Although the industrial centrifuge has been around for more than 100 years, it is only in the last 40-50 years that we have seen the major design developments. The main driving force behind these developments has been the requirements of end users, although environmetnal and saftety legislation have also played their part. Nigel Day takes an in depth look at how centrifuge technology has changed in that time, using the batch basket filtering centrifuge as the example.

The Evolution of the Batch Basket Filtering Centrifuge

This particular article is not about facts and figures, but is an overview of the general evolutionary development that has taken place with the batch basket filtration centrifuge over the last 40-50 years.

Though in a rather basic and crude form the technique of centrifugal liquid/solid filtration separation has been around for several hundred years. However, it is the last 50 years that have seen the more major developments emerging.

From the time the very first manufactured industrial centrifuge, now over 100 years ago, to the present day, the design, developments, specification and configuration have nearly all been driven by the end users' specific requirements. For example, possibly the first mass produced centrifuges were sold to the dairy, textile and sugar industry, all of which require very specific and widely different manufacturing design criteria.

Figure 1: The safe operation of steam driven basket centrifuge installations relied heavily on the operator. (Image courtesy of Thomas Broadbent & Sons Ltd).

As you continue to read through the article you will see that virtually all core design improvements has been driven by the end user. Of the remaining developments these are driven by the constantly evolving regulations, legislation and various directives coming from organizations such as the Food & Drug Administration (FDA), the Health and Safety Executive (HSE) and numerous environmental agencies.

All the leading centrifuge manufacturers (OEMs) will incorporate their own 'bells and whistles' to try and keep ahead of the competition, but all major design developments are, in some shape or form, driven by the end users' needs.

Thankfully we have moved away from the totally unacceptable and potentially lethal situation provided by the 36 inch basket diameter, steam driven, centrifuge installation (Figure 1). Whilst the mechanical integrity of the centrifuge was sound, overall safety at that time was heavily reliant on the diligence of the operator. A situation that thankfully cannot happen nowadays.

Potentially there are six major batch basket filtration centrifuge configurations that can be employed in the vastly diverse market place. This in itself is an indication of how batch filtration centrifuges have evolved according to the products and processes being offered for separation.

(i) Vertical overdriven
- Top discharge
- Bottom discharge

(ii) Vertical underdriven
- Top discharge
- Bottom discharge

(iii) Horizontal Peeler

(iv) Horizontal Inverting Bag

It would for example now be (or at least it should be) unheard of for a manual top discharge centrifuge to be employed on final pharmaceutical products, where contamination of both the product to the atmosphere and of the operator is prohibited.

Yet it would be uneconomical to select a fully enclosed centrifuge with a sterile, high quality surface finish, along with

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Figure 2: Broadbent 46A centrifuge features an energy-efficient electric drive system. (Image courtesy of Thomas Broadbent & Sons Ltd).

a high specification control system, working on a very low cost, low volume, none hazardous product.

Outlined below are some of the major developments that have occurred over the last 50 years or so.

Drive Systems

One of the major developments has been with the main drive systems. Most early motors were only single speed, although some two-speed units did exist. This resulted in centrifuge processing being predominantly a manual operation. At the end of feeding the suspension, then washing (if required) and finally spinning, the solids were invariably removed manually from the stationary basket. As a result of the restrictive number of motor speeds process cycle times were prolonged.

A large number of batch basket filtration centrifuge manufacturers employed hydraulic drive systems. One of the main reasons for this was that they could, via a series of timers and solenoids, create a 'variable' drive system - a first on such centrifuges. Such drive mechanisms became the norm, and in some cases remain in place today.

Around the mid 1970s came the biggest breakthrough in the area of centrifuge drives, the employment of the variable-frequency drive system. This meant that a fully variable drive, capable of operating the centrifuge at any speed between 1 rpm and the maximum permissible speed of the machine, was developed.

Precise speed control systems paved the way for significant improvements to existing processes, as well as providing vital assistance to the more difficult suspensions being put forward. Time cycles were significantly reduced resulting in higher product throughput.

The very latest variable frequency drives are very energy efficient as they have the ability to regenerate power during deceleration throughout the whole speed range (Figure 2). Reducing the voltage supply to the motor can also reduce magnatizing losses at predetermined rotational speeds.

Currently the employment of hydraulic drive systems are falling sharply and is only a matter of time before all previously hydraulically driven centrifuges will be replaced with electric drive systems. Centrifuge OEMs with their own in-house service department are actively offering electric drive conversion packages to such existing machines.

Residual Bed or Heel Removal

A major disadvantage inherent in the design of batch filtration centrifuges, both with the vertical and horizontal axis units, is their inability to discharge the entire solid from the basket.

It is not possible to scrape, peel or plough solids close to the filter media without the risk of causing damage. In the majority of cases if the discharge mechanism came into contact with the filter media it would simple rip it out of the centrifuge basket.

This major disadvantage has posed a large problem for centrifuge design engineers since their entry to the filtration and separation market. Whilst most manufacturers have developed various mechanisms, such as an air/nitrogen lance, reverse jetting and inflatable cake breakers, none have managed to design a device that is successful for all products.

The nearest design development to appear in the market that can guarantee total solid removal on virtually all products is the horizontal inverting bag centrifuge.

Here product is fed to the centrifuge in the conventional manner. The major difference comes at the end of the cycle when the solids have to be removed. Both the filter media and cake are literally pushed out of the centrifuge basket into a separate discharge chamber, and turned (inverted) inside out. Due to the simple action of spinning at high speed all the cake solids including the residual heel is spun from the filter media. The filter media is then returned to its original position in readiness to receive another batch of slurry.

Clearly a major development to a problem that has been around for over a century. Figures 3a & 3b) show the filter media and pushing device in its closed and open (inverted) position, respectively.

Safety and Interlocks

As Figure 1 demonstrates, early safety standards when operating a centrifuge was very much down to the personal care and diligence of the operator. Thankfully this situation has changed. Now an operator cannot operate a centrifuge unless the Programmable Logic Controller (PLC) or another sophisticated control system has checked numerous safety interlock devices. Devices that control not only the centrifuge lid interlock for instance, but also equipment surrounding the centrifuge. Equipment such as the feed pump, filtrate take off pump, discharge valving, etc.

Figure 3a: A horizontal inverting bag centrifuge in 'invert closed' mode. (Image courtesy of Heinkel AG)

Figure 3b: Horizontal inverting bag centrifuge in 'invert open' mode. (Image courtesy of Heinkel AG)

If flammable substances form part of the process then there will be a need for additional interlock checks to be carried out because of the involvement of a suitable inert gas blanketing system.

All such interlocks and checks have drastically improved the overall safety of the machine, providing even further protection for operators, and that of the environment surrounding the centrifuge installation.

Materials of Construction

When compared to the vast array of potential materials at the disposal of engineers today, early centrifuge engineers were restricted to a relatively limited number. Early designs incorporated large amounts of cast iron. Cast iron was used predominantly for the centrifuge framework and centrifuge outer casings. This meant that an early centrifuge compared to one of a similar size today was probably twice if not three times heavier. Manufacturing, assembly and certain component lead times were also significantly longer, unless manufacturers had their own on-site foundries.

The availability of stronger stainless steels has enabled the production of deeper baskets and baskets with larger diameters. These, coupled with the ability to rotate the baskets at higher speeds, have increased the active separating force to approximately 1500 times the force of gravity. This alone is around twice that of early similar centrifuge designs.

Modern materials have resulted in lighter, more versatile, high performance centrifuges without compromising mechanical integrity, reliability and more importantly safety.

Good Manufacturing Practice (GMP)

Good Manufacturing Practice, or more commonly known as 'GMP', is used internationally to describe a group of principles and procedures which, when followed by manufacturers of goods such as industrial centrifuges, helps ensure that the products produced will have the required quality and safety.

GMP guidelines can and have been applied to manufactured goods for many years, far longer than possibly people realize. They have many and varied implication for everyone involved in 'manufacturing' and in some ways, as they are only guidelines, are still very much open to the individual's own interpretation. However, when talking specifically about centrifuges, GMP has become synonymous with those supplying equipment primarily to the fine chemical, food and pharmaceutical industry.

GMP implications for a centrifuge mean it must have a system that ensures that products are consistently processed and controlled according to predetermined quality standards.

Therefore all components that come in contact with the product must be as clean and sterile as possible. To achieve this the manufacturer of the centrifuge must be able to satisfy the following.

- Can the centrifuge be cleaned?
- How is the centrifuge cleaned?
- Can it be proven to be clean?

The first two requirements are quickly and relatively easily achieved, this is normally carried out by a validated clean-in-place system (CIP) and/or a steam-in place-system (SIP). The third requirement, proving the centrifuge is clean, has been very difficult for some manufacturers. Almost overnight existing and long proven excellent designs became obsolete when required to comply fully with GMP requirements. Or at the very least became very difficult for end users to work with.

The main difficulty lies mainly in the vertically orientated basket designs. Without removing the actual basket it is almost impossible to prove that the underside of the basket is clean. Some manufactures have successfully addressed this problem by designing centrifuges that can lift the outer casing up and over the basket (Figure 4).

Figure 4: The centrifuge's outer casing is lifted up and over the basket to show that the underside of the basket is clean. (Image courtesy of Comi Condor)

Whilst this design is a vast improvement and acceptable to some manufacturers, the real trend over the last decade has show that end users are moving away from vertical axis design centrifuges and installing horizontal designs.

In addition to complying better with the GMP issues surrounding the internal product contact zones, virtually all manufacturers have taken GMP even further by offering horizontal 'through the wall' designs. Such installations provide a dirty end and a clean end to the centrifuge, which can be kept completely separate from each other (Figure 5).

Conclusions

I am sure that there will be some centrifuge OEMs who may wish to dispute some of the points made above, but the fact remains that the customer remains king. He dictates what is ultimately required, and it is up to the centrifuge engineers to respond. Those who have responded well to these, at times complex, demands will continue to flourish, those who have not are may well be struggling to remain competitive or have even lost the battle already.

The industrial batch basket filtration centrifuge is now regarded as possibly the most flexible and highly sophisticated piece of processing equipment available to the liquid/solid separation industry.

As engineering technology, controls, instrumentation, etc, continue to evolve further than we can currently imagine, the next 50 years look very positive for the manufacturers of batch basket filtration centrifuges that can continue to maintain the pace.

For end users such competition, where the boundaries are continuously being pushed outwards, will ensure they continue to have at their disposal a highly flexible and efficient piece of separation plant equipment.

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Figure 5: Examples of the horizontal 'through the wall' design that enable the clean and dirty ends of the centrifuge to be kept completely separate. (Images courtesy of Thomas Broadbent & Sons Ltd and Comi Condor)