Engineering Practice

Operate Your Filtering Centrifuges Troublefree

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Match the centrifuge operating parameters to the characteristics of your feed. And develop a working knowledge of the design of the equipment

Centrifuges isolate solids from liquids, or separate one liquid from another. They bring about the settling of a heavy phase out of a light phase, or the filtration of suspended solids from a liquid, by magnifying the forces of gravity. Although centrifuge usage is widespread, there are many misconceptions as to proper operation and maintenance of this equipment. Misconceptions particularly arise with respect to centrifugal filters (or filtering centrifuges) that operate in the batch mode.

Filtering centrifuges provide filtering action by forcing liquid through the cake of solids as it builds up, and on through a filtration medium, leaving the solids on that medium. Because of the centrifugal forces — typically 800 to 1,000 times gravity —associated with centrifuges' high rotational speeds, liquid is driven through the cake faster than in any other type of mechanical separation.

Obviously, centrifuges are not the optimal choice for every filtration situation. In approaching any filtration task, the first consideration is the relative amount of solids to be isolated and liquid to be filtered away. The smaller the proportion of solids, the larger the area required to handle the hydraulic loads. For small proportions of solids, equipment such as sand filters, filter presses and rotary vacuum drum filters should be seriously considered, because they have large areas; upon those areas, thin cakes become formed during operation.

Conversely, if a large proportion of solids must be isolated, filtering centrifuges that have a high ratio of cake-handling capacity to filter volume area are considered. More specifically, filtering centrifuges are preferred if the solids concentration is 10 to 60%, the solid is noncompressible, cake washing is required, and the final moisture content must be as low as possible. Screening tests for application to a given slurry appear in the box on p. 51

CENTRIFUGE OPERATION

During its operating cycle, a batch centrifuge goes through the following sequence of steps:

1. Acceleration to feed speed; although that speed varies from case to case, up to 500 rpm is typical
2. Feeding the slurry
3. A delay or pause of about 30 s while the centrifuge continues to rotate at the same speed
4. Washing of the cake as it forms
5. Acceleration to spinning speed, typically 600 to about 1,100 rpm
6. Spinning for about 10 min, to extract fluid from the cake
7. Deceleration, or braking, to the plow speed, typically about 30 rpm
8. Cake plowing for about 3 min
9. Return to Step 1

From the standpoint of the feed slurry and of the filtrate and cake recovered, several successive activities take place during that sequence:

Acceleration

Before trying to introduce the feed slurry into the centrifuge, the latter should be accelerated from its plowing speed up to a value above its critical rotational speed (the speed at which the machinery would oscillate at its first natural frequency); as a rule of thumb, the acceleration should be to about 350 rpm.

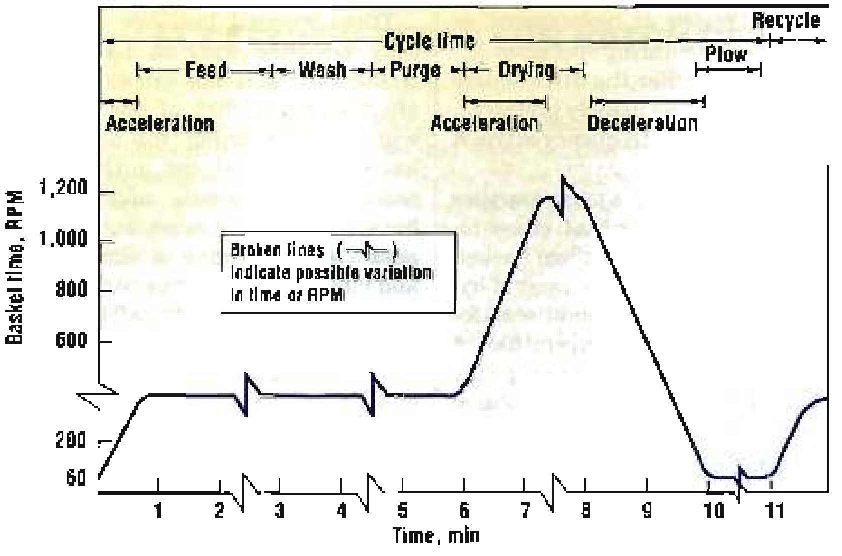
The typical feeding (loading) speed to be used with most slurries is higher than 350 rpm, as noted above. But it is not necessary to wait until the centrifuge reaches this higher speed before introducing slurry into the centrifuge basket. The centrifuge will continue to accelerate up to the higher speed even though slurry is being fed into the basket, provided that the feeding rate does not exceed the drive capacity.

Feeding

The rate at which a centrifuge can be fed varies with the product handled. Normally, it is advisable to feed the slurry at a rate slightly greater than that at which it would begin to settle out (in other words, slightly in excess of its drainage characteristic). This strategy will keep the load fluid, so it may distribute itself evenly in the basket. There are, of course, exceptions to this rule; in particular, poorly draining materials are likely to require special arrangements of feed-distribution nozzles.

Problems with feeding are among the most common type in operating a centrifuge. A few problems and suggested remedies are as follows:

- Free-draining materials may drain too fast. This will cause unbalance, as a result of the slurry being



Here is a typical operating cycle for a 48-by-30-in. batch centrifuge

dewatered upon impact. Solids become deposited at the point of impact before the slurry has time to distribute itself evenly up, down and around the basket side wall. Here are several remedies:

a. Use a more-dilute slurry
b. Increase the feed rate
c. Reduce the centrifuge speed
d. Increase filter resistance by using denser or multiple layers of filter media or, in some cases, by removing the backing screen entirely

- Conversely, slow-draining materials may drain too slowly and cause unbalance because of "liquid load" shifts in the centrifuge basket. Most of the remedies in this event are converses of those above for fast-draining material. Specifically,

a. Use a more-concentrated slurry
b. Decrease the feed rate
c. Increase the machine speed
d. Decrease the filter resistance by employing a more-open filter medium and by using a backing screen
e. Rinse the filter medium to clean it of embedded solids

- Other causes of imbalance in load include: breaks in the filter medium, causing excessive drainage in that area; excessive overlap on the backing screen (the screen ends should instead either abut or have a slight gap between them); excessive overlap on filter screen or filter cloth; incomplete plowing out of the cake; overfeeding the basket; inadequate feed system installed; and inadequate case draining, causing the liquid to back up within the case (this results in excessive power demands, slowing of basket speed, and leaks into the solids discharge chute).

The last-named two inadequacies deserve more discussion. Likely causes of an inadequate feed system are (1) the pump or head on the feed tank being too small to provide a proper feed rate to machine, (2) the feed lines or feed valve being too small, (3) restrictions, such as elbows or reducers, causing intermittent plugging of feed lines, which in turn cause intermittent feeding, and/or (4) improper or inadequate agitation of the feed material, resulting in feed that is not uniform.

The causes of inadequate case draining may include the following: (1) restriction in the case outlet, due to use of a pipe or elbow smaller than the case-outlet nozzle size, (2) the case outlet being connected to an excessively long drain line with restricting elbows or valves, (3) lack of venting on a closed tank into which the case outlet is discharging.

Note that these inadequacies in the feed system or case-draining system basically amount to a failure, during the design phase, to understand how centrifuge installations operate. They demonstrate the need for better understanding of centrifuge systems.

Washing

Although the cake of collected solids may need to be washed for any of several reasons, two very common reasons are simply to displace the mother liquor in the cake with the wash liquor (displacement wash) or to dissolve impurities out of the cake.

Normally, washing takes place at the same rotational speed as feeding, and immediately after feeding. This is particularly the case if the cake is compressible, because increasing the speed or extracting the liquid in the cake before washing would result in a more dense cake, reducing the drainage rate. Another possibility is that the cake may crack, thus giving the wash liquid a short-circuit path, which would result in an inefficient cake wash.

From a machine-operating standpoint, improper cake washing can unbalance the load. Too high a wash rate, resulting in slow liquid drainage, can build up a liquid load inside the centrifuge.

The spray should be somewhat tangential to the surface of the cake. Improperly positioned wash nozzles can cut holes in the cake, as can improper sizing of nozzles.

The washing time should be a function of drainage rate, and of the volume of wash liquor required to accomplish the desired results.

Moisture extraction from cake

There is an optimal time interval for removal of moisture from the cake during the high-speed rotation. The length of this interval depends on not only the desired final moisture content but also the force developed, the size and type of crystal, and the viscosity of the liquid, and it should be determined experimentally. The graphical plot of moisture content as a function of extraction time is asymptotic, and continuing the extraction beyond the optimal interval only wastes power and time.

Braking

The optimal time interval for braking is a function of the inertial load, the inherent friction and windage in the system, and the power of the drive. The inertial load is a function of the weight (mass) of the basket plus that of the cake, and of the rotational speed.

Unloading

The time interval for unloading is a function of the cake's resistance to shear, the rate of movement of the plow, the power of the drive, and the ability of the solids to drop through the discharge opening.

In practice, the unloading time is difficult to predict, because of the widely varying differences in material behavior. For estimating purposes, the author has calculated an unloading time on the basis of plow movement. For example, for a basket 48 in. in diameter and 30 in. high rotating at 60 rpm and with a 1/10-in. depth of cut per revolution, the rate of removal of solids is 13.7 ft^3/min.

Some materials are very sticky and claylike, whereas others are hard as chalk and difficult to unload. If a cake is particularly difficult to unload, it may be necessary to use a larger drive or to use an unloader jogging control; that is, a hydraulic-system leakage compensator, which allows the machine to maintain high torque and constant low speed during unloading.

KEEPING BATCH CENTRIFUGES RUNNING

Unbalanced loads and vibrations in centrifuges are very detrimental, and can drastically shorten the life of the machine if not remedied. Unbalanced loads lead to a need for high maintenance on what otherwise is a simple, low-maintenance piece of equipment.

Centrifuge imbalance has many causes, but the four most likely ones are:

- Improper installation of the equipment
- Inappropriate filter medium, or improper installation of a suitable medium
- Poor or irregular supply of feed slurry, due to poorly planned cycle times (see above) or inappropriate rotational speed for the centrifuge
- Improperly or poorly maintained equipment

What can go wrong

To avoid imbalance or other problems, here are the features most likely to be in need of review or replacement, or special attention during operation.

The drive: Whether the drive source is a hydraulic or, as usually preferred, an electric variable-frequency drive, it requires inspection.

In hydraulic drives, a pump supplies oil to a hydraulic motor that either rotates or brakes the centrifuge basket. This system requires a reservoir of hydraulic oil that must be conditioned for both cleanliness and temperature. A water-cooled heat exchanger keeps the oil at the temperature that is optimal with respect to viscosity and lubrication properties; a suction filter keeps the oil clean. Check the hydraulic hoses and connections frequently for leaks, which can lead to oil loss and/or contamination.

The electric-drive version requires only electrical power from a remote-mounted control panel that, by means of frequency changes, controls both the speed and braking of the basket rotation. Electric motors are larger and heavier than hydraulic motors, and therefore are side-mounted. The electric motor is cooled by an integral fan or a separately driven fan. This arrangement requires an adequately large ventilated area that is clean and free of obstructions.

Drive-power transmission: The power from the hydraulic or electric motor is transmitted to the basket spindle and bearing assembly by sheaves and V-belts. Important in this regard are the sheave alignment and the belt tension. Belts too loose will lead to unintended rates of acceleration and deceleration; they are noisy; the belt life is shortened. Conversely, tightening the belts excessively will shorten both the belt life and the bearing life.

Above the bearing spindle sheave is the speed pickup. Proper alignment of the pickup head with the spindle-mounted disc or gear is necessary to ensure correct speed.

Spindle and bearings: The spindle and bearings constitute the center from which, at a fixed radial distance, the basket and its load revolve. Typically, the bearing housing consists of the upper and lower bearings which are shrink fit onto the spindle and sealed from the environment by O-rings and oil seals.

These greased bearings are typically designed with an L10 life of 30,000 h (that is, one can expect that after 30,000 h, 90% of the bearings will still be running, the other 10% having failed). At the author's employer, each spindle and bearing housing assembly must successfully pass a 4-h test run with temperature and vibration monitoring before being considered ready for installation into the centrifuge.

Access to the spindle and bearing-assembly is through the curb top (the curb is the case of the centrifuge, and its top is the cover, which is usually fully opening in today's centrifuges). With the curb top in the full open and secured position, the spindle flange cover and nut can be removed, followed by removal of cap screws and flat washers. Two lifting eyes can then be threaded into the tapped hole in the basket hub; finally, a suitable chain hoist can lift the assembly off the tapered spindle and out of the machine.

Because the spindle and bearing are of maximum importance to the operation and longevity of the centrifuge, only qualified personnel or shops should attempt to rebuild the spindle and bearing housing assembly.

Centrifuge support: Centrifuges are typically supported by a system of three link-and-buffer assemblies. The rubber buffers restrict and dampen the vertical and horizontal motion. The amount of dampening imposed is controlled by the compression of the buffers of the retaining plate.

In addition, the use of a ball-and-socket design can allow the machine to find its own center of balance under uneven basket loads. In such a system, the spherical faces of the ball joints are grease-lubricated to allow for free movement of the centrifuge under unbalanced or process-condition upsets. Normally, only occasional relubrication of these joints is necessary.

Adverse basket gyration or imbalance can be controlled by a side-mounted, analog vibration monitor and a gyration-unbalance switch. If gyration of the basket curb exceeds 3/4 in., the switch can close the feed valve or disconnect the power to the main driver, or both.

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SCREENING TESTS FOR BATCH CENTRIFUGE APPLICATION

Before selecting or specifying a centrifuge, it is beneficial to run preliminary screening tests with the feed slurry, to assess its settling behavior and to determine whether the use of a filtering (perforate bowl) centrifuge is feasible. If not, the alternative may be either a sedimentary (imperforate, solid-bowl) centrifuge or a separation method other than centrifugation.

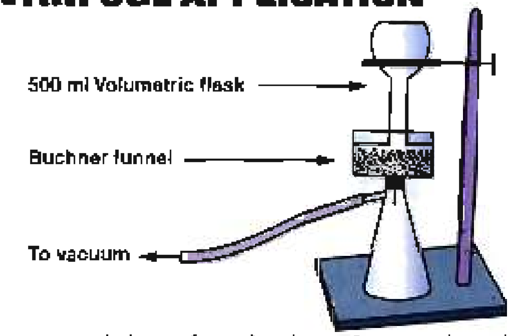
A. Preliminary settling test:

1. Vigorously agitate a 750-ml sample of the slurry in a beaker to ensure good particle distribution
2. Let the beaker stand on the bench for about 30 min. During this period, observe the following:
   a. The rate at which liquid clears as the solids settle
   b. The degree of clarity of the mother liquor above the solids

If the solid material does settle and the mother liquor does clear up, proceed with two further tests. The first one assesses the applicability of a filtering (perforated-bowl) centrifuge; the second does the same with respect to a sedimentary (imperforate bowl) version

B. Buchner funnel test (screening for perforated-bowl application):

1. Insert into a 4-in. Buchner funnel an all-purpose filter disc with a medium to fast drain rate. Then insert the funnel in a vacuum flask (diagram)
2. Put enough feed solids into the funnel chamber to furnish 1.5 to 2.0 in. of filter cake
3. Hook up the Buchner funnel to the laboratory vacuum system.
4. Take a known quantity of mother liquor and invert it over the surface of the cake in the funnel
5. Record the time it takes for all the mother liquor to drain through the cake and into the vacuum flask. If the drain proves to be 0.5 gal/min or greater per square foot of filter area, and if no liquid pool of significant depth remains on the cake after filtration, then



further testing with the perforate bowl centrifuge is indicated.

If the drain rate is instead less than 0.5 (gal/min)/ft^2, the indication is that the slurry solids are more or less amorphous (non-crystalline) or very fine. Such solids do not generally have interfaces between which liquids can migrate easily and drain well; rather, they blind off any available liquid passages. Solids of this type might better be handled in an imperforate- (solid-) bowl centrifuge; further testing as described below is recommended.

C. Settling test to screen for an imperforate-bowl application

1. Place two 15-ml samples of the slurry in a benchtop imperforate-bowl (test tube) centrifuge
2. Spin for 30 s and observe the solids layer and liquid layer.
3. Spin the material for an additional 60 s

If, at the end of the first 30 s of spinning, there is a definite solid phase, and liquid phase of good clarity, there is a good chance that the material will separate in an imperforate bowl centrifuge.

If, instead, the clarity of the liquid phase is not good even after 90 s, more G-forces are needed to effect a separation. Because most basket centrifuges are limited to 1,300 G, a horizontal-bowl decanter centrifuge should be considered, because that type can produce up to 3,500 G ❏

It is a good idea to take an initial footprint on each new, clean machine upon its installation, and to record that footprint as a benchmark for future readings. Doing so provides an excellent base point from which to track bearing failure and process problems.

The discharger: The discharger is the means of removing the solids from the basket wall. It can be a pneumatically or hydraulically actuated cylinder. It rotates on a lower sleeve bearing and two bronze rings that are sealed at top and bottom to prevent damaging vapors from entering the housing.

If the discharger were out of adjustment, uneven cake removal and imbalance in the next cycle could result. To forestall this possibility, the position of the discharger is indicated by two limit or proximity switches. If the discharger is not in the park or rest position and the basket speed is not between 60 to 80 rpm, the discharger solenoid valves (DSVs) will not energize.

Once the limit switches and speed requirements are met, the pneumatic or hydraulic cylinder begins to extend, rotating its cutting tip toward the cake. The relative speed of the discharger with respect to the basket is typically controlled by a field-adjustable, hydraulic checking cylinder.

This same checking cylinder can be set up to give two-speed operation, as well as freezing of the plow position. While the cylinder controls the plow speed, there are two mechanical stops that limit the total plow travel. The inward stop is adjustable for final cake-heel thickness, normally 1/2 to 1 in. It is a good idea to readjust this inward travel stop after the installation of a new filter medium, to avoid plowing it out on the first cut.

In this same vein, remember that improperly installed media can cause poor filtration, product breakthrough and uneven cake distribution, leading to unbalanced loads. Indeed, improperly installed filter media represent the major cause of centrifuge breakdown.

With a heel-removal system, 100% of the product is recovered from the basket. There are two heel-removal options:

- A blowback system can be added to the curb, whereby jets direct a spray of gas or liquid through the perforated basket to assist in the removal of residual cake
- An "air knife" system can be built directly onto the discharge plow of the centrifuge

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Engineering Practice

Year-round attention

The following schedule is offered as a guide for routine maintenance. It may be varied to suit local conditions and the service required of the centrifuge.

Daily:

1. Inspect for cleanliness
2. Visually inspect all oil lines and exposed shaft seals for leakage
3. Check oil level in lube oil reservoir and in air line lubricator
4. Check cooling water flow in lube oil cooler
5. Check air flow in bearing air-purge line if applicable

Weekly:

1. Check inside belt tunnel for oil leaks and belt condition
2. Check lube-oil pressure readings during a normal centrifuge cycle
3. Check orientation of loading pipe with respect to basket
4. Check orientation of wash pipe with respect to basket

Quarterly:

1. Remove pedestal covers and visually inspect links
2. Inspect lube-oil hoses for chafing or other mechanical damage
3. Lubricate the pump drive motors

Annually:

1. Remove curb top and all accessories
2. Remove and inspect baskets
3. Inspect interior of curb for corrosion or mechanical damage
4. Inspect belts and bottom bearing seal
5. Inspect top seal
6. Inspect bearings
7. Disassemble pedestal assemblies; inspect and lubricate. And during reassembly, apply an anti-seizing and lubricating compound to each end of the link where the link ball fits

Strict adherence to a schedule such as this should go a long way toward keeping a batch filtering centrifuge in reliable operation. ■

Edited by Nicholas P. Chopey

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