The development of centrifugal separation technology for tailings

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ABSTRACT

The recent Energy Resources Conservation Board (ERCB) directive states new industry-wide criteria for managing oil sands tailings and specific enforcement actions if tailings performance targets are not met. The directive applies to all existing and future oil sands operators. The consequence of this is that environmental demands balanced with production growth and efficiency are more critical to project viability than ever before.

Either as an independent solution or in combination with more traditional techniques, such as Consolidated Tailings (CT), Decanter Centrifuges for the accelerated dewatering of fine tailings is seen by many as a leading solution to this issue. Decanter centrifuges have been used in oil sands treatment for over 30 years, but the application of this technology to tailings treatment has needed certain developments to accommodate the requirements of this new duty.

This presentation describes the decanter centrifuge basic principles and combines the experiences gained from comparable duties to form a new generation of centrifuge. With reference to full scale test-work carried out in 2008, the presentation will review a working solution and describe the changes necessary to meet the recent market demand.

1 CENTRIFUGE TECHNOLOGY

Centrifuges have developed from 10s of liters per hour at 100s of rpm in the late 19th century to what we have today. 300 m3/h at up to 8000 rpm and numerous applications including the separation of cream from milk, purifying beer and wine, cell separation in the biotech industry and the purification of bitumen in oil sand.

Figure 1. Decanter centrifuge

For separation applications with comparatively high solids loading the decanter centrifuge is the most suitable. Decanter centrifuges were originally developed for industrial applications in the late 1940s. Its design is based on a horizontally driven bowl to induce accelerated sedimentation. This combined with a conveyor, running with a speed differential to the bowl, transports separated solids up a conical beach and discharges solids in the form of a dry cake. The clarified liquid phase is discharged at the opposite end of the centrifuge over weir plates.

2 BASIC PRINCIPLES

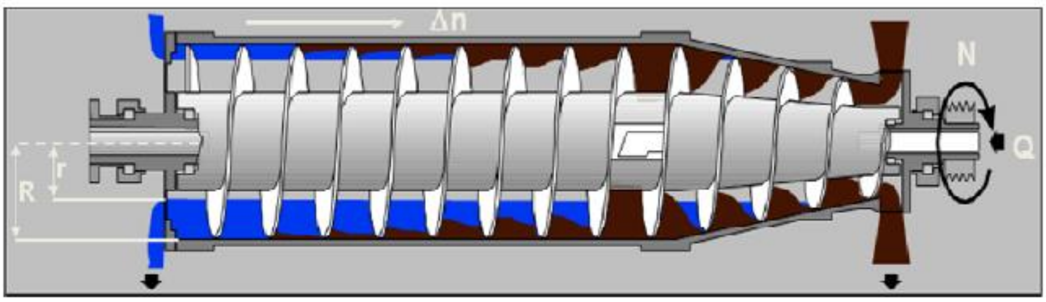

Figure 2. Decanter cross-section

Process Parameters

- Feed rate (Q)
- Particle size (polymer addition)
- Viscosity (heating)

Decanter design

- Bowl speed (g-force)
- Conveyor differential (_n)
- Pond depth (R-r)

Process parameters such as feed rate, particle size and viscosity, together centrifuge configuration, for example bowl speed, conveyor to bowl differential speed, liquid pond depth and cone beach angle will directly affect separation performance and solids removal.

3 TECHNOLOGY DEVELOPMENT

Sigma factor (developed in 1948). Used in the very early days of decanter development, where sedimentation was the only factor been considered and any practical information from various applications was very limited.

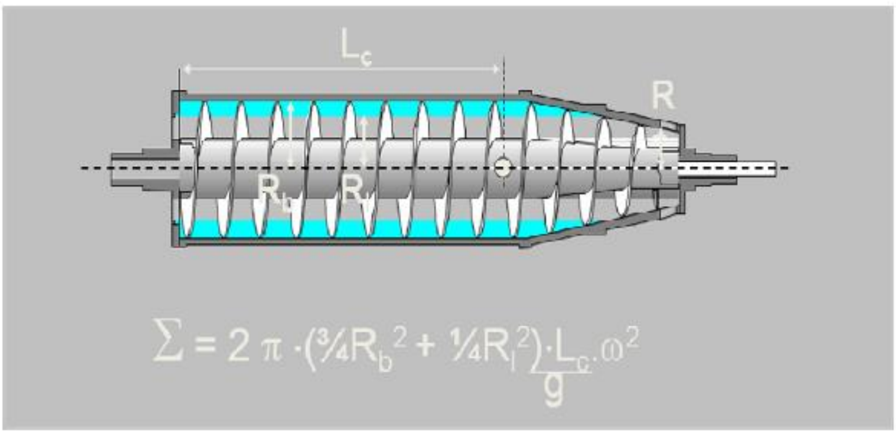

Figure 3. Sigma factor & centrifuge performance

Despite limitations of this formula it has still been used for a large number of old designs. Some of these decanter centrifuges have been upgraded, but they still have a very large radius to the liquid surface. As it is noted, the formula states that this should give a high capacity. In reality, a larger radius to the liquid surface will reduce the capacity of a decanter! In the late 1980s a number of studies revealed the limitations of the Sigma factor and in general it was realized that the solids handling capacity was the real limiting factor for most decanter applications. Since then the main focus for decanter development has been to improve solids handling capacity. In this context, solids handling capacity means two things: the capability to achieve high cake dryness and to discharge large volumes of cake at the same time. For example Alfa Laval, a leading supplier of decanter centrifuges, switched focus to solids handling ability as a general guide to equipment design. The result was a clear increase in solids handling ability in a variety of processes, from drilling mud treatment to fish and meat dewatering.

Again, using the Alfa Laval products as an example, a couple of important designs demonstrate the development since then. The LYNX 40 decanter normally runs on drilling mud where the main goal is to discharge as much solids as possible and dryness is less important. The solids in drilling mud are relatively large and dense, so residence time is not so critical and it is therefore run with a high differential speed. The shallow cone angle of 6 degrees allows the solids to travel up the beach more easily for high solids removal. General belief would suggest designing such a decanter with a large radius to the solids discharge ports, but instead the LYNX 40 has the same radius to the solids discharge ports as a deep pond decanter and the deeper pond is used to increase the scrolling capacity of this unit. All internal solids passages are designed for high solids handling capacity and the small solids discharge radius has not limited the capacity.

In mature fine tailings, MFT the demand is to achieve a dry cake and still operate at a high solids load (tonne/h). In order to capture the fine particles in MFT we need to add polymer. This will give solids with a cake like behavior and this will not readily allow liquid to drain off. In order to get a dry cake it will be necessary to operate with a deep layer of solids and with low differential speed. This way of operating a decanter is very similar to the way decanters for dewatering of municipal sludge is operated. Sludge dewatering also involves flocculated suspensions and here Alfa Laval introduced a new design in 2003 under the name "G2", generation 2. The scrolling efficiency of the G2 range is so high that most decanters of this type are designed with a 20 degree cone angle without any negative effect on solids handling capacity.

To design a suitable machine for MFT involves a lot of detailed knowledge about cone angles, flight pitch variation and inclination, pond depth, G-level and differential speed coupled with the conveyability of the solids as a function of dryness. The optimized decanter design is based on experience gained in testing the LYNX 40 on MFT in 2008.

Controlled levels of shear are needed for effective distribution of the polymer in the feed to the decanter. Low shear in the decanter gives the driest cake and highest quality centrate. High cake discharge radius result in a limited possibility for deeper pond depths and separation performance. A large liquid surface radius will automatically introduce a high shear in the decanter feed zone and the lower pond depth will limit the solids handling capability, particularly with flocculated solids. Incidentally, the larger discharge radii on both solids and centrate discharge areas will also cause high shear and hence high wear in those areas. It is therefore predictable that discharging both solids and liquids at smaller radii will reduce discharge velocities, limit wear in those areas and reduce power draw as a result.

4 HANDLING WEAR EFFECTIVELY

The nature of a separation process with high solids loading and centrifugation will promote the possibility of increased wear. In the design of the decanter there is a trade-off between component life and the use of higher cost, wear resistant materials to limit wear. The choice of materials must meet acceptable component life and cost of ownership for the centrifuge.

Using material inserts in the known wear locations help to meet market expectation. An example of this is the use of tungsten carbide wear liners in the decanter feed zone. The benefits of this are to limit material change only to the affected area and to keep the time necessary for repair to a minimum.

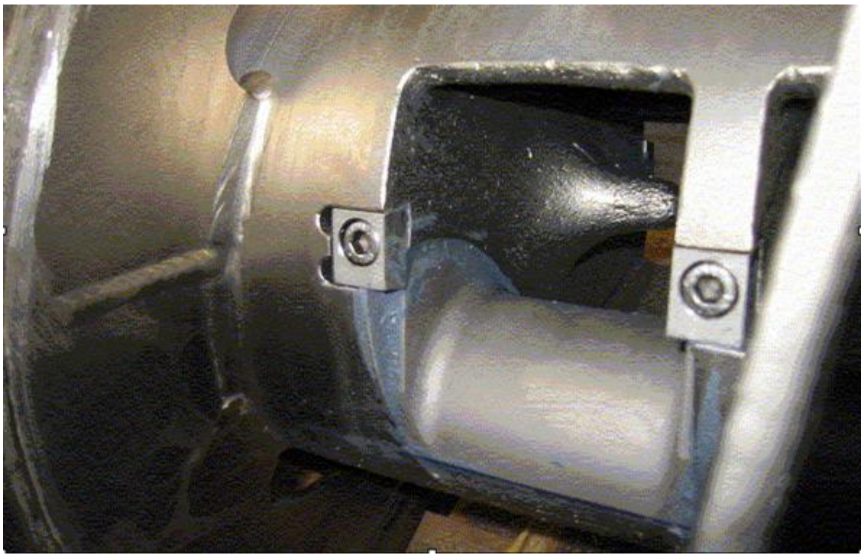

Figure 4. Erosion protection with inserts in the decanter feed zone

Wear due to the differential speed between the decanter conveyor and bowl can be effectively handled with the simple inclusion of ribs, welded to the bowl of the decanter centrifuge.

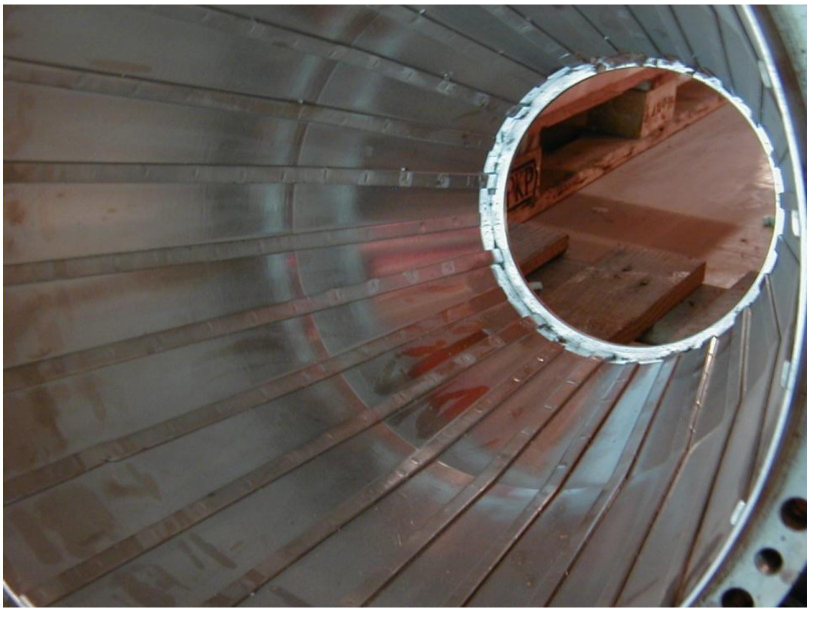

Figure 5. Ribs in the centrifuge bowl

Solids naturally collect between the ribs providing a layer of protection. The positive effects of this design are increased wear protection of the bowl and conveyor, and improved solids transportation. For added protection of the conveyor, tungsten carbide tiles are attached to the conveyor flights.

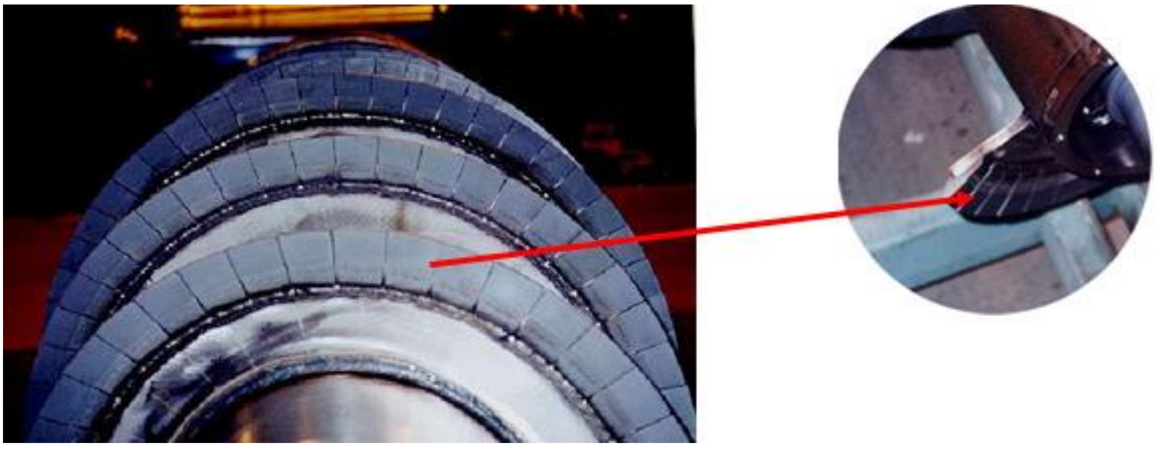

Figure 6. Tiles protect the conveyor flights

5 CENTRIFUGE CONTROL

With a fixed differential speed decanter a reduction in the solids loading in the feed to the centrifuge will cause a reduction in cake dryness. With tailings treatment the centrifuge will typically be solids limited, so an increase in solids loading in the feed to the centrifuge will increase the risk of over-torque on the unit.

Monitoring the torque between the bowl and conveyor and automatically varying their differential speed make it possible to maintain the optimal performance of the centrifuge and consistent cake dryness. Variable differential speed control will also protect the centrifuge against the possibility of overtorque.

6 PROCESS VISION

Step 1 in the process is for MFT dewatering using flocculent addition and centrifugal separation to form two streams. The ultimate aim is for the centrate to be recycled as process water and help reduce the need for fresh water.

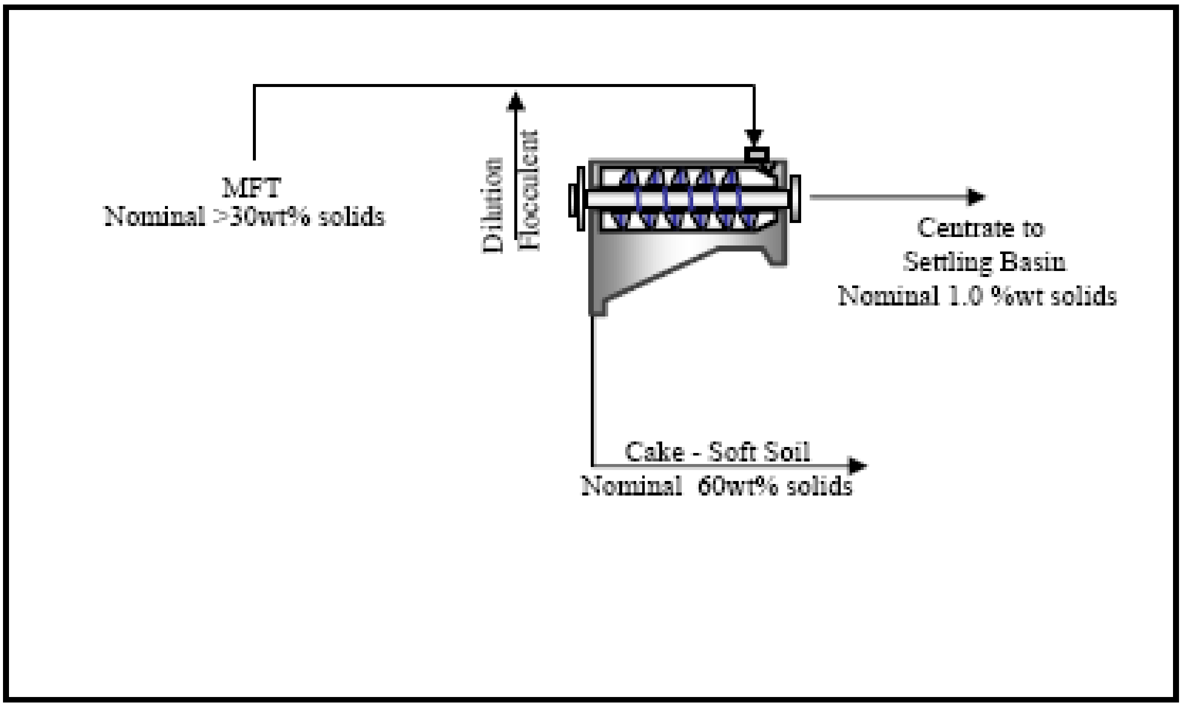

Figure 7. The decanter in the process

Step 2 is the subsequent dewatering of the cake by natural processes, with the final goal of land reclamation.

7 ACHIEVABLE PERFORMANCE

Decanter centrate quality <0.5% wt solids

Produced decanter cake with 60% wt solids dryness

Polymer dosage 600 g/dry tonne achievable

Scaling from the test indicate that 54 dry tonnes/hour, 270 m3/h wet feed can be treated by a single centrifuge. For the scale of intended projects multiple centrifuges will be needed.

8 CONCLUSIONS

Decanter centrifuges are a well-established, heavy duty technology and initial tests have achieved positive results showing that this technology can contribute to the viable dewatering of MFT. There is however no ‘silver bullet’. The treatment of MFT will require a major investment for both initial accelerated dewatering and distribution of produced dry cake for final drying and land reclamation.