first basket.
- Magmatizing of initially spun sugar.
- Dry substance discharge and formation of magma, or
- Melting of the magma fugalled in the second basket.

The K 1500 DS machine has two baskets and a screened acceleration stage for green syrup separation, a sugar/syrup magmatizing facility, and a device preventing re-contamination of the washed sugar.

Referring to Figure 5, the sequence of process steps in this double continuous centrifugal is as follow:

a) Initial centrifuging of solid-liquid mixture in the upper basket - separation of dry substance and mother liquor and initial washing of the solids.
b) Mixing of the centrifuged solids (e.g. with a saturated solution).
c) Centrifuging of the mixed-in massecuite in the lower basket, separation of solid and mixing agent and renewed washing of the solids.

Figure 6 shows a machine in which the upper basket is fed from the lower basket. The precuring of massecuite is effected in the lower basket, magmatizing of spun sugar follows between baskets. The upper basket represents the affination stage for all grades of massecuites.

Figure 7 shows a triple spinning machine with two affination stages. This machine is used for processing of high grade massecuites; the spun sugar is remelted in the centrifugal itself. Basket angles are 26°.

The DS 1513 and DS 1311 are machines which combine two independent centrifugals (Figure 8). First, massecuite enters the pre-spinning stage where it is subjected to centrifugation. In a following magmatizing system the resultant sugar is mixed with a suitable medium to form a magma which is then fed through two ducts into the second centrifugal, i.e. the after-spinning stage. Thereafter the sugar passes into the respective melting system.
FIGURE 6. Principle of double continuous centrifugal having two baskets on one shaft with massecuite feed from lower basket to upper basket.

FIGURE 7. Triple spinning S&L-continuous centrifugal type Twinmix with two affination stages.
The pre-spinning and after-spinning stages have separate drives; these allow each basket to be adjusted optimally to the prevailing operating conditions thus enabling minimum use of energy.

**BASIC DESIGN CRITERIA FOR HIGH CAPACITY CONTINUOUS CENTRIFUGALS**

Within the context of this presentation only some of the key design parameters, those influencing chiefly the effectiveness and economics of continuous centrifugal operation should be noted:

- Massecuité feed-, treatment-, distribution- and basket design.
- Basket material quality requirements.
- Filtering- and supporting screens.
- Sealing arrangement between molasses/run-off and sugar compartment.
- Centrifugal force.
- Diversification in process application.
- Energy consumption.

Massecuité feed, treatment, distribution and basket design

Design innovations are shown in figure 9.
Massecuite enters centrally through a special massecuite heating device where water and steam are carefully added. The massecuite, water and steam are intensively mixed in an acceleration cup from which they flow to the distribution bell. Further steam is added in the bell thus ensuring good flow to the working screen. This type of massecuite pretreatment increases the throughput of low grade massecuites by 5-20% but care is necessary to control crystal dissolution.

Basket design is influenced by the required duty. Low grade massecuites are effectively fugalled in smaller baskets at highest possible basket speed with wider basket angles. High grade massecuites are processed in larger baskets at varying lower basket speed with steeper basket angles.

High viscose low grade massecuites in the cane sugar industry are centrifuged in single units most effectively in basket sizes between 800 mm and 1,350 mm diameter. The respective basket angles are between 35 degree and 30 degree. High grade massecuites are handled in single curing centrifugals with baskets between 1,000 mm diameter and 1,600 mm diameter, having basket angles between 30 degree - 25 degree.

Optimal massecuite distribution pattern and crystal retention time during the separation process are of paramount importance!

**Basket material quality requirements**

The provision of long and safe service life of centrifugal baskets of any size and shape demands very precise design, fabrication and quality control. Damping systems to ensure minimum vibration of baskets have proved beneficial.
Filtering and supporting screens

The condition of the filtering screens used for separating sugar crystals and mother liquor in continuous centrifugals has a major influence on sugar losses, separating efficiency and massecuite throughputs.

The following parameters are important:
- Mean slot width.
- Slot uniformity.
- Percentage open area.
- Resistance to the flow of mother liquor through the screen.
- Screen wear including changes in the slot profiles and its relevant changes in the resistance to flow of mother liquor.

Electroformed hard-chromed nickel screens with various perforations (determined by the mean-crystal size) have open areas between 6.5% and approx. 15% and screen thickness of 0.26 to 0.32 mm.

Great emphasis is placed on perforation patterns to ensure maximum drainage efficiency, while minimizing crystal losses through the filtering screen.

Laser cut stainless steel screens with relatively high open areas are recent successful entrants to this field of continuous centrifugal operation.

Stainless steel backing or supporting screens in various forms play a vital role in drainage efficiency and in the life expectation of the filtering screen. Tests with wedge wire supporting screens have been carried out in Australia with encouraging results.

Sealing arrangement between molasses/run-off and sugar compartment

The importance of an effective sealing arrangement between the molasses/run-off and sugar compartments has to be emphasized because of the importance of preventing recontamination of the sugar. Each manufacturer offers its own effective sealing arrangement.

Centrifugal force

With regards to the interaction of centrifugal force and effective energy usage it has to be noted that:

The electrical energy input per ton of massecuite increases proportional to the G-force-factor “Z” as well as to the outer basket radius; however, decreases in accordance with the throughput-increase.
Practical experiences over many years have proven the following standard values for G-force (Z) requirements:

- $Z = 2,500 - 2,900$ for high viscosity low grade m/c
- $Z = 1,500$ for raw and C affination m/c
- $Z = 700 - 1,000$ for raw sugar affination magma
Diversification in process application

Magmatizing and remelting of various sugar grades presented a new field of application for continuous centrifugals thereby minimizing investment and operating costs and reducing space requirements.

Figures 10 and 11 illustrate the principle of magmatizing and melting in continuous centrifugals.

It is well-known that continuous centrifugation causes crystal destruction to varying degrees depending on crystal size, centrifugal speed, the respective housing diameter and its wall design. It should therefore be noted that any magma produced through continuous centrifugation does not grant the desirable degree of crystal uniformity to enable the magma to be used as seed.

Energy consumption

Continuous centrifugation is more energy intensive than batch centrifugation. An analysis of the steady state power consumption in a continuous centrifugal was conducted by Greig et al.\(^1\) and revealed that only about 50% of the total energy invested in continuous centrifugation is required for massecuite separation. A significant loss occurs due to the windage, the windage being strongly dependent on the basket type, basket diameter and rotational speed.

The rest of the total energy input is lost by friction in the filtration of liquor through the crystal bed and screen, the shearing and sliding across the screen of molasses and crystal respectively and by bearing frictions and electrical losses.

The stringent demand for lowest energy requirement in continuous centrifugation demands careful selection of basket size, form, speed and filtering screen perforation.

CENTRIFUGAL PERFORMANCE AND OPERATIONAL RESULTS

General

The comparatively high viscosities of low grade massecuites in the cane sugar industry require the use of high G-forces in centrifugation. Steam and water have to be used very carefully otherwise excessive crystal dissolution takes place.

The purity difference between mother liquor and molasses in the cane sugar industry of good crystal spectrum should be below 1.5 points. In this context it is stressed that the purity rise in continuous centrifugals is largely dependent on the
effectiveness of the crystallization process; poor pan boiling resulting in conglomerates and false grain will cause trouble in any kind of centrifugal operation.

It should be further noted that consistent centrifugation of any kind of massecuites is also dependent on adequate massecuite flow. Therefore it is generally important to combine the crystallizer with the massecuite headers above the continuous centrifugal in a closed circuit. The closed circuit should include a lump catcher and a magnetic device to catch metal objects.

Steam and water application during the fugalling of all grades of massecuites in continuous centrifugals have to be rated individually in strict relation to the prevailing massecuite conditions and the required sugar quality.

Curing capacities of continuous centrifugals vary considerably from country to country, season to season and even factory to factory. Cane quality and subsequent crystallization behavior of all massecuites determine the degree of centrifugation efficiency.

**Performance results**

In assessing performance it is important to note the considerable influence of massecuite properties. Under normally prevailing massecuite properties in the worldwide cane sugar industry the BMA continuous machine model K 1300 (Turbo) is rated for the fugalling of properly conditioned low grade massecuites between 10 and 14 t/h.

Processing high viscosity low grade massecuite at

- Water temperature: 80 - 82 °C
- Massecuite temperature: 50 - 52 °C
- Crystal content in massecuite: 26 - 27 %
- Mean crystal size: 0.25 mm

produced the results shown in Table 1.

The power/performance diagram for the K 1300 having a basket angle of 30° is shown in Figure 12.

From the three current/performance lines A to C the specific energy consumption $E^*$ amounts to:
TABLE 1. Low grade massecuite throughput and results in BMA continuous centrifugal K 1300 (Turbo).

<table>
<thead>
<tr>
<th>Massecuite</th>
<th>M/C Purity</th>
<th>M/C brix</th>
<th>Molasses Purity</th>
<th>Molasses brix</th>
<th>Sugar Purity</th>
<th>Purity Rise</th>
<th>Water l/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>t/h</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.67</td>
<td>56.78</td>
<td>93.91</td>
<td>36.82</td>
<td>82.94</td>
<td>84.95</td>
<td>1.98</td>
<td>717.2</td>
</tr>
<tr>
<td>8.35</td>
<td>58.90</td>
<td>92.75</td>
<td>38.19</td>
<td>84.51</td>
<td>84.5</td>
<td>1.51</td>
<td>280.5</td>
</tr>
</tbody>
</table>

A) 5.7 kWh/t: low grade massecuite  
B) 3.1 kWh/t: middle grade massecuite  
C) 1.38 kWh/t: high grade massecuite

Proper massecuite conditions prevailed. Modern continuous centrifugals can process over 60 t/h of high grade massecuite.

Performance of a specific BMA double continuous centrifugal, model DS 1513

The DS 1513 machine superseded the K 1500 DS and is designed for high grade massecuites. Model DS 1311 is for low grade massecuites. Both models produce...
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dry sugar or magma or melt. Comparative dimensions of the baskets vary according to the nature of the massecuite to be processed. Optimum performance is achieved with automatic control of massecuite feed, mixing agent, washing liquid and melting agent. The interlinked control of a DS 1311 machine is shown in Figure 13.

![Flow diagram for DS 1311.](image)

**FIGURE 13.** Flow diagram for DS 1311.

The upper curve presents the specific electric energy requirement for the proper fugal of the middle grade massecuites at $\text{bal/ba}^2 = 1,160/960 \text{ min}^{-1}$; the lower relates to the processing of high grade massecuites at $\text{bal/ba}^2 = 700/960 \text{ min}^{-1}$.

This performance data refers to the processing of beet sugar massecuites. The procession of cane sugar massecuite should produce similar results. The double continuous centrifugal DSA 1513, thus specifically designed as a centrifugal unit for “wet operation”, i.e. producing a melt-sugar solution serves technically and economically best when recrystallization in a refinery is demanded.

The mass balance when a DSA 1315 model is used on beet raw sugar II massecuite is given in Figure 15 and it illustrates the potential of the machine to produce a good yield of high purity sugar solution with only 4% of the original color.
FIGURE 14. Specific energy consumption $E^*$. DSA 1513.

The double continuous machine uses less energy than a single machine in sequence. An example is given in Table 2.

The advantages are lower investment, installation and maintenance costs and simplicity of operation. Sugar purities from continuous centripetal processing are high.

ADVANTAGES AND DISADVANTAGES OF CONTINUOUS CENTRIFUGAL OPERATION.

Major advantages are lower investment, installation and maintenance costs and simplicity of operation. Sugar purities from continuous centripetal processing are high.
FIGURE 15. Massflow diagram of separation process in BMA double continuous centrifugal DSA 1513.
### TABLE 2. Comparison of specific electric energy consumption $E^*$ for double curing of low grade massecuite.

<table>
<thead>
<tr>
<th></th>
<th>Installation A</th>
<th>Installation B</th>
</tr>
</thead>
<tbody>
<tr>
<td>One unit Z = 2400</td>
<td>$E^* = 5.8\text{ kWh/t}$</td>
<td>ba 1: $E^* = 5.2\text{ kWh/t}$</td>
</tr>
<tr>
<td>precurer</td>
<td></td>
<td>ba 2: $E^* = 5.1\text{ kWh/t}$</td>
</tr>
<tr>
<td>One Unit Z = 1600</td>
<td>$E^* = 3.3\text{ kWh/t}$</td>
<td></td>
</tr>
<tr>
<td>aftercurer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Periphery equipment:</td>
<td>$E^* = 1.0\text{ kWh/t}$</td>
<td></td>
</tr>
<tr>
<td>(magma/mixer, pumps, etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Spec. Electr. energy</td>
<td>$E^* = 10.1\text{ kWh/t}$</td>
<td>Total: $E^* = 8.3\text{ kWh/t}$</td>
</tr>
</tbody>
</table>

Viscosity low grade massecuites are approximately 2 to 4 points higher than those achieved by batch operation. When high quality white sugar is required, the double curing of middle grade massecuites enables high sugar purities and low colour values to be achieved.

**Disadvantages:**

- **Crystal destruction**

Crystal destruction is still troublesome. Damage results from high velocity impacts with the centrifugal housing and from mid air collisions on the flight path from the basket edge to the sugar chamber wall. With an increasing level of polarization the degree of crystal damage increases too.

Crystal destruction is the major barrier to production of commercial sugar by continuous centrifugation. Various devices for minimizing destruction have been tried but none are completely satisfactory. Increased housing diameter does alleviate the problem.

- **Lump formation during high grade sugar fusing**

With the varying degree of crystal destruction, damaged crystals tend to stick together in lumps.
- **Variation of massecuite feed into the centrifugal**

Massecuite density-variation, lumps, foreign objects and unsteady water and steam application can lead to substantial process and time losses even when an automatic massecuite feed control is applied. Changing crystal sizes can lead to excessive crystal dissolution if machines are not re-set frequently.

- **Higher moisture content of sugar discharged**

Spun sugar from continuous centrifugals shows a higher moisture content than that from batch machines.

**FUTURE DEVELOPMENT REQUIRED FOR CONTINUOUS CENTRIFUGATION**

Future development should concentrate on:

- More profound study of the mechanism of continuous centrifugation in conjunction with the massecuite behaviour in continuous centrifugals.
- Improvement on purging performance of centrifugal screens and baskets.
- Elimination of crystal destruction.
- Optimization of water and steam application.
- Improvement of syrup separation, specifically during processing of high grade massecuites.
- Improvement on filtering screen service life, reducing the present wear rates.
- Further minimization of electrical energy requirement.
- Increased application of effective automation and meaningful monitoring for higher productivity.

**MONITORING AND AUTOMATION SYSTEM FOR A CONTINUOUS CENTRIFUGAL STATION**

In developing an automation system the following process values should be controlled:

- Magma brix, molasses brix, magma temperature, massecuite flow rate through the crystallizers, crystallizer drive, molasses pumping rate, massecuite reheat water temperatures, loads of sugar transport elements, etc.

Molasses purities need to be monitored consistently.

The control system needs to be factory specific and must interlink crystallizers,
FIGURE 16. A Concept of control center for a continuous centrifugal station.

The concept shown in Figure 16 illustrates the integration of centrifuges and vacuum pans. The various interlinks in one such automation concept are shown in Figure 16.
CONCLUSION

Continuous centrifugation of all grades of massecuites nowadays represents an advantageous alternative to discontinuous centrifugation. Each case however requires careful analysis before deciding on the potential advantage of continuous centrifugation. Improvements in performance are still to be expected and the processing of high grade massecuites is becoming increasingly attractive. With further improvements on purging efficiencies the specific energy consumption will be favourably comparable with that of discontinuous centrifugals. It can be expected that the double spinning continuous centrifugal type will be attractive for application in low grade affination in raw sugar factories and in high grade affination in refinery operation. Good factory data management combined with an individually structured monitoring and automation system are goals for the very near future.

REFERENCES


LA CENTRIFUGATION EN CONTINUE DES PRODUITS DE BASSE ET HAUTE PURETE, DEVELOPPEMENT ET EXPERIENCE

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RESUME

Comme pour tout autre procede technoeconomique, la centrifugation des massecuites, en betterave ou en canne, doit etre rationalise pour economiser l’energie et pour ameliorer la qualite du sucre. Plusieurs centrifuges ont ete developpees et testees dans le monde sucrier, au cours des dernieres annees. On s’est concetre sur des machines de fortes capacit’es, en continu et s’appliquant a toutes les massecuites de sucreries et de raffineries. Les considerations importantes ont ete la bonne qualite du sucre, des puretes de melasses les plus basses possible et la reduction de l’energie. Finalement les couts d’installation et d’entretient
doivent être bas. Le papier présente les critères de conception et des détails operationnels. On compare l'application des machines continues pour la centrifugation de toutes les massecuites, en bettraue et en canne.

DESARROLLO Y EXPERIENCIAS EN CENTRIFUGACIÓN DE PRODUCTOS DE ALTO Y BAJO GRADO EN MASAS COCIDAS EN CENTRIFUGAS CONTINUAS

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RESUMEN

Como cualquier otro proceso técnico-económico la centrifugación de distintas masacocidas de azúcar en la remolacha y en la caña de azúcar está bajo la permanente compulsió del racionalizar, ahorrar energía y el de mejorar la calidad del producto procesado. Durante estos últimos años un número de avances tecnológicos sobre las máquinas continuas de diferentes diseños se han desarrollados y operados en toda la industria azucarera mundialmente. El desarrollo en este campo específico se ha enfocado en la provisión de altas capacidades en las máquinas continuas para la aplicación en todas las masacocidas de azúcar en las fábricas de azúcar crudos y refinerías; apuntando a los puntos claves como son la alta calidad en el azúcar con minimización de mieles o purezas de productos de retorno y consumo energético. Bajo, costo de instalación, operación y mantenimiento han sido importantes puntos en sus criterios de diseños. Criterio de diseño, detalles de diseño y resultados operacionales son presentados en este papel los subrayado pros y contras entre la aplicación de centrífugas continuas y máquinas de descarga periódicas dentro del campo de aplicación sobre el rango total de las masas cocidas de azúcar en la industria de la remolacha y la de la caña de azúcar.