BROADBENT

Observations on centrifugal operation – Part 1

by **Clive Grimwood, John Thewlis and Phil Thompson**

Reprinted from International Sugar Journal, December 2002

Observations on centrifugal operation– Part 1

by **Clive Grimwood[1]*, John Thewlis[1] and Phil Thompson[2]**

[1]Broadbent Centrifuges, Huddersfield, HD1 3EA, UK.
Tel +44 1484 477200, +44 1484 477230
Email: cgrimwood@broadbent.co.uk, jthewlis@broadbent.co.uk
[2]Consultant, Tel:+44 1780 783522, Email: phil@yarwell.demon.co.uk
*Corresponding author

Abstract

Aspects of centrifugals are considered in terms of reducing the operating costs and improving the safety of centrifugals within the sugar factory. Some common misconceptions on the use of centrifuges are also discussed. Topics considered include washing, discharging, power consumption, and basket maintenance. It is intended that the information provided will be of help to users wishing to improve operation of their existing centrifugals and assist when selecting new centrifugals.

Basket safety

Centrifuges have the potential to be hazardous. This is a inherent in their design. Similar comments apply to many items of equipment used in the sugar industry such as pressure vessels, dryers, pumps, etc. For a typical 1.2 m batch centrifugal basket spinning at 1200 RPM the stored energy within the basket is approximately 4 MJ and the peripheral speed of the basket is 168 mph (271 km/h). The energy stored in such a rotating basket is equivalent to that of a typical family car travelling at 175 mph (280 km/h) or a 2.5m^3 vessel pressurised with gas to 16 bar.

A major safety concern for any centrifuge is the long term integrity of the basket. Failure of the basket whilst rotating at high speed will destroy the centrifugal and possibly anything or anybody near it. Some users of centrifugals assume that the casing is designed to act as a containment device in the event of basket rupture. One way to look at the effect of releasing 4 MJ in a basket rupture is to consider the example above of a 1 tonne car travelling at 168 mph (271 km/h) running into the end of your centrifugal battery - it is not hard to imaging the level of damage this is likely to do to the centrifugal battery and anybody or anything nearby. It takes a lot of steel to contain this kind of energy release, for example a casing made of mild steel would need to be at least 50 mms thick to have a good chance of containing a rupture of a 1.2 m diameter basket rotating at 1200 rpm. Centrifugal cases are typically 6-12 mms thick depending on the design.

Clearly the basket design must be such as to avoid rupture. It is well know that any mechanical item subject to a cyclic stress is in some danger of fatigue. Two good examples of fatigue are aircraft and batch centrifugal baskets. For an aircraft the main cyclic loading comes from the takeoff and landing cycles, for a batch centrifugal it is the process cycle. Consider a centrifugal operating at 20 charges per hour for 23 hours per day and 120 days per year. Over a 20 year life the basket will undergo 1.1 million stress cycles. For a refinery operating 350 days per year the figure is likely to be in excess of 3 million stress cycles and the more cycles a centrifugal performs during its life the greater the significance of fatigue.

Whilst baskets are generally designed for an infinite or extremely long fatigue life the inspection regime should be such that if for any reason a fatigue crack becomes visible the day after an inspection it doesn't grow to a point where failure will occur before the next inspection. Fatigue crack growth is a complex phenomenon and for a component that will eventually fail by fatigue the majority of the life (e.g. 90-95%) is taken up initiating the crack, and only a small proportion of the time (e.g. 10-5%) is needed to grow the crack from a point where it is visible to the point where the component fails.

Inspection and maintenance therefore play a major role in the life and safety of a centrifugal basket. Repairs to the basket may be necessary during the 15-25 year life of the centrifuge due to erosion, corrosion or mechanical handling damage. Correct repair procedures by trained personnel are vital to ensure that no crack is introduced by an unsuitable repair procedure and that the original design calculations and assumptions are not invalidated by the use of unsuitable repair materials or methods.

Basket inspection should be carried out by qualified and experienced personnel who are aware of the operation and the loads on the baskets. Inspection procedures and guidelines are available from most centrifugal suppliers and their recommendations should be followed. These procedures normally focus on:

- The general loss of material from the basket (e.g. by erosion or corrosion).
- The presence of cracks. Any basket found to contain a crack in the basket shell or hoops (if fitted) should be taken out of service.
- The tightness of hoops (if fitted) on the basket shell.

Given good maintenance a centrifugal will operate safely for many years as shown by the thousands of centrifugals in sugar mills & refineries throughout the world.

Similar comments apply to continuous basket centrifugals however as they run at constant speed and are subjected to stop / start stress cycles perhaps once per day rather then 20 times per hour they are less prone to fatigue failure.

Washing

Washing is an important part of most centrifugal cycles - particularly for 'A' raw and refined sugar production. Where sugar is dissolved by excess washing or has to be washed off a poorly ploughed basket (see below) it will follow one of two paths. If the centrifugal is fitted with syrup separation it may be recycled to the pan feeding the centrifugal. Where there is no syrup separation the additional sugar increases the purity of the runoff syrup or molasses and again there are two alternative outcomes - the subsequent vacuum pan stage may recover all of the extra sugar and recycle it or the final molasses purity may be increased by some or all of the extra sugar passing through to final molasses as increased purity.

The worst economic case is the loss to molasses, because sugar is usually worth at least twice the price of molasses. Even if the sugar is captured and recycled the additional water dilution and electrical power involved in reprocessing adds a cost. In this discussion a reprocessing cost of $0.015 per kg ($0.007 LB) is taken as an average of the various possible scenarios.

For the purposes of illustration assume a wash quantity of 2% water on massecuite (a good figure to aim at for 'A' beet massecuite). Further assume that a centrifugal is using excess wash water. This could be occurring for a variety of reasons such as one or more of the following :

- Poor wash pipe performance not washing the sugar evenly (e.g. bad wash pipe design, blocked or incorrect jets or variable wash water pressure).
- Non uniform massecuite loading in the basket.
- Operator is using excess water to ensure sugar colour is always well in specification.
- Wash set for full baskets but baskets are only partly full.

If 2.25% water on massecuite is being used rather than the ideal of 2.0% (i.e. 20 seconds wash rather than 17.5) then for a 1750 kg basket massecuite load this is 4.4 kgs of additional water every cycle. Typically this water dissolves two and a half times its own weight of sugar so 10.9 kg of sugar are dissolved every cycle. This is 1.25% of the 875 kg of sugar produced every cycle by the centrifugal. Taking typical figures of 20 cycles per hour, 23 hours per day operation and 120 days per year this gives a total sugar dissolved of 10.9 x 20 x 23 x 120 = 600,000 kg per year and this sugar has to be reprocessed through the subsequent boilings. At a reprocessing cost of $0.015 per kg the cost of reprocessing is $9000 per year or $181,000 over an average 20 year life of a batch centrifugal. At 5% interest this equates to a present value (PV) of $113,000. This is approximately the same as the capital cost of the centrifugal. Put another way if one centrifugal uses 2.25% wash water on massecuite and has a purchase cost of $100,000, its lifetime costs are higher than another centrifugal of the same size using 2.0% wash water and costing $200,000 to purchase. Some beet campaigns and all refineries operate significantly longer than the 120 days per year used in the example above - for these the costs of dissolved sugar are higher still.

It is not uncommon to see centrifugals operated with an excessive wash in an attempt to 'wash the sugar colour down'. Often this produces the desired result of lower colour sugar - but it also leads to a large recycled sugar load for the pans. What is the excess water addition doing in these cases? Washing in a centrifugal is designed to remove the high colour molasses layer adhering to the crystal surface. Once this has been achieved further washing has little beneficial effect. Broadly speaking the occluded colour within in the crystal is constant throughout the body of the crystal and further washing serves only to shrink the crystal by dissolution without further reducing the colour of the solid sugar remaining.

Why then does this excessive washing approach seem to work? The probable answer to this is that the excess water is simply remelting so much additional sugar that the molasses purity rises sharply pushing up the purity in the pans. This is turn leads to higher purity sugar at the subsequent crystallisation which means less colour. If this description is correct and such action is necessary to achieve the desired sugar quality then it is best to recirculate the highest purity syrup possible. The primary purpose of washing is to remove the high colour syrup adhering to the crystal surface and no matter how good the wash classification system on the centrifugal recirculation of the wash liquor will always recirculate a proportion of this high colour. It is therefore an advantage to dissolve some of the sugar after centrifugation and route the melt back to the pans rather than use excessive washing within the centrifugal.

Sugar discharge - Ploughing

As with washing inefficient ploughing can also lead to large sugar recirculation loads. A layer of sugar just one crystal thick (0.6 mms) left on a 1750 kg centrifugal basket and washed out before the next cycle results in 3 kgs of lost sugar per cycle. Over the lifetime of the centrifuge this 'layer one crystal thick' would result in around 3,300 tonnes of recycled sugar and at an assumed reprocessing cost of $0.015 per kg cost this is around $50,000 over 20 years (PV $31,000 at 5%).

Some centrifugal types are designed to operate with virtually zero sugar left on the screen (see Fig 1) whereas others are designed to operate with a thicker residual layer. Some manufacturers recommend that 0.75 mms is left on the screen but

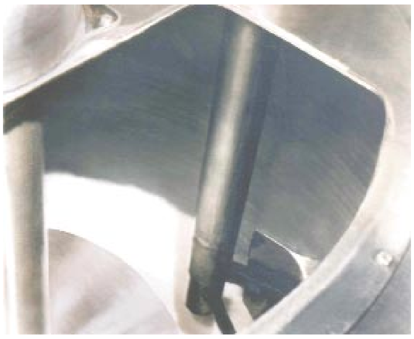


Figure 1. Full sugar removal during ploughing.

Table 1.

Typical energy input (kWhrs) per tonne of massecuite processed:

Charges per hour	25	20	15	10
2 speed drive mechanical brake	1.7	2.0	2.3	2.6
3 speed drive mechanical brake	1.5	1.7	1.9	2.2
3 speed drive DC injection brake	1.6	1.8	2.0	2.3
inverter drive	0.95	1.05	1.3	1.5

Cost comparisons - motor & controls:

3 or 2 speed (mechanical brake)	100%
3 speed (DC injection braking)	108%
inverter (diode/thyristor input)	180%
inverter (IGBT input)	215%

Figure 2. A modern 1300 Kg batch centrifugal with 3 speed motor and DC braking.

in practice many machines actually operate with 2 mms or more remaining in the basket to be washed out prior to the next cycle. For a 2 mm layer the 20 year losses above increases to 11,000 tonnes. At $0.015 per kg reprocessing cost this amounts to $165,000 over 20 years (PV $103,000 at 5%) which again is broadly equivalent to the original cost of the centrifuge.

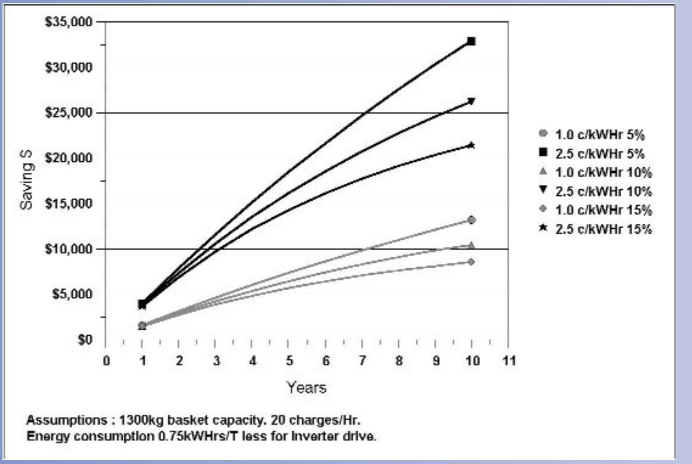
The examples above highlight the major impact that poor ploughing or washing have on centrifugal operating costs. This poor performance results from poor centrifugal design, maintenance or operation. Clearly there is real financial benefit in using centrifugals that wash efficiently and discharge all the sugar every cycle.

Drive power requirements - Batch centrifugals

Much has been written about centrifuge drive requirements [Refs 1 - 5] and it remains a regular topic of discussion. All batch centrifugals have some form of drive that recovers energy as the basket decelerates from spin speed - and generally the more sophisticated and expensive the drive the more energy is recovered. Table 1 above, based on the data in Ref 4, is an approximate summary of the position and considers only the power consumed by the drive motor itself (excluding fans, ancillary systems, etc.)

All batch centrifugals with capacities larger than 1300 kg per charge are only available with single speed electric motors fitted with electronic controls to vary the frequency and hence the speed of the basket. Three speed pole-changing motors are still available on new batch centrifugals of 1300 kgs or less (see Fig 2). Are these worthy of consideration? A typical drive price for a 150 kW electronic drive system (motor plus associated electronics) suitable for a 1300 kg batch centrifugal is in the region of $25,000 whereas the cost of a simpler three speed drive system is around $13,800. The cost difference of $11,200 has to be offset against the cost of supplying the electrical power in the factory. Graph 1 below shows the savings resulting from the lower electrical energy demand of the inverter drive system compared with a 3 speed drive with DC braking when operating at 20 charges per hour for 24 hours per day for 365 days per year (a saving of 1.8 - 1.05 = 0.75 kWh/T see Table 1). Data is shown for power costs of 1.0 and 2.5 cents per kWh and interest rates of 5, 10 and 15%. The graph shows that for a cost of money of 10% and a power cost of 2.5 cents per kWh it takes just over 3 years to save the initial capital outlay of $11,200. For the case of 10% interest and 1 cent per kWhr the payback period is off the edge of the graph at 11.2 years. If the centrifugal is operated for less than 365 days a year then the payback period will be longer and if the power saved is greater than the

Graph 1. Payback of inverter against 3-speed drive system



Assumptions : 1300kg basket capacity. 20 charges/Hr.
Energy consumption 0.75kWHrs/T less for Inverter drive.

example of Graph 1 then the payback period will be shorter.

In addition to the relative costs considered above it may be necessary to take other operational factors into consideration such as :

- If a centrifuge battery has a significant idle time 'waiting for the next strike' it is common to leave the centrifuges running at some low speed such as feed speed. In this situation the inverter drive system consumes considerably more energy than the three speed pole changing drive and this can reduce the energy benefit expected from an inverter drive system. The 'fixed losses' in an inverter drive can be quite large (see Ref 4) and the best energy efficiency is achieved by turning the power off to the inverter drive during any waiting time in excess of a few minutes.
- Not only is the energy demand from a pole changing drive higher the current peaks drawn from the electrical supply are slightly larger and more frequent. If this means that the electrical distribution system or the alternator has to be uprated to cope then the benefits of the inverter drive systems are much greater.
- The growing practice of co-generation makes the inverter option much more favourable by increasing the value of electrical power.
- The simplicity of 3 speed pole changing drives contrasts sharply with the complexity of an electronic inverter and this has implications for reliability. It is also important to consider the long term support and spares availability for inverters.

Thus the cost comparison given in Graph 1 is generalised and only part of the story, but illustrates that the cost benefit over the life of a batch centrifugal is sensitive to capital costs, the cost of power, the usage per year and operating procedures. It is possible to see real scenarios where an inverter drive system is not cost effective. All manufacturers supply inverter drives systems for their centrifuges and some still produce modern multi-speed motors which incorporate full electrical braking and the option to convert to an electronic inverter drive at a later date if required (see Fig 2). Where a simple, low capital cost modern centrifugal of 1300 kg capacity or less is required they are still worth an investigation.

Drive power requirements - Continuous centrifugals

It is sometimes said that low grade continuous centrifugals consume less power than a batch centrifugal and this is one of the key reasons they are used in place of batch centrifugals for lower grade massecuites. Generally speaking continuous centrifugals consume more power then a batch machine on 'B' massecuites. For example a large modern low grade centrifugal (1500 mms diameter) is typically fitted with a 90-100 kW motor. The maximum capacity throughput will be in the region of 25 tonnes per hour depending on the application. This is around 3.5 - 4.0 kW/h per tonne of massecuite. As table 1 above shows a 3 speed batch centrifugal operating at low cycles per hour on a low grade massecuite consumes the under 3. This is to be expected, the sugar leaving the continuous centrifuge basket at (say) 2000 rpm has a high energy content which is lost in crystal discharge centrifugals and partially lost on magma and melter designs. The batch centrifuge however recovers the bulk of this energy during deceleration to discharge the sugar at low speed, typically 60 rpm. The situation is reversed if we consider the high grade continuous centrifugal. The low basket speed used by this machine to limit crystal damage leads to a power consumption which is less than even a modern inverter driven batch centrifugal (Ref 7). The low basket speed also leads to a wetter sugar discharge of perhaps 1.0 - 1.5% moisture rather than 0.5%. Depending on the application it is common to add additional energy to heat the massecuite or discharged sugar to assist the dryer to remove this excess moisture. If this additional heat energy is included in the comparison then the batch centrifugal remains the most energy efficient way to produce dry sugar. See references 6 & 7 for more details on the benefits and shortcomings of high grade centrifugals.

References

1. James M. Coleman. October 1995. Variable frequency centrifugal drives - a convergence on converters. Sugar y Azucar, 26 pp.
2. R.Osman & J.Bange. Nov/Dec 1991. IEEE Transactions on Industry Application. 27 (6):1076-1080.
3. D.Zeigler. Dec 1995. Centrifugal variable speed drive installation at Savannah Sugar. International Sugar Journal, 97 (1164): 661-668.
4. G.C.Grimwood, G.L.Grimwood, G.Hindle. December 1999. Variable and multi-speed batch centrifugal drives. International Sugar Journal, 101 (1212) :591-596.
5. P.Franzen. 1991. Aspects of energy consumption in sugar factory centrifugals. International Sugar Journal, 93 (1116): 247-254
6. R.Broadfoot, K.Miller. 1999. Performance of continuous high grade centrifugals. Zuckerindustrie 124 (6): 447-450.
7. G.C.Grimwood, P.D.Thompson, M.J.Thewlis. 2000. The development & use of high grade continuous centrifugals. International Sugar Journal, 102 (1224): 639-645.

Observaciones sobre la operación de centrífugas. Parte 1

Resumen

Se consideran diferentes aspectos de las centrífugas en cuanto a la reducción de los costos operativos y la mejora de la seguridad de las mismas dentro de la fábrica de azúcar. Se discuten también algunos de los conceptos erróneos en el uso de las centrífugas. Los tópicos analizados incluyen el lavado, la descarga, el consumo de energía, y el mantenimiento de las canastas. El objetivo de este trabajo es el de proveer información que podrá ser de ayuda para los usuarios que desean mejorar la operación de las centrífugas existentes y además de asistirlos en la elección de nuevas centrífugas.