

Filtration and separation technology: What's new with centrifuges?

Continuing his series of articles covering new developments in a number of broad classes of filtration and other separation equipment types, Ken Sutherland looks now at recent developments in centrifuges, operating both by sedimentation and filtration.

The centrifuge, including inertial sedimentation devices such as the hydrocyclone, is a separating device for solids from liquids or for liquids from liquids. The centrifuge achieves these mechanical separations by means of the accelerated gravitational force achieved by rapid rotation.

In practice, the term covers a wide range of equipment, with uses throughout industry. In terms of industrial usage the centrifuge dates from Gustaf de Laval's invention of

the centrifugal cream separator in 1878, but simple spinning drum washers and filters were in use before that date (and live on to this day in laundry equipment).

The separation achieved in a centrifugal device is similar in principle to that achieved in a gravity sedimentation or filtration process, but with the much higher driving force resulting from the rotation of the liquid. In the case of sedimentation, where the driving force results from the difference in density between the solid particles and the

suspending liquid (or between two immiscible liquids), the separation is achieved with a force from 1000 to 20,000 times that of gravity. In the case of filtration, the filtrate is driven through the filter medium, and any cake built up on it, with a force of 100 to 2500 times gravity.

The types of centrifuge used for separation by *sedimentation* include:

- tubular bowl,
- chamber bowl,
- imperforate basket,
- disc stack separator, and
- decanter.

This list is in order of increasing complexity of design – as with any centrifuge (or indeed any filter), design complexity increases according to the increasing concentration of solids in the feed, and to the wish to discharge these solids on a continuous basis.

Thus the tubular bowl centrifuge and the simplest version of the disc stack separator are used primarily for the separation of immiscible liquids. In this duty, they can accept a small solids content in either or both liquids, which will then accumulate inside the centrifuge during the separation of the liquids, until it is necessary to stop operation, open the centrifuge and clean it free of accumulated solids.

These two types, together with the chamber bowl design, are also used specifically for liquid clarification, where the dirt content of the liquid is low (so that stoppages for cleaning are infrequent). If the solid content of the suspension is higher, then the imperforate basket centrifuge may be used to separate the solids, and produce a reasonably clean liquid (separation efficiencies are not all that high with



Alfa Laval's Culturefuge 400 is used for mammalian cell cultures and has a skid-mounted modular design. Image courtesy of Alfa Laval.

this type). The accumulated solids in the basket may be removed manually, or semi-automatically (by knife or skimmer pipe), but in either case these solids will not have been dewatered at all.

Higher solids contents in the feed suspension can be accepted by the disc stack centrifuge, when it is fitted with a means for automatic discharge. Separation of the solids from the liquid is much more efficient, because of the higher centrifugal forces, but the solids are still fairly saturated with liquid at the point of discharge. The methods of solid removal include the use of nozzles, which run continuously, allowing a thick slurry to discharge; valved nozzles that open automatically when the solid depth in the bowl reaches a pre-ordained figure; and the opening bowl design, in which the shell splits at the widest part of its periphery for a short period, also controlled by solid depth.

The decanter centrifuge is intended to handle significant solid concentrations in the feed suspension, and, at the same time achieve quite good degrees of clarification of the liquid centrate (or, in the three-phase decanter, of both liquids). The decanter has a drainage zone, so that the discharged solid is partially dewatered, with lower moisture levels possible in the screen bowl decanter.

The disc stack separator and the decanter make up most of the centrifuge market, and have been developed into important processing tools – to become the separation equipment of choice, so long as their cost is not a problem. The two types overlap in application to some extent, but they broadly have their own distinct uses: the high speed separator for liquid/liquid separations, for relatively low feed concentrations (as low as 0.1%) and for finer particles (0.1 μm to 250 μm), while the decanter can handle higher feed concentrations (up to 65%), can dewater effectively, and deals with larger particles (10 μm to 10 mm or more).

Centrifugal *filters* are intended to handle high concentrations of feed solids, but are best suited to solids that filter and drain easily. As already noted, their design complexity is very much the result of providing ease of solids removal from the filtration zone. The types of centrifugal filter, classified by this solids release mechanism, include:

- fixed bed (batch and semibatch)
 - manual discharge
 - scraped through open base
 - removable bag
 - automatic discharge
 - knifed from vertical basket
 - peeler (horizontal basket)
 - inverting basket
- moving bed (continuous)
 - cone screen
 - pusher



Alfa Laval has been involved with separation technology since the company was formed in 1883. Image courtesy of Alfa Laval.

The simplest type of centrifugal filter has a drum rotating about a vertical axis, with motor and shaft either below the drum (underdriven) or above it (overdriven), the latter making for easier solids removal from the manual discharge ranges. The drum may be in the form of a perforated basket (coarse wire mesh or perforated plate), or it may have no base, just perforated walls. When the accumulated solids reach a certain level, the feed is stopped and the cake of accumulated solids can be washed and then allowed to dewater by drainage. The rotation is then stopped, and the solids either dug out, or lifted out in a bag of filter medium. The drum (or filter bag) is washed and the process repeated.

The same type of machine can be fitted with a knife that will cut the cake out, without the rotation having to be completely stopped (although this will need to leave a heel of cake, to protect the medium's surface). This automatic knife function is developed in the peeler centrifuge, where the drum is now mounted horizontally, and the filtration, washing, dewatering and cutting out all occur at the same rotational speed, on a constant cycle.

A quite different form of automatic discharge is achieved with a horizontal basket by having it lined with a fabric to act as the filter medium, which, when the cake is sufficiently dewatered, is pulled out of the basket by its centre and is thus turned inside out, releasing the solids into the casing of the centrifuge.

The most complex of the centrifugal filters are those in which the separated solids move along the filtering surface, from the feed end

of the basket to the opposite end, where they are discharged into the surrounding casing. To make this movement easier, the screens that do the filtering are usually made of wedge wire bars, mounted lengthways in the screen. During the passage along the screen, the solids are filtered, washed and dewatered, and the system must ensure that sufficient time is available for these all to occur to the necessary degree.

The cone screen centrifuges are all, as their name implies, fitted with a screen in the shape of the frustum of a cone, and all rotate about the axis of this cone. They can be mounted with the axis of rotation horizontal or vertical. The slurry is fed to the narrow end of the screen, and the solids tumble "downhill" to the widest end. The component of the force pulling the solids towards the machine's central axis is obviously the greater, the wider the angle of the cone, and if this angle is greater than the angle of repose of the wet solids, then they will move along the screen. One specific cone angle may only be suitable for a limited range of solids, so cone screen centrifuges exist with an ingenious range of devices to slow down the movement of the solids (such as the baffle ring centrifuge), or to speed it up (a screw conveyor or various vibrational motions).

The other main form of continuous centrifugal filter is the pusher centrifuge. Here, the basket rotates about a horizontal axis, and the screen is in the form of an open drum, but the drum is in two or more annular segments, of increasing diameter away from the feed end. These segments move backwards and forwards

across one another, pushing accumulated heaps of solid ahead of them. In this way, the solids are moved along the totality of the screen, and the pusher can provide very effective washing and dewatering of the solids.

Centrifugal filters generally cannot handle solids as fine as those processed easily by many pressure filters, and another drawback, especially of the moving bed machines, is that they need a fairly stiff feed, to stop it running straight out of the basket unfiltered – i.e. it needs to be thickened prior to filtering. The continuously filtering centrifuges promote dewatering of the moving cake of solids, but care must be taken in design or machine selection that this movement does not damage the separated solids (by breaking crystals, for example).

Market developments

The centrifuge business is characterised by the relatively small number of companies of which it is composed – there are several thousand filter makers and suppliers in the world, but only a few dozen centrifuge makers. The two largest companies – Alfa Laval and GEA Westfalia – hold a large share of the market between them, a share that has recently increased by Alfa Laval's acquisition of Hutchison Hayes. It is of interest to note that both have comparatively recently moved into the quite different membrane separation business (Alfa Laval by the purchase of Danish Separation Systems, and Westfalia by acquiring Membraflow), and also that both make only sedimentation centrifuges (separators and decanters).

An important part of the centrifuge market, especially for decanters, is the aftersales equipment maintenance business. There are quite a number of specialised service companies, who do not make their own equipment range, but supply rebuilt machines originally made by one of the major suppliers. These major suppliers have always serviced their own machines, but are now beginning to take on servicing of their competitors' products. Andritz has gone one step further by acquiring Contec Decanter, a specialist maintenance company.

As with most other branches of the separations business, the centrifuge segment is growing rapidly in China, to the extent that Robatel Rousselet made its move into China by acquiring Shanghai Chemical Machinery Plant.

Equipment developments

The centrifuge business is effectively about 60 years old, despite de Laval's 1878 separator, and a 1902 patent looking a lot like a decanter, because of the burst of activity in the 1940s that led to cross-transfer of technology to new applications for the separator, while the first real decanter, the Sharples P1000, appeared in 1945 (in the fish processing business). In the first 20 or so of those 60 years an amazing range of centrifuge



Westfalia has introduced the higher speed HDE200 for ethanol recovery from sugar and molasses processing. Image courtesy of Westfalia.

types was developed, but it is probably fair to say that the engineer of 1970 would be able to recognize any of today's machines for what they are, at least from the outside. The last major type to appear on the market was probably Heinkel's inverting basket design.

In the cases of the cyclone and the hydrocyclone, there have been no significant design changes over the last decade or two, although a number of hydrocyclone-like devices have been introduced (with little impact on the market).

The same is true of centrifugal filters, in that there have been no significant equipment developments in a range that now consists of the perforate basket (sugar centrifugal), the knife discharge peeler, the invertible basket, and the various designs of conical screen and pusher centrifuges. Some effort, however, has been put into making as many of these as possible into gas tight machines, so that organic liquids can safely be used in the process.

The basic components of the high speed separator have seen little change, but there has been significant development of the internal structures, in terms of automatic solid discharge systems, and centrate offtake, to be as energy efficient as possible, and to cause as little impact as possible on downstream processes. The feed zone design has also been developed to enable the feed suspension to be accelerated to bowl speed as smoothly as possible. The disc centrifuge has become a vital separating tool in the many fermentation applications in the pharmaceutical and biotechnological industries.

The same basic fermentation process, to produce fuel ethanol, is creating new opportunities for business. Westfalia, for example, has introduced the higher speed HDE200 for ethanol recovery from sugar and molasses processing. An important new development, also from

Westfalia, is the integrated direct (in-line) drive system for the disc separator.

As with the disc centrifuge, so also with the decanter is the market being very much end-user driven, with a wide range of design variants available to make the particular centrifuge as relevant to its application as possible. This is especially true in sludge dewatering, which became a huge market for the decanter when synthetic flocculants became available. An important recent development has been to fit baffles at the solids discharge end of the decanter scroll so that the bowl becomes almost full of solids, rather than having a relatively shallow layer at the bowl periphery. This "Dry Solids" version does, indeed, produce a much drier solid discharge. Westfalia has a new "CDforce" range of decanters for sludge processing, and Alfa Laval the SG2-700 decanter for distillers dry grains production, as well as an in-line variable frequency drive for its decanters, enabling better control of the machine's behaviour.

Similar "tweaks" of machine internals can be expected to continue to appear, in both the high speed separator and the decanter, to meet end-users' needs. Efficient gas tightness, if not actual pressurised designs, will become important to meet some of these demands. ●

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