Dewatering Tailings:
Rapid Water Recovery by Means of Centrifuges

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At present, most tailings are dewatered by static settling in tailing dams. The environmental impact of these large settlings ponds is dramatic, not to mention the space requirements and the potential risk of dam failure. This method of disposal also results in the loss of process water due to evaporation. This can be significant in areas where fresh water is in short supply. The high centrifugal force in a decanter centrifuge drastically increases the dewatering efficiency, as one would expect when comparing static settling at 1 x g with centrifugal separation at up to 3000 x g. The continuously discharged solids do not contain any free liquid and can be easily transported to a dump site to be deposited. The recovered water can be reused in the process of the mineral processing operation and will increase the water efficiency of the entire mining community. This paper gives a review of current practices for tailings dewatering and provides an example of the application of Flottweg decanter centrifuges for such an application.

INTRODUCTION

Mine tailings are the ore waste of mines, and are typically a mud-like material. Worldwide, the storage and handling of tailings is a major environmental issue. Many tailings are toxic and must be kept perpetually isolated from the environment. Scale of tailings production is immense, since metal extraction is usually only ounces or pounds for every ton of ore. Tailings containment facilities are regarded as the world's largest man-made objects.

TERMINOLOGY

When metal is mined, the rock is separated into three categories, as illustrated in Figure 1. The first to be excavated is overburden, which includes plants, topsoil and rocks that are inert and unrelated to the mined deposit. The target rock is then divided into ore and waste rock. Both may have similar mineralogy, but only the ore has enough valuable metal in it to be worth processing. The ore is then milled, usually on-site, to separate the metallic minerals (e.g., metal sulfides) from lower value minerals like silicates and iron sulfide (pyrite). The resulting concentrate is ready for refining and has high enough value per mass that it's worth shipping long distances to a refinery. What remains after processing is called "tailings".

Tailings are disposed of in special impoundments meant to prevent pollution from escaping, and often waste rock must be dumped here as well to prevent it from releasing acid and metals into the water. Overburden is usually safe to be used as fill.

Mine tailings size and composition depends on the mining method. For hard rock metal mines, tailings are usually a very fine mud or powder, which is left over after ore is crushed and valuable minerals are extracted from it. Tailings may also contain chemicals used for mineral extraction.

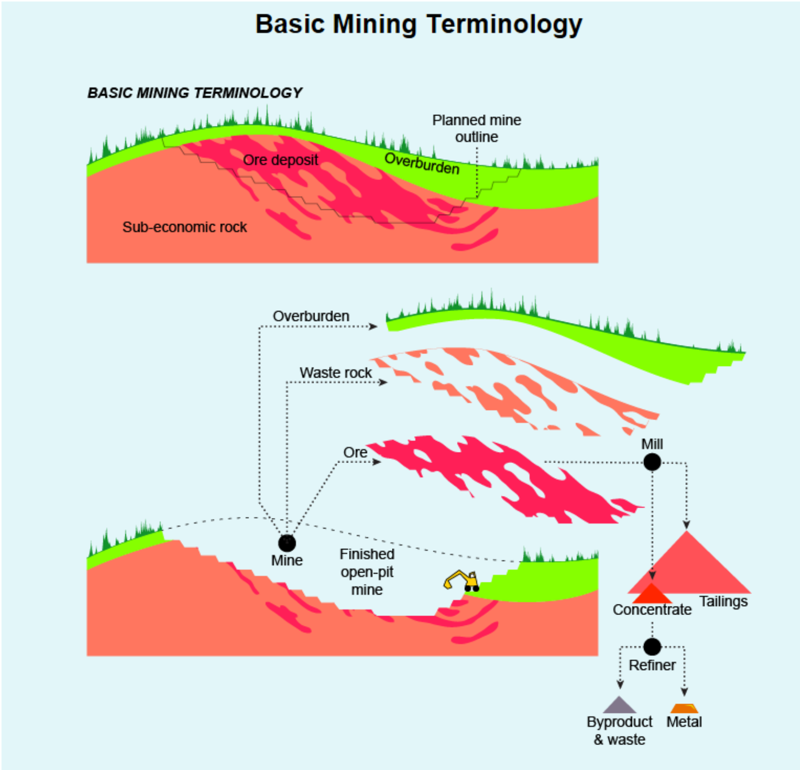


Figure 1. Basic mining terminology. (Source: www.idc-online.com.)

Oil sands production also produces tailings, which are substantially different. Oil sands tailings are the residue which remains after bitumen is separated from virgin oil sands. Although this article focuses on hard rock tailings, oil sands tailings can contain a similarly complex and toxic brew of minerals and chemicals, and pose a similar handling and storage challenge.

DISPOSAL

Disposal of mine tailings is usually the single biggest environmental concern facing a hard rock metal mine, and creates very long-term environmental liabilities which future generations must manage. Many mine tailings do not become appreciably safer over time, if stored properly, and therefore must be stored for an indefinite period using current technology.

The historically used alternative to storage was to dispose of tailings in the most convenient way possible (such as river dumping), which led to widespread environmental contamination in mining areas. This was nominally viable in earlier eras, but human production of mine tailings has increased by several orders of magnitude in the modern age, making such methods unacceptable to many societies.

Hazardous Properties

Toxic chemicals used to extract the valuable materials from the ore, used in gold mining, remain in the tailings at the end of the process, and may leach out into ground water. Rock may naturally contain dangerous chemicals, such as arsenic and mercury, which leach into water much more readily after rock has been ground up and exposed to the wind and the rain.

Acid mine drainage is the most frequent and widespread problem. Many hard rock mines (including most gold mines) extract minerals that are bound up with sulfide compounds. These compounds produce sulfuric acid on contact with air and water, a process that occurs at a very low rate in undisturbed rock, at a higher rate in unprotected waste rock (which has a large surface area and is now exposed to air) and a much higher rate in unprotected mine tailings which have a massive surface area. The result can be the production of very acidic water, which additionally leaches metals and other chemicals from the surrounding rock.

Wet Storage in Pits and Lakes

Most modern hard rock metal mines dispose of tailings as a wet mud, held in pits lined with clay or a synthetic liner. Many mines put the tailings back into the original mining pit. Some large mines use entire existing valleys sealed off with earthen dams, and others store tailings in natural lakes. In most cases, disposal pits are covered with water, forming an artificial lake which reduces the rate of acid formation.

Wet storage often requires long-term oversight, to monitor and attempt to mitigate contaminated groundwater movement, and to maintain any crucial facilities, such as dams. Many wet storage facilities require perpetual water treatment.

On-Land Storage ("Dry-Stack")

In "dry-stack" disposal, tailings are stored in dry form, typically by burial in a covered and lined pit. In this regard, dry-stack storage is more similar to a modern, sealed landfill. This method takes up much less space, is less susceptible to earthquake hazards, and does not require active water treatment. This makes it particularly relevant in locations where precipitation, earthquake risks are high, or space is limited.

However, dry-stack disposal has much higher up-front costs than wet storage. Dry-stack tailings must be dried, and the solid tailings must be transported by truck or conveyor instead of by slurry pipeline, which adds logistical complexity and cost.

Pit covers for dry-stack storage, like the damns around artificial lake impoundments, must be maintained in perpetuity. However, the long-term maintenance is much less than it is for large, wet tailings impoundment with dams. In some cases, where the material dewaters well, the tailings can be stored in stable deposits requiring no retention bunding, as is the case at La Coipa in Chile (Figure 2).

Figure 2. The "dry stack" tailings facility at La Coipa, Chile.
(Source: http://www.cbc.ca/kamloops/mt/2014/08/28/dry-tailings-stack-versus-wet-tailings-pond.)

DEWATERING OF TAILINGS

Tailings do not have to be stored in ponds or sent as slurries into oceans, rivers or streams. There is a growing use of the practice of dewatering tailings using vacuum or pressure filters so the tailings can then be stacked.(Davies & Rice, 2001). This saves water which potentially reduces the impacts on the environment in terms of a reduction in the potential seepage rates, space used, leaves the tailings in a dense and stable arrangement and eliminates the long-term liability that ponds leave after mining is finished. However although there are potential merits to dry-stacked tailings, these systems are often cost-prohibitive due to increased capital cost to purchase and install the filter systems and the increase in operating costs (generally associated electricity consumption and consumables such as filter cloth) of such systems.

Alternative Technology to Dewater Tailings

In a tailings dam, the solids are settled by sedimentation, so the force on the sediments is the natural earth gravity. There are several technologies available to speed up the dewatering.

Belt Filter Press

The coagulant-treated, low concentration sludge is loaded into a hopper at the top and distributed onto a moving, porous belt, as illustrated in Figures 3 and 4. The sludge is squeezed through a series of progressively tighter rollers to expel water. The thickened sludge "cake" is collected in another hopper, while the water is generally drained.

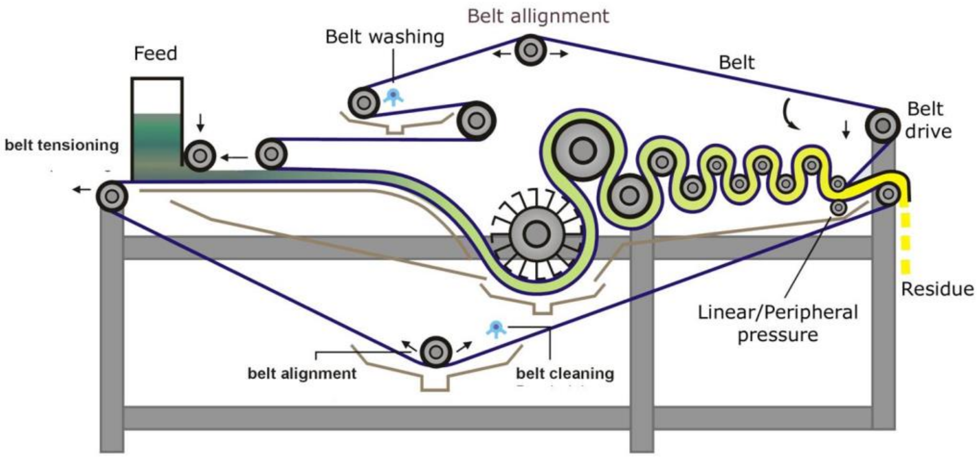


Figure 3. Operation of belt filters press. (Source: Flottweg SE.)

Figure 4. Belt filter press. (Source: Flottweg SE.)

Chamber Filter Press

Chamber filter presses are made up of polypropylene squares with a concave depression and a hole in the centre. Two plates join together to form a chamber to pressurize the slurry and squeeze the filtrate out through the filter cloth lining in the chamber. The mechanism is illustrated in Figure 5.

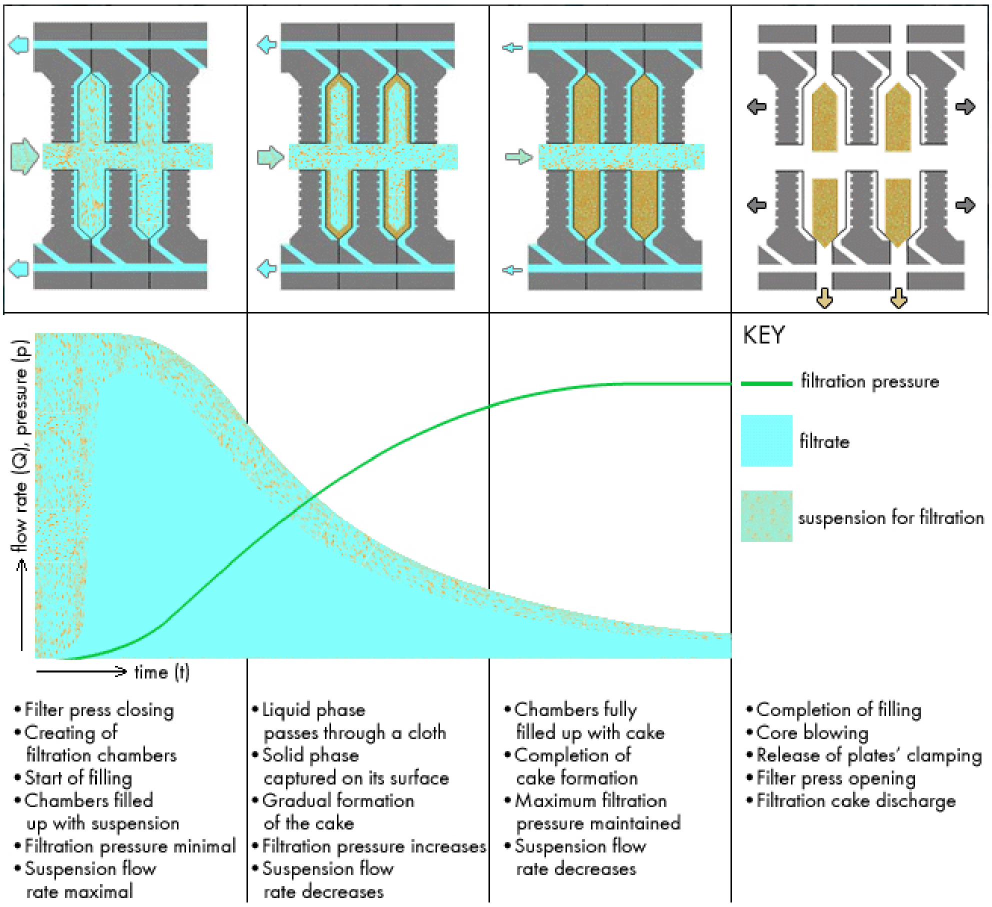


Figure 5. Operation of chamber filter press used for dewatering sludge. (From Internet, www.envites.cz.)

As the filter cake becomes thicker, the filter resistance increases as well. When the separating chamber is full, the filtration process is stopped as the optimum pressure difference is reached. The filtrate that passes through filter cloth is collected through collection pipes. The plates of the filter press are then pulled apart and the cake which accumulated in the hollow frame falls out, to be discharged to the final collection point. Cake discharge can be done in many ways: for example, by shaking the plates while they are being opened or shaking the cloths. Scrapers can also be used, by moving from one chamber to another and scraping the cake off the cloth. The cloth needs to be cleaned regularly using wash liquid. Figure 7 provides an example of a filter press being applied to tailings dewatering.

While the use of filter presses for tailings dewatering was mentioned as early as 1903, it is only in the 1980s that this was put into large-scale commercial practice. By 2011, filter presses had actually become more common than thickened tailings operations (Murphy & Caldwell, 2012). Figure 6 shows a tailing filter press used in a gold mine.

Figure 6. Chamber filter press.
(Photograph taken by Robert Klug, Flottweg SE, at La Sopresa Minera Mine, Mexico.)

Centrifuges
Mechanical separation technology by centrifuge was developed around 100 years ago. This is a modern technology that allows a continuous processing of sludge. In a centrifuge, the solids are affected by centrifugal force. Centrifugal force is linked to two parameters: distance to the rotating axis and the speed of rotation. Today, centrifugal forces of 3000 times earth gravity (g) are typical to dewater all kind of sludges.

In a centrifuge, the sludge is continuously pumped into the feed pipe and enters through the feed chamber into the fast rotating rotor. Figure 7 shows a sectional view of the inside of a decanter centrifuge.

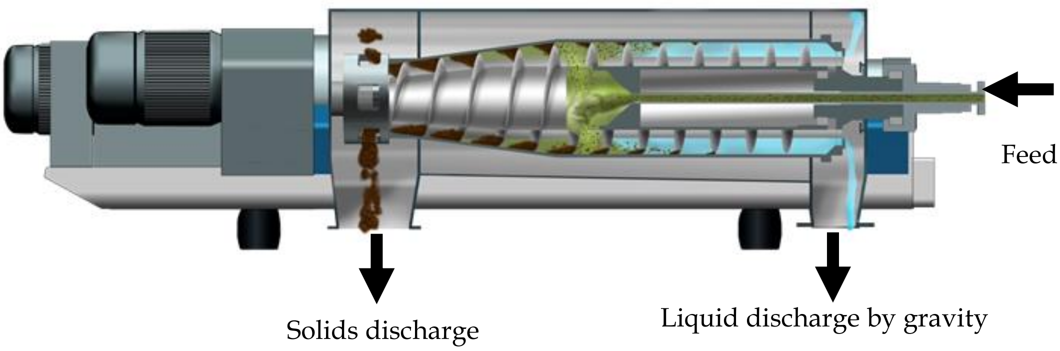


Figure 7. Cut-away of solid bowl centrifuge. (Source: Flottweg SE.)

The centrifugal force causes the sludge to form a ring inside of the rotor. As the density of the solids is higher than the liquid density, the solids will settle on the inside wall of the rotor. To remove the settled solids, a scroll rotates inside the rotor, with a differential speed towards the rotor, and picks up the accumulated solids.

The bowl is tapered toward the solids discharge of the centrifuge so, at a certain point, the solids will leave the liquid zone and will pass the "beach area" into the dry area. Here, the solids dewater further until they are discharged through ports via centrifugal force. As the discharge diameter is smaller than the diameter of the liquid discharge, the liquid (centrate) can only exit the rotor on the liquid-discharge side. By adjusting the weir plates, the pond depths and the dry area can be adjusted. The following effects result from the adjustment of the weir plate:

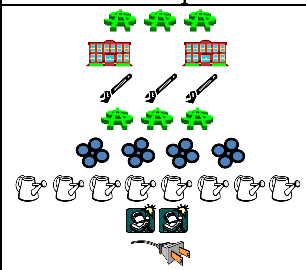
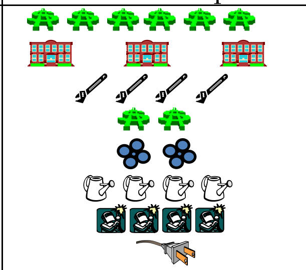
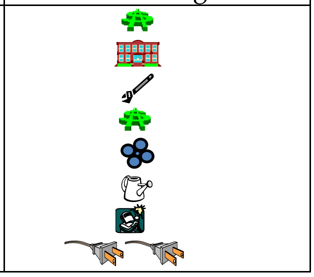
- Setting the weir plates to a larger diameter;
- Decrease of pond depths;
- Less retention time for the sludge;
- Less time for clarification;
- Liquid discharge (centrate) may be dirty;
- Increased drying distance;
- Dryer solids discharge.

Decreasing the diameter of the weir plates has the opposite effects.

THE EFFECT OF USING CENTRIFUGES

The use of centrifuges for dewatering of tailings has several advantages over other dewatering technologies, such as belt filter presses or chamber filter presses, as illustrated in Table I.

Table I. Comparison of several dewatering technologies based on long-term business experience.

	Belt filter press	Chamber filter press	Centrifuge
Installation Space Maintenance Solids disposal Ventilation Water Labour Power			

Space Requirements

Figure 8 shows the extent to which the typical space requirements for the installation of mechanical separation technologies differ.

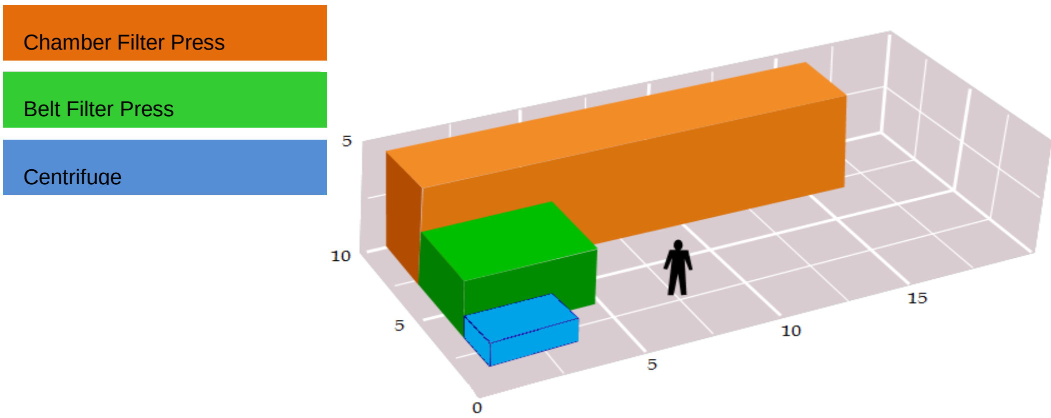


Figure 8. Space requirements (in m) of separation equipment with a hydraulic capacity of 40 m³/h and solid load of 000 kg dry matter/h, based on business experience. (Robert Klug, Flottweg SE.)

Dewatering Results

The dewatering capacity of a centrifuge and a chamber filter press are almost identical. A centrifuge will usually capture all particles above 5 µm in size. The use of a suitable flocculant is necessary to capture the ultra-fine parts if clean centrate is required. Figure 9 shows typical dry solids percentage which one could expect from the solids discharge in a mineral sand-type application. The actual residual moisture achievable for any particular application is dependent on the particle size distribution of the solids. The finer the particle size range, the more moisture will be entrained. Typically the solids discharged would have a crumbly consistency, without free moisture, as shown in Figure 10

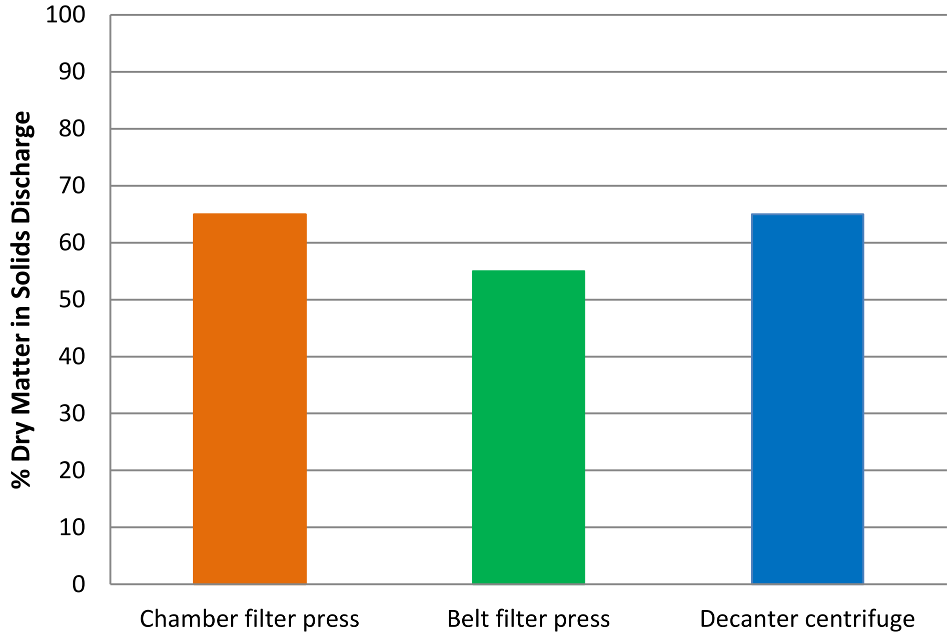


Figure 9. Comparison of residual moisture contents achievable on mineral residues with different dewatering technologies (typical industry average in the mining business). (Robert Klug, Flottweg SE.)

Figure 10. Continuous discharge of solids after centrifugation.
(Photograph taken by Robert Klug, Flottweg SE, at Sibelco sand pit mine, Italy.)

Separation Efficiency
Figures 11 and 12 illustrate the drastic volume reduction of the tailing sludge which is achievable with a centrifuge. One specific advantage a decanter centrifuge has over filters is that there is no filter cloth which can become blinded with fine particles. This means that the flow rate through a centrifuge will remain constant.

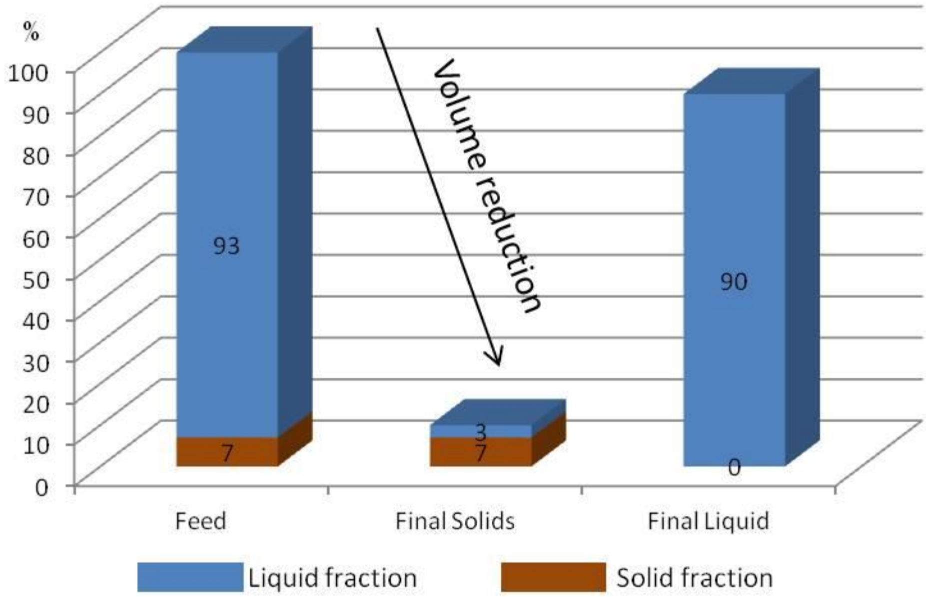


Figure 11. Typical volume reduction of solids containing fraction. (Robert Klug, Flottweg SE.)

Figure 12. Photographs of feed, solid discharge and centrate from centrifuge.
(Photographs taken by Robert Klug, Flottweg SE, at Sibelco sand pit mine, Italy.)

Wear Protection
To withstand the abrasion by the minerals on the contact surfaces, special kinds of wear protection surfaces have been developed. The areas which are subject to abrasion in a decanter centrifuge are highlighted in Figure 13. The wear protection bushings are made of hard cast iron or silicon carbide and the hard facing of the scroll flights is made of tungsten carbide, hard metal or silicon carbide tiles. The solid discharge is protected by an exchangeable sheet metal covered with a layer of tungsten carbide.

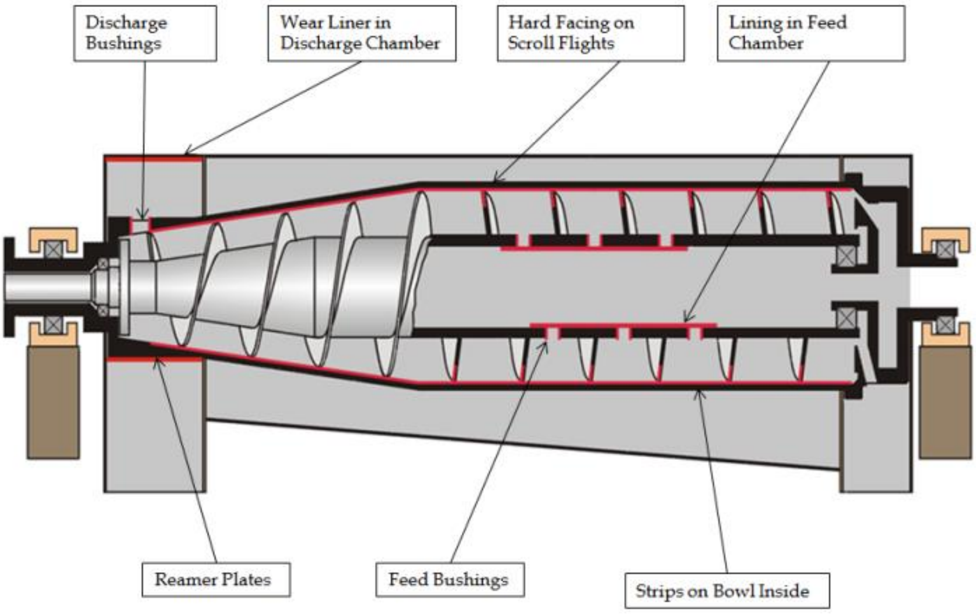


Figure 13. Wear protection in a decanter centrifuge. (From Internet [http://www.flottweg.com].)

To protect the rotor from the abrasive material, strips are welded to the inside of the bowl, as shown in Figure 14, to make use of the solids depositing inside the bowl. The first solids settling inside the bowl form a solid layer on the circumference of the rotor (brown layer in the middle image of Figure 14), so the passing scroll flights will just scrape off the excess solids build up, without touching any metal of the rotor. To prevent the solids layer from rotating or sliding inside the rotor, there are longitudinal stainless steel strips welded to the inside of the cylindrical and conical part of the rotor. Since the differential speed between scroll and rotor is very small, the wear is minimized.

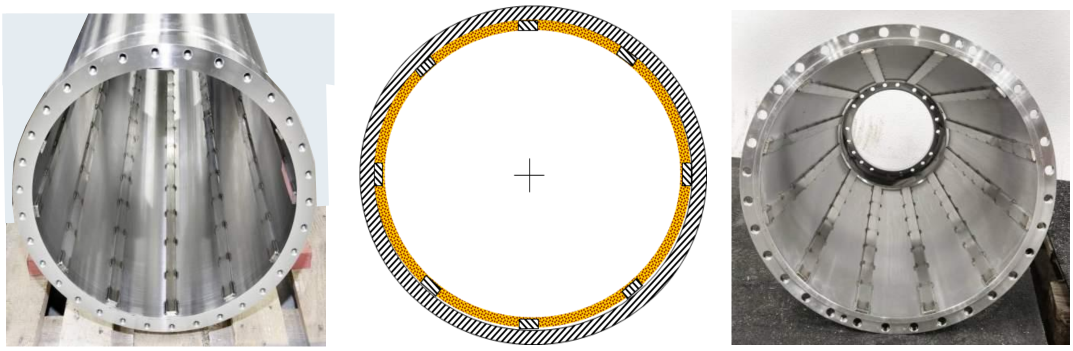


Figure 14. Flottweg wear protection inside the rotor.
(Photographs taken at Flottweg SE and drawing by Robert Klug, Flottweg SE.)

The hard facing of the scroll flights and the feed and discharge bushing are the parts which have the most contact with the abrasive material. A decanter centrifuge operation at a sand pit in Germany did not show any signs of wear on these wear surfaces after as much as 16 000 h of operation.

Maintenance

All the items on the centrifuge are designed for non-stop operation. Running times of 8000 h/year are not uncommon, as mining and processing operations are continuous. The entire centrifuge operation is automated and no operator interaction is required during regular operation. Maintenance requirements are limited, except for checking the V-belts and greasing of the bearings, no additional work is necessary. As a safety regulation, it is mandatory to change the main bearings regularly (suggested every two years) to prevent failure.

APPLICATION EXAMPLE

The Tiebaghi Nickel Mine in New Caledonia is located in a mountainous region where there is a general shortage of water. This shortage, as well as consideration of the fragile ecosystem, led Eramet to focus on the usage and disposal of water at the site. While Tiebaghi uses 650 000 m^3 of fresh water per annum for its operation, Eramet's efforts have resulted in 98% of the process water being recycled within the process. A significant factor in this success is the use of centrifuges for the dewatering of tailings.

In 2006, Flottweg was contacted by the engineering office Technip in France to find a solution for the tailings dewatering at Tiebaghi. Flottweg installed eight Z92-4 decanter centrifuges, shown in Figures 15 and 16, to handle a design flow rate of 1040 m^3/h of tailings slurry, containing an average of 10% solids. This means that in excess of 9 000 000 m^3 of process water can be directly recycled. By eliminating the need for tailings dams, not only was the environmental impact reduced, but huge evaporative losses of water were prevented. Operating parameters for the centrifuges are as shown in Table II.

Figure 15. Centrifuge installation at Tiebaghi Nickel Mine in New Caledonia.
(Photographs taken at Tiebaghi Nickel Mine, New Caledonia by Erwin Thalhammer, Flottweg SE.)

Table II. Design operating parameters for centrifuges at Tiebaghi Nickel Mine.

Feed flow rate	up to 130 m^3/h
Solids loading	8 to 10 %
Solids feed rate	up to 14.3 t/h
Drum speed	1 300 rpm
Centrifugal force	860 x g
Solids recovery	99.5 %
Dry matter contents in solids discharge	37 - 44 %
Operational power consumption	56 kW main drive, 28 kW scroll drive
Flocculent consumption	0.93 kg/t dry matter

Figure 16. Satellite image of centrifuge installation at Tiebaghi Nickel Mine in New Caledonia. (Screenshot from Google Earth.)

CONCLUSION

The use of centrifuges for dewatering tailings is a viable alternative to the existing technologies. Based on environmental impact, space requirement and investment cost, the mechanical separation of solids and liquids by centrifugal force will find its way increasingly into modern mining and minerals processing operations.

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