

Today's production requirements – how material selection and innovative design contribute to their fulfilment*



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Abstract

For many years, the materials used for sugar production equipment were selected based on criteria such as material strength, corrosion resistance, availability and current prices. Today, additional requirements have to be considered, which are defined by the location where the equipment is to be installed. Examples include food safety (hygiene), operational reliability and maintainability. Material selection enhanced by innovative design allows meeting the highest requirements regarding process optimisation and productivity while also ensuring low wear and tear of the components, low maintenance, and a long service life. This paper gives examples to explain the selection of materials in view of present requirements. They include compliance with hygiene standards through use of inert materials, non-breakability, low surface roughness, cleanability, low abrasion, detectability, resistance, but also a long service life and ease of maintenance. A particular focus will be placed on the consistent use of stainless steel, which results from most of the requirements mentioned. Furthermore, the latest innovations in centrifugal design will be presented; the basket design, for example, significantly contributes to a longer life, and to a simplification of the mechanical system, thanks to a reduced number of components. This helps not only to minimise maintenance requirements and thus costs and downtimes, but also reduces the risk of machine failures.

Keywords: selection of materials, hygiene standards, design, long service life, ease of maintenance

Introduction

Food safety is a prerequisite for any food producer. In order to be successful on the global sugar market, sugar producers have to ensure a high quality of their product by complying with international standard and regulations. To do so, they have to select their production equipment carefully, in terms of material, design and overall production cost.

This paper illustrates a manufacturer's contribution to these requirements.

Material selection

For many years, the materials used for sugar production equipment were selected based on criteria such as material strength, corrosion resistance, availability and current prices. Today, additional requirements have to be considered, which are

defined by the location where the equipment is to be installed. The closer a material is to the final production step of white crystallised sugar, the higher the selection criteria rank.

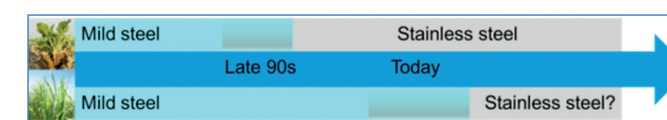
Material selection has to meet the requirements of international regulations such as the European EC No. 1935/2004 on materials and components intended to come in contact with food. The equipment has to be designed to comply with this regulation, to allow the sugar producer to fulfil his obligations regarding food hygiene (EC No. 852/2004) or feed hygiene (EC No. 183/2005). In addition, the material selected must also ensure high operational reliability, low and easy maintenance of the equipment.

The equipment at the sugar end has to meet the most stringent food hygiene criteria. Quality requirements have become stricter over time, which is why they serve as the best

example to illustrate the crucial importance of material selection. White-sugar production in the sugar-beet industry has always led the way. One would, therefore, expect standards established in the beet industry to be adopted by the sugarcane industry in the near future.

Even a few decades ago, mild steel was the standard material choice in the production of white sugar from beet. Since then, the demands of the industry have shifted to equipment made from stainless steel, either completely or at least those parts that are in contact with the product. Nowadays, these requirements may even have to be taken into account in cane-sugar production. To meet product quality specifications, stainless steel is, therefore, now included as a standard option in offers for vacuum pans, centrifugals and drum driers (Figure 1).

Figure 1: Development of the use of stainless steel in the beet and cane industries



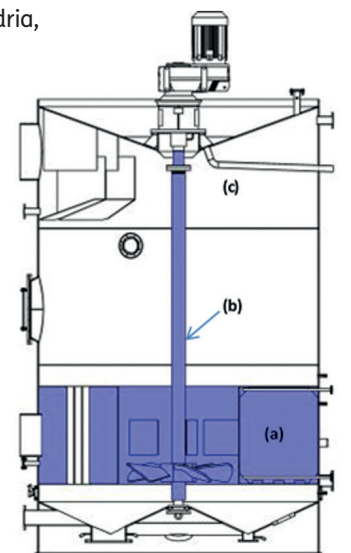
Batch pan

A batch pan is made from several major components. Even today, the material selected depends on the component type and on the quality of sugar to be crystallised.

In the past, the calandria (Figure 2a) was made from mild steel. It had only a short service life, due to low corrosion resistance. Since the late 1990s, calandrias have been manufactured in stainless steel for all types of sugar.

The agitator (Figure 2b) must have specific strength properties, as torsional moments are transferred and load cycle changes can occur. Manufacturing the shaft completely from stainless steel would result either in additional wall thickness or larger diameters in the case of a solid shaft, as the tensile strength of stainless steel is typically lower than that of medium carbon steel. It is technically feasible, but in most cases not justified economically. For all these reasons, the shaft is made from medium carbon steel with a stainless steel cladding. However, as the sealing is designed with a stuffing box, this part of the shaft (Figure 2c) cannot be cladded and is therefore manufactured from high-quality solid stainless steel.

Figure 2: Batch pan: (a) calandria, (b) agitator, (c) stuffing box



In the past, the vapour chamber was only made from mild steel. The problem with this is that rust particles could not be avoided, especially at the beginning of the crushing season. Later, the vapour chamber was manufactured with stainless-steel cladding. However, the cladding was not sufficiently resistant to the large and frequent changes in temperature and pressure. Cracks would appear at the welding seams, and juice would get behind the cladding, starting corrosion and increasing the risk of contamination. Experience showed that, in some factories, there was damage to some parts of the cladding after every crushing season. It, therefore, had to be taken off to permit cleaning underneath, and the seams had to be resealed, thus contributing to higher maintenance costs.

Currently, vapour chambers for white sugar are made from solid stainless steel, so as to ensure the quality of the finished product, a long service life and reduced maintenance. The installation of solid stainless-steel vapour chambers is standard for white and refined sugar. For a long service life, it is also recommended for the recovery batch pans in refineries.

Borosilicate is the best choice for sight glasses. It offers perfect product safety, as it does not break due to rapid temperature changes, while other materials could.

Continuous pan

A vertical continuous pan (VKT, Figure 3), is made up of four or five stacked batch pans. The same criteria apply as for a single batch pan, though with one difference in the selection of the material for the vapour chamber. As the VKT runs continuously, there are significantly fewer and lower temperature and pressure changes during the course of operation. For this reason, it is usually built with stainless steel cladding, in order to reduce

investment costs. In any case, it is highly recommended for maintenance-free refinery operation to have all vapour chambers manufactured in solid stainless steel.

Figure 3: Vertical continuous pan VKT: (a) calandria in solid stainless steel; (b) vapour chamber clad in stainless steel; (c) VKT during assembly; (d) VKT insulated



Batch centrifugal

Batch-type centrifugals are the best example to show how material selection has developed over the past decades. Since the late 1980s, screens that are in direct contact with the sugar crystal have been made from stainless steel; previously they were

Figure 4: Batch centrifugals: (top left) G-series in mild steel; (top centre) G-series parts in contact with crystals in stainless steel; (top right) B-series with housing in stainless steel; (bottom left) E series with complete housing in stainless steel; (bottom right) E series with frame in stainless steel



made from brass. The housing parts in contact with the sugar crystals started to be made from stainless steel at that time too.

The centrifugals launched in 1981, were made in mild steel (Figure 4 top left), with the option of having the housing part in contact with the sugar crystals made from stainless steel (Figure 4 top centre). In the new model launched in 2012, all housing parts were made from stainless steel, including those not in direct contact with the product. Even the complete frame of the centrifugal is now available in stainless steel as an option (Figure 4 bottom). This was a gradual development. Between the two centrifugal models there was another model, offering all parts in contact with the sugar crystals made from stainless steel, except the housing plate (Figure 4 top right).

More and more beet sugar factories in Western Europe are installing batch-type centrifugals made entirely from solid stainless steel to meet the high product safety standards and reduce maintenance costs. The risk of flakes of paint falling into the product is eliminated, which reassures the quality auditors of the sugar producer's customers. A repainting of the frame is no longer necessary. The extra cost of a stainless steel frame is in fact lower than the typical cost of repainting.

Material selection is even an issue for non-core components such as the lights. Nowadays LED lights are installed. The benefits are low energy consumption, and no overheating or breakage risk.

Since the early 1990s, all our baskets have been made from high-strength stainless steel that is resistant to stress-corrosion cracking, in order to ensure the product quality, and not only for white and refined sugar centrifugals. This material also offers a longer service life due to its higher wear resistance and superior behaviour under the cyclical load conditions in a batch centrifugal. It thus reduces the risk of cracks significantly and makes a major contribution to reducing maintenance requirements. Nevertheless, new centrifugals with mild steel baskets are still available on the market.

Basket hubs made from cast stainless steel offer the best properties to meet food-grade requirements, as well as being

less prone to wear and therefore requiring fewer checks for cracks appearing. Basket hubs are still offered in cast steel, but one has to keep in mind that sugar is highly abrasive to this material, which results in more wear. Due to the lower strength and toughness of cast steel, cracks appear sooner, the hub needs more frequent inspections and its lifetime is shorter than that of a cast stainless-steel hub.

Continuous centrifugal

The baskets of our continuous centrifugals have been made from stainless steel for many years. This is quite an affordable solution that also safeguards product quality. Baskets in mild steel are still available on the market.

The screens used in the sugar industry for continuous centrifugals today are mostly made from hard chromium-plated nickel. Stainless-steel screens are available, but significantly more expensive.

Currently, continuous centrifugals are operated more and more with stainless-steel wedge-wired screens. In addition to the fact that these meet food-grade requirements more closely, they are also less prone to abrasion, last longer, and prevent frequent stoppages for screen replacement during production.

It the past, continuous centrifugal housings and parts in contact with the sugar crystals were built in mild steel (Figure 5a). Since the launch of the new model in 2009 (Figure 5b), the housing parts in contact with the sugar crystals have been made from stainless steel, thus meeting food-grade requirements and being maintenance-free. For the same reasons as with batch-type centrifugals, most sugar factories in Western Europe are installing continuous centrifugals with a complete stainless-steel housing (Figure 5c). This is the best solution to meet the high product safety requirements; it is maintenance free and reassures customers' quality auditors.

Figure 5: (a) Old continuous centrifugal with mild steel housing; (b) continuous centrifugal K3300 with stainless-steel housing; (c) continuous centrifugal K3300 with complete stainless-steel housing



Continuous centrifugals are now equipped with a sealed feeding pipe. A sight glass allows verifying the centring of the massecuite jet. This can be made from either temperature-resistant plastic or borosilicate, both of which comply with strict food safety regulations. Whenever the plastic becomes dull, which may happen after a while, the sight glass has to be

replaced. It therefore has to be considered a wear part. European sugar factories mostly use borosilicate.

Sugar-drum dryer

Sugar crystals are quite abrasive to mild steel. Their movement inside the dryer causes wear that can be neither avoided nor eliminated. The worn metal remains in the final product.

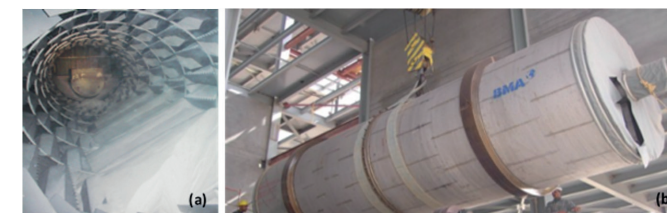
Nowadays, all parts of a white sugar dryer that come into contact with the sugar crystals are made from solid stainless steel or at least clad in stainless steel. The drum (Figure 6a), the trickling facilities, and the inlet and discharge housings are manufactured in solid stainless steel. The first BMA solid stainless-steel drum drier was installed in 1997 in a beet sugar factory.

The riding rings (Figure 6b) are still manufactured in mild steel. Riding rings in solid stainless steel would suffer too much wear and tear and they would be expensive due to their weight. They would also have to be made wider, in order to bear the weight of the drum and the sugar, as stainless steel is not as hard as mild steel.

A polyamide sealer is now installed between the drum and the inlet/outlet housings instead of a metal sheet with splits.

Some sugar producers even install a housing around the roller chain used to drive the drum dryer, in order to avoid any risk of grease spilling, even far away from the sugar.

Figure 6: (a) Drum dryer in stainless steel; (b) drum with riding rings in mild steel



Latest innovations in centrifugal design

For many decades, centrifugals have been absolutely vital for sugar production. Over the course of time, their design and features have been modified and upgraded many times, in order to achieve very high processing capacity and sugar yield. This has to be ensured by keeping the safety of a high product quality on the one hand and low operating cost.

Batch centrifugal

In the development of its latest batch-type centrifugal E series, BMA has continuously reduced the components to the bare minimum, movements have been simplified, and high-maintenance components have been eliminated. All this was achieved while still increasing the efficiency of production.

Impressive simplification of components

Our monoaxial discharger (Figure 7 left, centre) is the best example to illustrate this. Since the discharging starts without a vertical motion axis, the discharging time is reduced by up to 20%. Once the discharging speed has been reached, the discharger only swings horizontally into the sugar layer; the sugar is removed along the entire height of the basket in one single pass. The discharger therefore considerably contributes to higher throughputs of up to 8%, which is achieved with the same motor

power as in the earlier centrifugals series.

The vertical motion axis could be eliminated because the basket comes with a novel hub geometry (Figure 7 right), which also provides enhanced torsional rigidity compared with the earlier hub version. The basket volume has been increased too. It can handle at least one additional batch per hour. At the same time, maintenance has been drastically reduced, thanks to the reduction of moving parts by 40% compared to previous dischargers (Figure 8).

Figure 7: Monoaxial discharger: (left) rest position, (centre) discharging position, (right) flat hub

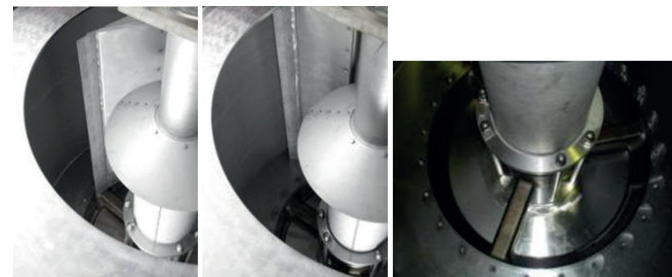
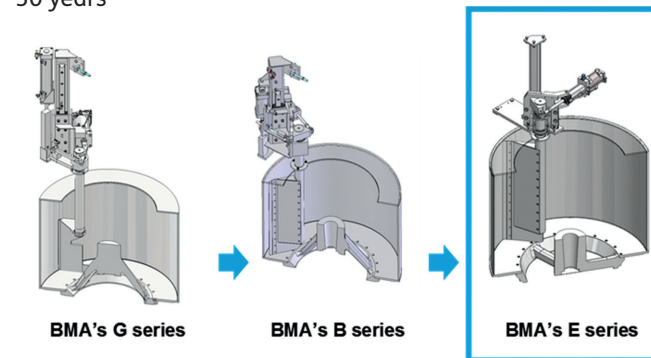


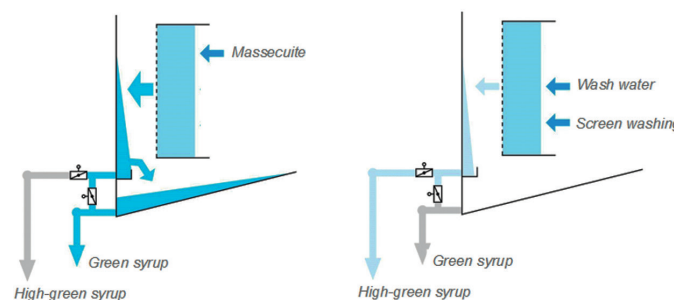
Figure 8: Evolution of the discharger design over the past 30 years



Simple design combined with outstanding efficiency

Simple design can sometimes provide the best improvements in a process, and even be maintenance-free. The new syrup separation (Figure 9) is as simple as it is efficient. The syrup separation flume provides excellent separation into green and high-green syrup – without any internal mechanical elements. The discharge nozzles are operated exclusively from outside the centrifugal. Back-mixing of the syrup film that flows down along the inside wall of the housing is minimised at crucial points. This is a particular advantage when separating the high-green syrup during the screen washing phase.

Figure 9: Simple and efficient syrup separation



Extended service life

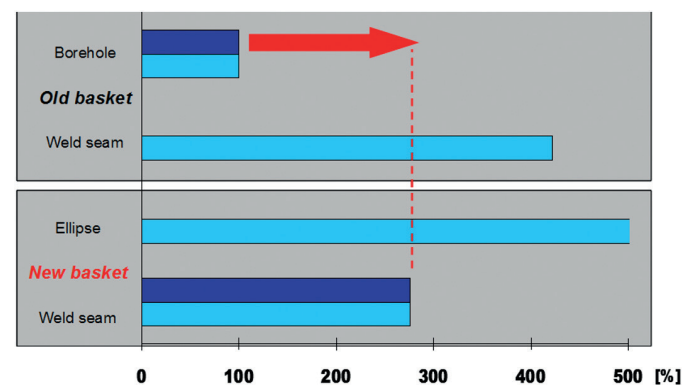
Only mechanical components made from stainless steel and designed for more than 100 million load cycles can be said to have long fatigue life. If alternating stresses and corrosive effects act on an element at the same time, long-life fatigue strength is not being reached at all. Given the conditions under which baskets of batch centrifugals have to operate, they can never reach the number of load cycles that are required for long fatigue life strength and are therefore high-strength components with a limited service life.

The factors that limit service life in conventional baskets are the holes required to drain the syrup from the basket, as it is here that maximum stress appears. Until the launch of the E series, batch centrifugal baskets worldwide featured cylindrical boreholes. In order to increase safety and performance, we have adapted the basket openings to reduce the peak stress. The new basket design is based on elliptical openings. Compared with cylindrical boreholes, the maximum stress found with elliptical openings is about 40% lower!

With regard to notch effects such as those caused by the openings of a basket, the geometry of a component has a major impact. The notch effect is much smaller with elliptical openings than it is with cylindrical boreholes, and the roughness of the inside surface is therefore much less relevant.

The comparison of maximum stresses is not only decisive, but the comparison of the calculated service life values under a dynamic load. Figure 10 compares the expected service life of the optimised new design with that of the old borehole design. The calculation model shows a service life that is at least 2.5 times higher than that of the old baskets (limited by boreholes).

Figure 10: Expected service life of old versus new baskets.



Maximum hygiene standard and low maintenance thanks to design details

Maximum hygiene can be achieved not only with the core components, but also with details in the design:

- Grease collector tray (Figure 11 left) below the drive head: prevents all contact of the lubricant with the product.
- Inspection openings (Figure 11 right) located across the entire height of the basket: allow in-situ eddy current testing, without the need to take off the basket.
- Tree-piece housing cover: permits a replacement of the screen or discharger without lifting of the frame.



Figure 11: Batch centrifugal: (left) grease collector tray, (right) inspection openings



Continuous centrifugals

Improved hygiene and easy access: straight lines, right angles, compact size

When several new design continuous centrifugal machines are placed in a line, their cuboid shape leaves few spaces where dirt can accumulate, as is usually the case – a major benefit in hygiene (Figure 12). With a height of just 1.03 m, the internals of this centrifugal is easily accessible, making it very user-friendly.

Figure 12: Continuous centrifugal station



Smooth and safe running for a long life

By finely adjusting the vibration isolators and placing them far from any heat source, BMA has achieved the outstandingly smooth running of the K3300 centrifugal. This not only reduces vibration stress of individual components, it extends the service life of the centrifugal as a whole. What is more, the centrifugal helps to reduce the noise level in production, protecting operating staff from excessive noise at their place of work.

Figure 13: (left) central water and steam supply, (right) stainless steel piping



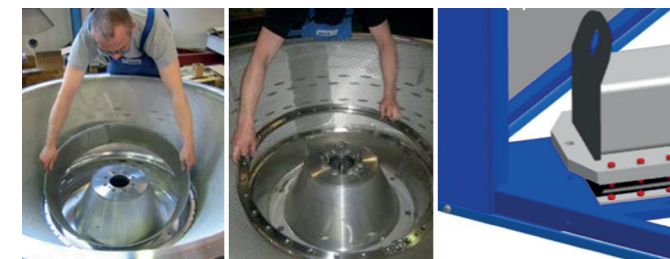
All important components have undergone FEM analysis to ensure high safety standards. The water and steam supply is centrally located and clearly marked (Figure 13 left) to prevent any wrong alignment and enable fast and easy installation. Furthermore, the distributing valves are protected against undesired contact and are clearly marked. Water and steam hoses are substituted by stainless steel piping (Figure 13 right) to further enhance the availability of the centrifugal.

Long service life

Very high availability at correspondingly low costs is achieved thanks to a minimised number of wear parts, the use of long-life components, and low maintenance requirements owing to the compact and easy-to-survey design.

The pre-separation step of the basket is equipped with a long-life wedge wire screen liner (Figure 14 left). Since the major part of the syrup is separated there, the screens in the upper basket stage are also subject to lower wear and their service life significantly extended. Furthermore, for maintenance, the screens are quickly and easily replaced, as they are fixed by a clamping ring system (Figure 14 centre). Another, often time-consuming part of maintenance is omitted, thanks to the intelligent new rubber-buffer concept (Figure 14 right). This incorporates a reduced number of buffers, all located outside the hot areas. This not only significantly enhances their lifetime; they can also be replaced in a fraction of the time formerly needed, as there is no need to wait for the machine to cool down.

Figure 14: (left) wedge wire screen liner; (centre) clamping ring; (right) rubber buffer replacement.



Conclusions

Adequate selection of material and innovative design is required to fulfil today's production requirement. The correct material choice is an important part of the solution to meet current food hygiene criteria. Intelligent design ensures efficiency in the process, productivity, an extended service life and low maintenance.

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