When problems occur in industrial processes the centrifuge is often blamed, but this is not necessarily where the problems lie. Nigel Day, NCD Separation Solutions Ltd, UK, discusses how upstream and downstream equipment can negatively impact on centrifuge performance, using a batch basket filtering centrifuge type as an example. He also presents details of a recent process optimization project.

How Other Process Equipment Influences Centrifuge Performance

Solid/liquid separation is a truly ubiquitous unit operation. It is almost impossible to consider any chemical or pharmaceutical manufacturing process that does not involve at least one such separation stage. In addition, there is a large effluent and environmental market that also uses such technology.

However, as common as it is, the field of solid/liquid separation is generally not well understood. In part, this is because of the very complex nature of fluid-particle systems. This lack of detailed understanding, not surprisingly, leads to many problems within the industrial processing plant. With greater demands constantly being placed on the process efficiency and improved final product quality it is imperative that engineers gain a better understanding of this technology.

Despite the increase in available information on the subject through industrial magazines, exhibitions, organizations the situation still presents a tough challenge to end users who are seeking to achieve the full potential of their separation equipment. The following article aims to go some way towards assisting the process/plant engineer in this complex subject matter. It is fully appreciated that there is a great number of different makes and types of solid/liquid separation equipment, but it is the intention of this article to concentrate solely on the operation of the batch filtering type industrial centrifuge.

Centrifuge manufacturers or centrifuge specialists are often called to the process plant to evaluate a batch basket filtering centrifuge that is reportedly causing problems to the process plant and its operators. Experience has told the visiting process engineer that in the majority of cases it is not necessarily the actual centrifuge that is causing all the problems.

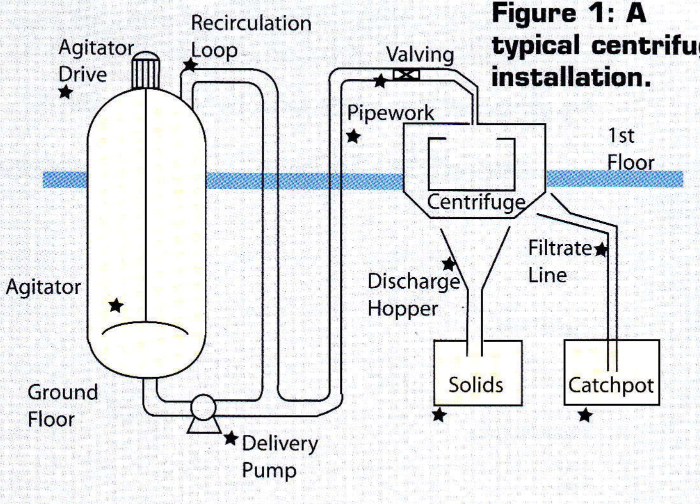

Figure 1: A typical centrifuge installation.

Before embarking on work of any kind on the centrifuge it is strongly recommended that time be spent with the operators or supervisors to establish a clearer picture of the situation. Once all data and a detailed evaluation has been collated one can then begin to look at the centrifuge and installation as a whole.

A centrifuge will tolerate a certain amount of minor problems, but if not fully optimized will quickly acquire a bad name, irrespective of all the latest refinements a manufacturer incorporates in its designs. There are many influencing factors that individually or collectively go towards a successfully optimized centrifuge.

The following article systematically covers several key areas that are often overlooked, which may lead to problems with the operation of the centrifuge. The list is not exhaustive, but is considered to cover the majority of the factors, both upstream and downstream, that affect the smooth operation of an industrial batch filtering centrifuge.

Typical Centrifuge Installation

We begin by looking at a typical, but not ideal installation. The schematic diagram in Figure 1 highlights at least ten potentially problematic areas (marked with an *) that must be considered prior to embarking on any kind of commissioning or optimization work on the industrial centrifuge itself. Prior to considering the centrifuge we look at the potential upstream and then the downstream influences.

UPSTREAM INFLUENCES

Impeller & Vessel Design

The first thing to note is that both these areas go hand in hand. Correct mixing vessel configuration and impeller type, size and position have to be considered together if the needs of a particular mixing operation are to be successfully met.

The first priority is to match the impeller to the total mixing requirements of the entire process in question. Secondly, and just as importantly, is to meet mixing requirements at a minimal capital expenditure and minimal cost of operation.

There are two fundamentally different impeller designs, one that specifically produces axial flow and the other radial flow. Impeller design is continually being developed to further improve process performance and reduce processing costs. In addition to the most common impellers there are other designs, such as the propeller, gasfoil, counter current, draught tube and pump mixing impellers, all of which are employed on more specific process applications. It cannot be emphasized enough that the choice of an impeller is heavily dependent on the vessel geometry, fluid characteristics and desired process results. Therefore before deciding upon a specific design of impeller the application under consideration must be clearly defined and understood.

(i) Vessel design

Feed lines to a large percentage of tanks where solids must be kept in suspension by impellers come directly into the tank tops. If the feed inlet is located at some other point on the tank this need not necessarily affect mixing requirements, but extra care must be taken. Practical considerations include avoiding feeding directly into particular tank areas such as behind a baffle, where solids build-up can occur. Also, the solids must be pre-slurried in the feed stream, or the controlling mixing requirement may be wetting-out of solids rather than solids suspension.

(ii) Draw off points

The careful selection of draw off points from vessels is extremely important for the success of a solids suspension operation. The best position for a draw off point is usually near the bottom of the tank. In special cases the draw off line may need to be positioned higher on the side of the tank. It may also be necessary to extend the outlet pipe inward from the wall of the vessel, and make other careful adjustments to achieve as close as possible an average outlet slurry consistency to that in the vessel. The bottom centre of the vessel is generally regarded as a poor draw off point. Where a bottom centre take off is employed it is beneficial to install an inverted cone for deflection of the impeller flow and protection of the outlet from blocking.

(iii) Vessel baffles

Anti-swirl baffles are an absolute must for developing the vertically upward flow streams required for the development of best suspension uniformity of solids in a mixing vessel.

For two, four, six or eight bladed impellers, four baffles should be used. Each baffle should be spaced 90° to each other, with each baffle a twelfth of the tank diameter in width, always set out from the tank wall (to a maximum of 30% of the baffle width). Note, that for three-bladed impellers there should be three off baffles, 120° apart and of increased width.

Higher solids content slurries generally become more viscous and non-Newtonian, and will require more individual consideration of impeller and baffle recommendations. Usually narrower and bolted design baffles are recommended. In circumstances, where the solids have any floating tendency, or in any operation where wetting-out of solids is a requirement, the baffles should be terminated well below the initial liquid surface. This will promote surface vortexing for better draw down. An upper impeller may also be desirable for such operations.

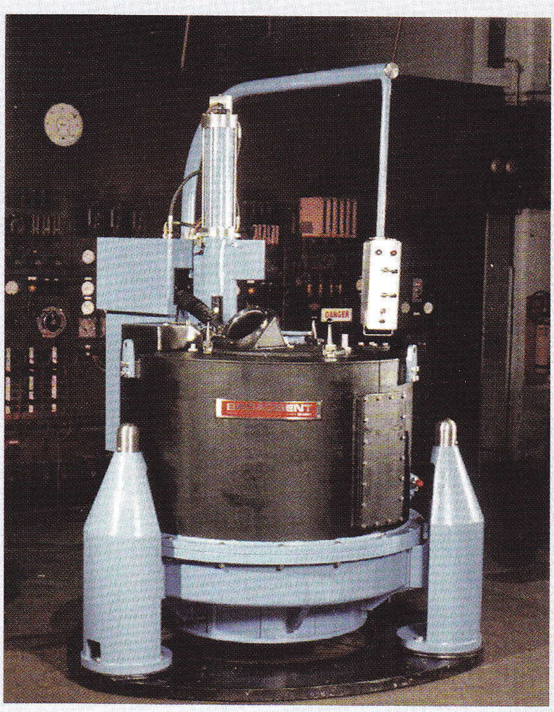

Image courtesy of Thomas Broadbent & Sons, UK.

A flat-bottomed tank is a very effective shape for the suspension of solids, and corner fillets in such tanks will minimize the problems of tank clean out and failure to keep materials in suspension.

If a dished bottom tank is used, the deepest such bottom tolerable for a good suspension of solids is the semi-elliptical dish. For more difficult applications, there may be a need to extend and contour the anti-swirl baffles into the dished bottom, to extend the mixing impeller downward and/or to fit a tail turbine design. Deep cones are not beneficial to solids suspension and should not be employed.

(iv) Other considerations

Most solids suspension applications are best satisfied by vessels with a slurry height to diameter aspect ratio of >0.9.

In continuous flow systems, the basic requirement is to establish equilibrium in the vessel such that the consistency of the outlet mixture will be equivalent to the average materials being added. This does not require that the vessel contents be 'uniform' at all times, but simply that the system is stable and not building up in total weight % of solids or % of the larger solids. Where other fluid mixing processes are involved e.g. leaching, mass transfer, etc, high degrees of uniformity are usually required. Continuous suspension process systems, particularly those where reactions and systems in series are involved, may use top level or intermediate level outlets. These may benefit by the use of upcomers to feed the slurry from the tank bottom to the elevated outlet. With tall tank continuous flow systems benefits may also be gained by considering draught tube mixer designs, which can offer increased mixing process efficiency and reduced capital costs.

By keeping these criteria in mind, and letting them guide you accordingly, one will be far ahead in the selection of the most appropriate impeller design for the mixing needs in question. All of which will lead to a homogeneous slurry mix moving forward towards the centrifuge for separation.

Slurry Delivery Pumps

Having now incorporated a slurry holding vessel and agitation system that will produce a homogeneous mix, with minimal degradation to the suspended particles, it is vital that all that good work is not undone by selecting an inappropriate type of delivery pump to move the slurry forwards to the centrifuge.

(i) Centrifugal pumps

Experience has shown that when faced with the problem of pumping a solid/liquid suspension the first reaction of most processing plant operators is to consider selecting a conventional 'centrifugal' pump. If the solids are hard and robust in nature then this is fine. However, there are large risks, especially when processing the delicate and fragile solid particles frequently found in the chemical and pharmaceutical industries.

Conventional centrifugal pumps function by enclosing a rotating vaned impeller inside a stationary casing. This means that the suspended solid particles make contact with the rotating impeller. Initially the particles impact on the sharp inlet edges of the impeller vanes, and then they impart a grinding action as they flow along the surface of the impeller vanes. In addition to these, further damage is caused as they leave the impeller and grind along the internal surface of the pump casing. Finally they impact on the discharge connection of the casing.

During impacts, the particles strike the surface at a very high angle and most of their kinetic energy is dissipated in fracturing the material surface, as well as themselves. The damage intensity for brittle solids is related to the rotation of the impeller/particle hardness. If the particles are soft or fragile, but with low hardness then particle damage can be extensive. In the grinding action the particles strike the surface at very low angles, which tends to rapidly spin the particle. The particle damage intensity is less intense because not as much of the particle kinetic energy is dissipated.

There is a derivative of the conventional centrifugal impeller pump, which replaces the vaned impeller with a vortex-generating impeller. The impelling action exerted directly by the vanes is replaced by a strong forced vortex in the casing. This is generated by the indirect action of an impeller that is largely buried away from the main flow. Such designs are called 'recessed impeller' pumps. The advantage of this design means that there is little direct physical contact between the particles and the rotating impeller, thus allowing soft fragile particles to be transferred with significantly reduced attrition.

Image courtesy of Thomas Broadbent & Sons, UK.

(ii) Progressive cavity pumps

An alternative, and probably a more commonly employed delivery pump, is the 'positive displacement, progressive cavity' type. Like all progressive cavity pumps they are a type of rotary, positive displacement pump. They have a unique design, which comprises a special configuration of its two main pumping elements and their respective relationship to each other with each shaft rotation. Because of the compression fit between the rotor and the stator, and the combination of the helical forms, discrete positively sealed cavities are formed. The sealing lines defining the cavities will hold pressure even when the pump is not running. Because the cavities are completely sealed, positively isolating the suction and discharge conditions from each other, the pump is capable of high suction lifts and relatively high pressures, independent of its operating rotational speed. Positive displacement and flow proportional to speed characteristics, together with their ability to pump against pressure at very low speeds and with very low mechanical damage to fragile suspended solids, make these pumps ideal for feeding most material encountered by filtration type industrial centrifuges.

Pipework

With the combination of an appropriate slurry vessel, agitation and delivery pump selection, it is now vital that the slurry is delivered to the centrifuge as quickly, but as gently, as possible. In order to achieve this, one should aim to produce a slurry delivery pipework line that is as straight as possible, as steep as possible and as short as possible.

Any possibility for solids to settle out or crystallize in the pipework will cause significant problems during the operation of the centrifuge. In order to remove this potential problem, the pipework must comprise minimal vertical and horizontal lengths, and 90° bends or elbows should be removed from the pipework and replaced with more gentle sweeping bends. This will not only maintain a steady feed velocity, but it will also further assist in reducing particle damage.

DOWNSTREAM INFLUENCES

In the next part of the article we look at potential problem areas downstream of the centrifuge. Having managed to get the slurry into the centrifuge it is just as important that it is adequately catered for as it leaves the centrifuge during and after processing.

Unlike the single stream of the slurry one is now faced with at least two separate streams, i.e. the solid phase and the filtrate phase (if a product wash is applied it means a third or more streams need to be considered).

Most vertical basket type centrifuges discharge the final solids cake through an opening in the bottom of the centrifuge, where it is handled in a variety of ways. It can, for instance, fall directly into a dryer, onto a conveyor or into catchment containers, such as bags or kegs. The key point to make is that whatever system is employed to look after both the solid and liquid phases it must, under no circumstances, delay or slow down the upstream processing. Delays in removing these streams from the centrifuge prevent the centrifuge from processing another batch immediately, which means that the slurry at the beginning of the process is receiving unnecessary agitation. This will lead to particle degradation, which will ultimately mean potential separation problems when it does eventually reach the centrifuge. This problem can be compounded further if a ring main feeding system is being employed because the slurry is continuously re-circulated through the pump and pipework.

Hopper Design

One important property that is often overlooked is the flowability of the final cake solids as they are discharged from the centrifuge. Factors such as particle size distribution, cohesion and friction between the particles and the hopper walls affect hopper-emptying behaviour. This friction and cohesion between particles will almost certainly lead to bridging or choking, piping and a non-uniform flow rate, if the hopper is not designed accordingly.

Knowledge of the cake flowability index will assist in the hopper design, especially with regards to wall angle, length of hopper and size of opening. It may still be necessary to coat the inside surface of the hopper with materials such as Teflon or PTFE to reduce the possibility of unwanted solids sticking.

Filtrate Line

Virtually all of the issues outlined above for the solids cake should also be followed here. An additional key point to make is that under no circumstances should the pipework be reduced from the outlet size provided by the centrifuge manufacturer. Due to high energy and the difficulty in predicting windage patterns in and around the centrifuge. It is imperative that the filtrate is allowed to get away from the machine as quickly as possible. Any restrictions or reduction in the pipework may lead to the filtrate building up into the centrifuge. This is a very serious scenario, and will result in extremely high and potentially dangerous vibrations as the liquor comes into contact with the rotating basket. Filtrate should leave the pipework from an open end well above the level of the catchment tank, and not allowed to become submerged.

The Centrifuge

Finally the centrifuge installation itself. All centrifuges must be installed on level, well prepared foundations. In the case of suspended pendulum type centrifuges or centrifuges supplied with vibration dampers the requirement for the base are not so onerous. Rigidly mounted centrifuges, on the other hand, require substantial foundations. Vibration analysis of the structure should be made to ensure that it does not contain resonant frequencies in either the horizontal or vertical axes, which could be excited by the movement of the centrifuge. External connections to the centrifuge such as process and filtrate pipes, solids discharge chutes and electric and hydraulic connections must all incorporate plenty of flexibility to allow for the movement of the centrifuge under the influence of out-of-balance forces, without themselves imposing any restrictive loading. There should also be sufficient space between the centrifuge and other process equipment (a minimum of 150 mm is recommended) to avoid collisions.

Conclusions

The batch basket filtration type centrifuge is a very versatile piece of solid/liquid separation equipment. It has the flexibility to satisfy a wide range of applications, providing excellent separation of solids, while maintaining essentially clear filtrates. It is all too common for the end user to view the centrifuge with a mild case of 'tunnel vision' and quickly call in the centrifuge experts. It can be clearly seen from the above that there are many factors, both upstream and downstream, that have a bearing upon the performance of any piece of separation equipment.

Pure theory alone is of limited help in the application of an industrial centrifuge. It is more a combination of application experience, testing and design capabilities of the centrifuge experts combined with the end users invaluable knowledge of their material which ensure that the centrifuge installation will produce a product on schedule, of the desired quantity and quality, economically and above all safely.

Case Study: Process Optimization

In the final part of the article we discuss a recent process optimization project conducted at Clariant Ltd, the UK subsidiary of global specialty chemicals company Clariant International, by NCD Separation Solutions.

To satisfy a significant increase in market demand for its products the company approached NCD Separation Solutions to assess whether or not it required an additional centrifuge to meet the growing demand. The company's existing primary filtration process comprised of three vertical batch basket filtering centrifuges. An on-site survey established that these centrifuges were collectively capable of recovering up to 1200 kg/h final cake solids. However, to achieve this level of throughput their process cycle times would have to be reduced and the payload of retained solids in each basket increased. One of the biggest problems of the whole separation process identified was that the upstream slurry holding vessel, agitation system, delivery pump and pipework were all contributing to particle degradation and varying concentrations and consistencies of the feed, which was negatively influencing the operating performance of the centrifuges.

A process optimization package was put together, aimed at increasing output, reducing production cycle times, improving operator working conditions and minimizing plant maintenance. Further evaluation of the process indicated that it would also be possible to achieve savings by using less wash fluid, with a corresponding reduction in effluent discharge levels

The optimization work was completed in approximately two weeks and resulted in the throughput of the three centrifuges increasing by 20%, with an overall increase in process throughput of 25%. The improved operation of the plant also reduced the frequency of basket inspection and cleaning operations by 50%. Now because of a much smoother operation of the process, the centrifuges are anticipated to have a much longer operating life.

Contact:

Nigel Day, NCD Separation Solutions Ltd,
4 Healey View, Ossett, Wakefield,
WF5 8LX, UK.
Tel/Fax: +44 1924 270369;
E-mail: info@ncdsep-solutions.co.uk;
Website: www.ncdsep-solutions.co.uk