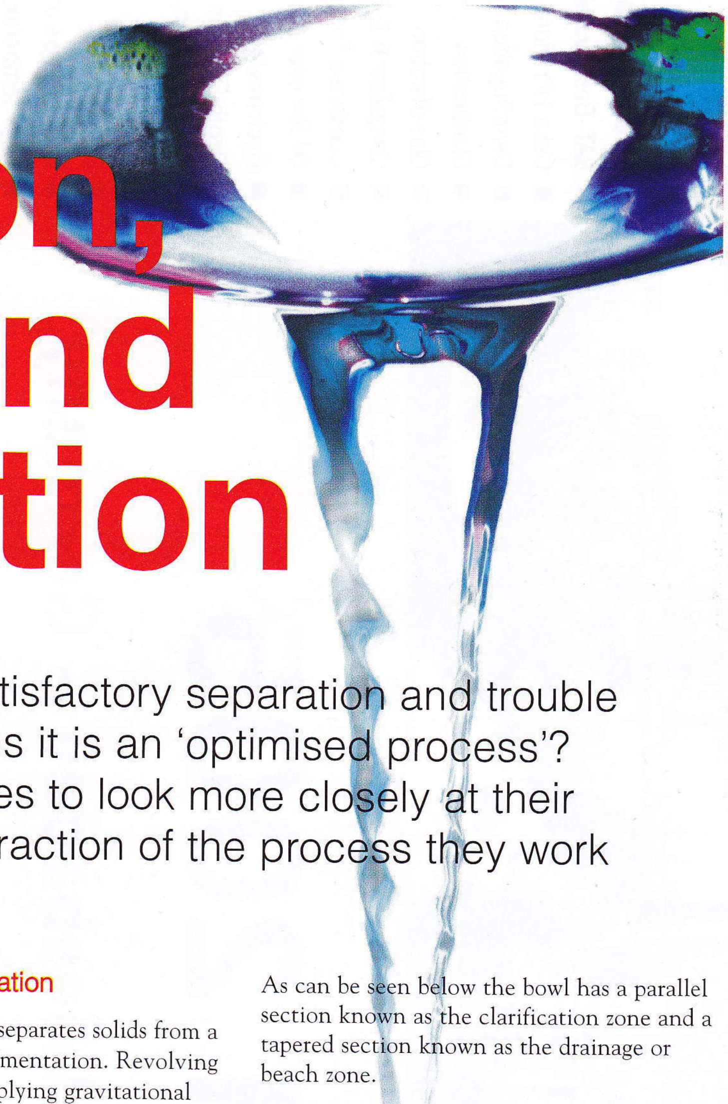

Centrifuge focus: evaluation, testing and optimisation

If a centrifuge is providing a satisfactory separation and trouble free operation, does that means it is an 'optimised process'? Nigel Day challenges operatives to look more closely at their centrifuges, as well as the interaction of the process they work with every day.

There are around 12 different configurations of industrial centrifuge currently available to the processing industry. Some adopt filtration techniques whilst others employ sedimentation techniques.

Experience has found in the vast majority of cases that operatives consider a centrifuge that is providing a satisfactory separation and trouble free operation to be an optimised process. Unfortunately this is not necessarily the case.

It is the intention of this article to provide guidance as well as challenge operatives to look more closely at the centrifuges and the interaction of the process they work with every day.

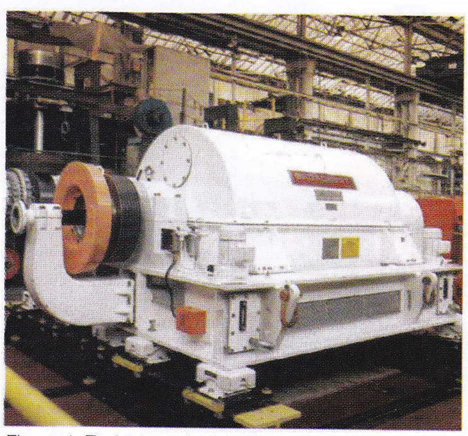

Figure 1: Typical continuous solid bowl decanter centrifuge – supplied courtesy of Thomas Broadbent & Sons Ltd.

Philosophy of operation

A decanter centrifuge separates solids from a liquid by means of sedimentation. Revolving the centrifuge, thus applying gravitational forces many times more than normal on the solids and liquid within the centrifuge, creates the sedimentation effect.

In order for a sedimentary type centrifuge to function correctly the suspended solids in the slurry must have a greater specific gravity than the liquid phase. From the section drawing below it can be seen that the machine consists essentially of two rotating elements. The outer element is a solid bowl whilst the second, inner element, is a helical screw.

The inner element rotates at a slightly different speed to the bowl, usually slower but can be faster. In effect we have a screw conveyor inside a rotating bowl.

The differential speed, as we know it is normally provided via a mechanical gearbox, though some configurations drive the conveyor using a hydraulic or electric motor back drive mechanism.

The gearbox is fitted to one end of the machine. The main body of the gearbox is fitted to the bowl element with the output driveshaft from the gearbox connected to the conveyor.

As can be seen below the bowl has a parallel section known as the clarification zone and a tapered section known as the drainage or beach zone.

Feed slurry is introduced through a stationary feed pipe and spills into the conveyor hub, accelerated as it passes through the feed ports and delivered onto they bowl wall. Feed exit ports are so located as not to spill slurry into the drainage zone.

Clearance between the periphery of the conveyor blades and bowl wall (approx 3mm) becomes packed with solids, the flow of liquid is back around the screw conveyor with the blades acting like baffles, preventing short-circuiting.

Liquid travels towards the discharge ports, the centrifugal force causes the solids to settle, so that the discharge liquor can be essentially clear. Solids, which are thrown out of suspension against the bowl wall, are consolidated, picked up by the conveyor then conveyed towards the solids discharge end of the rotating assembly.

Solids are transported up the drainage zone, out of the liquid and up the dry beach, before being discharged.

Both the liquid and solid phases are discharged into the stationary outercasing, which is equipped with baffles to prevent re-mixing of the two separated phases.

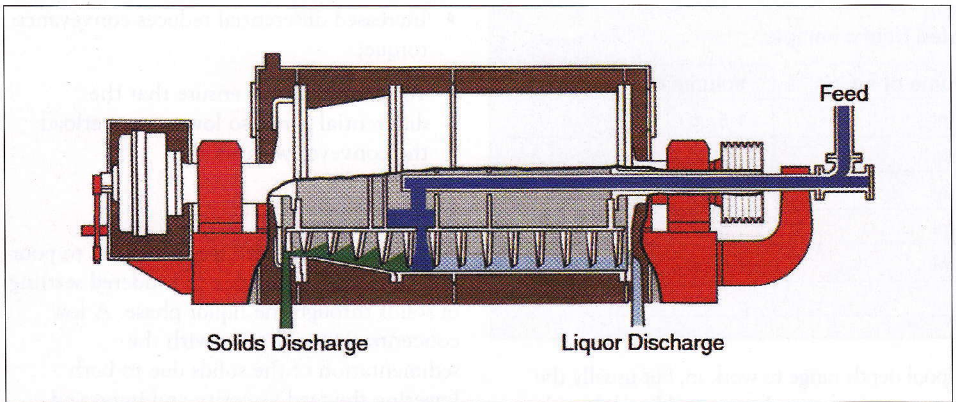

Figure 2: Sectional view schematic – supplied courtesy of Thomas Broadbent & Sons Ltd.

Gathering the data

Whether considering employing a decanter centrifuge or optimising an existing machine the value of preliminary testing and general data collation cannot be over emphasised. It is possible with a sample of only about 1 litre to obtain a considerable amount of information. On most materials, sufficient information can be obtained to rule out completely the use of a continuous decanter centrifuge or how best to optimise an existing centrifuge installation.

The following is a brief description of the approach used for examination of a small sample to determine:

- Can the material in question by successfully handled in a decanter centrifuge?
- What size and configuration of decanter centrifuge is required?
- What performance can be expected from the chosen centrifuge?
- What degree of optimisation is possible?

It is essential that the sample evaluated is representative of the material to be processed. Various physical data are then obtained from the material, providing insight relative to the nature of the material. Centrifuging behaviour, i.e. settling and packing characteristics, are then determined. Evaluation of the data obtained provides the basis for predicting type, size and performance of equipment for the duty. (*the properties that need to be determined can be seen in table 1 below.*)

In addition to the feed material properties we also need to identify the actual process requirements, as follows:

- Scale of the proposed operation?
- Which phase(s) of the feed slurry is required?
- What properties are required of the solid product?
- What properties are required of the liquor product?
- Is product washing required?
- How will the centrifuge integrate with surrounding plant?
- Reliability of equipment?
- What space is or will be available?
- What is the value of the product?
- Any special requirements?

Settling and packing characteristics

There are two main requirements that must be met if a material is to be handled satisfactorily in a continuous decanter centrifuge. The first is that the suspended solids settle in the length of time that the slurry can be subjected to centrifugal force in the machine for a satisfactory effluent is to be obtained. Secondly the solids so settled must pack firmly enough to be conveyed through the machine.

To determine settling and packing characteristics a small sample is spun, at 1000 x G, at the process temperature in a test tube centrifuge. The sample is examined after 10 seconds of spinning and the volume of settled solids noted, also the condition of the supernatant, i.e. clear, cloudy or turbid. It is then spun for a further 20 secs, making a total of 30 secs, and examined as before. However, this time a thin glass-stirring rod is slowly lowered into the test tube until it touches the settled solids.

The volume of solids that will support the weight of the rod is noted. The sample is spun again for an additional 30 seconds and examined as before. Spinning is continued and the sample examined with the results recorded in a table similar to that on shown page 24.

As a rule of thumb if the volume of solids and the volume of compaction come together within 90-120 secs with a clear effluent, as above, then the material being tested would be considered an ideal candidate for processing in a continuous solid bowl decanter centrifuge.

More difficult material may require spinning at a higher G force, up to say 2500 x G. This will not only influence the type and size of the centrifuge for the duty but also which manufacturer to approach.

Adjustments available and their effects

Assuming a centrifuge has been selected and installed, we have the following adjustments available for optimisation.

- 1 – Feed Rate;
- 2 – Bowl Speed;
- 3 – Pool Depth;
- 4 – Pool Length;
- 5 – Conveyor/Bowl Differential Speed;
- 6 – Feed Concentration;
- 7 – Feed Temperature;

1 – feed rate

This adjustment is probably the easiest to carryout and does not involve stopping the centrifuge. The effect of feed rate on performance can be generalised as follows.

The higher the feed rate the less residence time the liquid has in the bowl hence the harder to settle out possible ultra fines. Conversely the lower the feed rate the longer the liquor residence time and hence the easier to obtain clear liquors and in some instances 100% recovery of solids.

The feed rate can be further adjusted anywhere between the lower and upper limits to obtain either complete removal of the solids or to split and classify the solids at a particular micron size.

Table 1: Properties that should be determined prior to optimisation.

Solid phase	Liquor phase	Slurry
Particle size distribution	Specific gravity	Flowrate
Specific gravity	Temperature	Solids concentration
Particle shape	pH	Settling rate
Particle strength	Toxicity	Flowability
Solubility	Viscosity	Flocculated or dispersed
Toxicity	Volatility	Corrosion characteristics
Chemical reactivity	Flammability	Abrasion characteristics
Material value	Surface tension	Variability of properties
Abrasiveness	Material	Value

Table 2: Example of results collected and collated from a sample

Spin time	Effluent clarity	Volume of solids	Volume of compaction
10	Cloudy	25 ml	1.5 cc
20	Turbid	22 ml	1.6 cc
30	Turbid	20 ml	1.7 cc
60	Almost Clear	19 ml	1.8 cc
90	Clear	18 ml	1.8 cc
120	-	-	-

2 – bowl speed

Unless you have some means of changing the bowl speed i.e. frequency convertor, the usual method is by changing the driving pulley on the main drive motor. This of course means stopping the machine. The speed at which the bowl is driven is related to the 'G' force developed with the bowl. Machine speed can be generalised by the following statements;

- The higher the speed the dryer the solids on crystalline type solids;
- The higher the speed on finer material more fine solids will be captured resulting in wetter solids;
- The higher the speed the capacity of the machine solids wise increases due to the increase of the delta RPM provided by the gearbox. However conveyor-scrolling torque usually increases and the gearbox could be a limiting factor in how fast the machine can rotate;
- Increased speed leads to higher power consumption;

However, one must always remember the higher the speed the more abrasion takes place and more general wear and tear. Therefore the ideal situation is to operate the centrifuge at the lowest speed possible whilst maintaining the process performance.

Never exceed the maximum rotational speed specified by the original manufacturer of the centrifuge!

3 – pool depth

To adjust the pool the machine normally has to be stopped, though there are decanter centrifuges available that allow adjustment whilst running.

The pool is usually adjusted by moving weir plates onto different annulus settings. By increasing the pool depth the volume of liquid held within the bowl is also increased.

Consequently the deeper the pool the more clarifying capacity you have available.

However, the deeper the pool the shorter the drying beach, hence the wetter the discharged solids will be. Depending upon customer requirements, whether they want dry solids or clear liquids determines at which end of the pool depth range to work in, but usually the customer requires dry as possible solids with clear liquids. In this case you have to aim on a compromise.

Deep pools will also lower conveyance torque, as it is easier to convey solids under liquid.

4 – pool length

The effective pool length can be adjusted by feeding in one of usually two feed compartments. By feeding in the feed compartment nearest to the liquor discharge end of the bowl, the effective pool length is shortened hence the least residence time for the liquid.

Respectively the longer the pool the longer the residence time.

5 – conveyor to bowl differential

The conveyor to bowl differential (Delta RPM) is altered by changing the bowl speed due to the gearbox. The gearbox itself can be changed for a different ratio, though an expensive change once in the field.

The effects of changing the Delta RPM are as follows:

- The lower the differential the dryer the solids due to longer residence time;
- The lower the differential the least disturbance of the pool, hence better fine solids recovery and centrate clarity;
- The lower the differential the lower the solids throughput capacity;
- The lower the differential the less wear takes place on the conveyor;
- Increased differential reduces internal cake pile height;
- Increased differential greater agitation affecting centrate clarity;
- Increased differential reduces conveyance torque;
- You should always ensure that the differential is not so low as to overload the conveyor with solids;

6 – feed concentration

A highly concentrated feed may lead to poor separation efficiency due to hindered settling of solids through the liquor phase. A low concentration will assist with the sedimentation of the solids due to both lowering the feed viscosity and improved settling potential through the mother liquor.

7 – feed temperature

Feed temperature will affect the cake moisture to the extent that temperature affects the viscosity of the mother liquor. Generally speaking the hotter the slurry, the less viscous and thinner the film of liquid retained on the solids.

General

Over the years decanter centrifuge manufacturers have developed their own 'unique' configurations with many major developments being established. Whilst they may disagree, the general principles and philosophy of operation though remain virtually unchanged.

Parameters briefly discussed all have their own effects, to obtain the outright optimised performances from the centrifuge could involve adjusting several of these parameters as some directly influence or give similar effects to others.

The subject of centrifugal separation is highly complexed with a high degree of academic connotations. However, the combination of application experience, testing and design capabilities of the centrifuge experts combined with the end users invaluable knowledge of their material is what ensures that the centrifuge in question will produce a product on schedule, of the desired quantity and quality, economically and above all safely. ●

Contact:
Nigel Day
NCD Separation Solutions Ltd
01924 270369
info@ncdsep-solutions.co.uk

Table 3: Summary table

	Increasing					
	Feed rate	Bowl speed	Pool depth	Conveyor differential	Feed temp	-45 micron
Throughput	Increase	Increase	Increase	Increase	Same	Reduce
Centrate clarity	Reduce	Increase	Increase	Increase	Increase	Reduce
Cake moisture	Increase	Reduce	Increase	Increase	Increase	Increase