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The production and management of coal and copper dry tailings

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Abstract

The management and production of dry tailings present some considerable advantages to mining companies. The advantages are based on the technology selected, the composition of material and a number of other process variables. Rapidly developing dewatering technologies and reliable equipment for the production of dry tailings are making it viable in an increasingly large number of high tonnage operations. Various techniques for the production and handling of dry tailings have become the most desired trend, with different options available.

This paper reviews existing and potential applications of dry tailings technology for the treatment and management of wastes from coal and copper tailings operations. The advantages of coarse particle flotation (CPF) with regards to tailings are shared. The influence of particle size distribution, plant configurations, the composition of tailings and the management thereof are discussed, based on recent tailings applications. Recent changes to thickener and filtration technologies are provided.

Keywords: *coarse particle flotation, dewatering, composition, moisture*

1 Introduction

Tailings are being produced in ever increasing quantities. The accelerated production rate is largely due to the mechanised mining of poorer coal seams or continually decreasing ore grades at higher stripping ratios and in larger scale operations. Reject waste piles or the tailings in tailings storage facilities (TSFs), unlike the products, remain a necessary byproduct and are typically not consumed. Nor do they have a useful purpose. They accumulate and consume land space in competition with other requirements, and may become the source for surface or groundwater pollution. In some cases they have proved to be unstable, and catastrophic failure has resulted in substantial losses of life and property.

Large failures with substantial losses in life have received wide publicity and have served to focus the attention of industry, government and the public on the potential concerns associated with these waste deposits.

Technology, and regulatory and industry controls, are continually improving to reduce the potential for future failures. Owing to the scale of the current projects now being initiated, the tailings and waste dump designer is required to produce designs for impoundments of ever-increasing size and rates of rise. Therefore the boundaries of known experience are being pushed beyond the range of current experience. Tailings facilities can be classified into three groups, depending on the TSF design:

1. Contained seepage in natural or man-made embankments.
2. Controlled seepage in permeable embankments.
3. Dry tailings with little water available for seepage.

Dry tailings disposal is finding increasing application largely for the following reasons. It:

- Restricts the volume of contaminated water available for pollution release.
- Maximises recycling of water to the mill, and minimises reagent consumption and make up water needs.

- Decreases the potential for pore pressure development and the associated risk of waste embankment failure.
- Grants greater freedom for the location of the waste disposal site (valleys can be avoided if necessary).
- Improves ease of reclamation, minimises the size of unreclaimed area exposed at any time and permits reclamation to be completed immediately when milling ceases.
- Minimises the potential for long-term pollution or instability.

Recent trends in coal and copper tailings have led the way in tailings dewatering; in particular, the use of high-pressure filters.

Other trends include milling, which has resulted in finer particle grinding to liberate the desired product. This in turn has created a finer tailings size reporting to the TSF.

Lately, milling operations have employed CPF in copper concentrators. This has resulted in many process advantages, plus further advantages in the dewatering and handleability of the tailings discharge. A coarse sand material with P_{80} between 300 to 500 µm allows screen dewatering technology to prepare a sand material suitable for TSF placement.

When reviewing the overall economics of a dry tailings disposal alternative it is important that all economic factors be considered. Often overlooked are the costs necessary to comply with new rules and regulations that may be promulgated during the life of the operation and to address public concerns and pressures. In the long term these costs can have a significant effect on the overall economics of the mine.

This paper addresses the changes in process information that can severely impact the type of technology selected for tailings dewatering.

2 Design philosophy

Historically the rheological requirement of the deposition site dictated the upstream transport and dewatering unit process design requirements. Numerous designs therefore assumed that the dewatering process would dewater the tailings sufficiently to provide the ideal slurry rheological properties for the deposition site. Recently this has proven to be untrue and, in most cases, the deposition design has had to be modified to accommodate the density and rheological range achieved by the dewatering process. Fitton (2017, p. 246) recognised a change and correctly stated that:

> *'…the dewatering method dictates the type of storage that must be designed for the tailings…'*

The selection of management for a tailings system must therefore commence much earlier in the process, and can be attributed to a number of different technologies within the process flowsheet and the manner in which these plants are to be operated. Equally important is the composition of the feed material that geology and mining deliver to the plant, as well as the quality of the water used there.

The introduction of CPF to a copper flotation circuit serves to enhance recoveries and create opportunities for a different tailings recipe.

3 Production of dry tailings

There are numerous technologies available to dewater fine tailings. Historically, different commodities have favoured the same dewatering technology, however, the most appropriate technology depends on climate and rainfall.

3.1 Coal wastes

Coal mine wastes comprise a variety of sedimentary rock types, some of which may have the potential to produce acid. They are usually disposed of in dumps or tips as a 'dry' product.

Wet wastes originate from coal preparation facilities and can be broadly classified into coarse and fine waste. Coarse wet waste ranges in size from 100 mm to 1 mm, with fine wet waste ranging from 1 mm to ultra-fine particles. The clay content of the fine waste may be variable both in type and amount. Fine waste is usually thickened (in a thickener) to between 20 and 35% solids by weight prior to disposal in TSFs. It may contain substantial quantities of coal, quartz, feldspar and clays. Dolomite and calcite may also be present.

3.2 Copper waste

Copper mine tailings are typically flotation tailings containing ultra-fines from a low-grade copper sulphide or an oxide deposit. Typically, sulphides are crushed, milled and beneficiated by flotation. Oxides and mixed ores are typically treated by heap leaching, solvent extraction and electrowinning.

For many years sulphide copper flotation has selectively targeted the ultra-fine particles with little attention given to particles found in the size range of 150 to 400 µm.

Copper and coal tailings dewatering typically fall into the recovery and moisture ranges provided in Table 1.

Table 1 Typical tailing dewatering results after thickening

Application	Recovery %	Moisture %	Technology
Coal	94–98	20–30	Belt press filters, pressure filters
Copper	94–98*	10–25*	Horizontal and pressure filters

*Dependent on polymer addition, particle size distribution and country.

4 Practical applications

4.1 Coal waste

The conventional system of using settling dams is flexible particularly when the fine waste has a relatively high permeability which helps dams to drain at a reasonable rate. More recently it has become more attractive to wash the finer sizes of run of mine (ROM) coal to produce a higher yield of saleable product. The process has therefore led to a finer coal waste remaining, with a higher ash content and lower permeability. It is therefore a more difficult material to ‘dry out’ or dewater when left in settling dams and this is a major factor for consideration in the design stages of new coal preparation facilities.

In a typical medium-sized coal preparation plant with a capacity to treat 1,000 tonnes ROM coal/hour, up to 30% of the feed can be less than 0.5 mm in size. The proportion of fine waste may be 10 to 15% of ROM feed. This represents 100–150 tonnes fine waste/hour. Most plants operate continuously. Thus, one day’s operation will produce 2,400 to 3,600 tonnes fine waste in a relatively low solids content pulp.

At 1.7 particle specific gravity (SG) and 20% solids, 3,600 tonnes/day fine waste is contained in a bulk of approximately 4,000 m^3, which must be disposed of within a tailings impoundment if no further process treatments are to be used. Some further settlement of solids will occur, but this is at a very slow rate and only small quantities of water will be released. Thus, the tailings impoundment remains fluid for a long time after the final deposition of the slurry in the waste pond.

Recent experiences have shown that lower-than-anticipated settled densities mean that impoundments fill very much more rapidly than expected. Considerable difficulties can result in maintaining production while preparing and permitting new disposal areas or cleaning out the low-density sloppy settled products from existing facilities. Dewatered ‘dry’ coal waste is usually a simple mine waste product to dispose of and with many shallow open pit operations it can be backfilled into worked-out areas and finally covered to yield a usable landform within a short period of time.

Unlike some tailings slurries, the water contained in fine coal slurries can be recycled for further use when the solids have been removed. The concept of a ‘closed water circuit’ or ‘ zero water discharge’ from a coal washery is more readily achieved than for other more complex process operations. Dewatering of the fine waste in the plant permits the adoption of a 'closed water circuit' with all the attendant advantages relating to water consumption and environmental protection. Table 2 serves to illustrate some comparative water balance data for a typical coal washing plant using settling dams and for a 'dry' waste disposal system.

Table 2 Water requirements for various circuits

1,000 tph module	Open circuit – settling dam	Closed circuit – dry disposal
Water demand – m^3/h	190–250	40–60
Coarse waste – m^3/h	35–45	35–45
Fines waste – m^3/h	100–700	30–40
Water management	Extensive	Limited

Because of the advantages of dry disposal, numerous dry systems have been installed in plants worldwide and are now being considered for copper tailings.

Almost all fine waste dewatering methods employed are filtration systems. One or two installations in the USA and Australia use centrifuges but these are exceptions. Pressure filtration has become more versatile and sophisticated than 5–10 years ago, and coal waste dewatering is done by either batch (pressure filter presses) or continuous (belt presses) equipment. The choice of method depends essentially on the quantities and characteristics of the waste material.

4.2 Copper waste

Tailings from copper plants are much more chemically reactive than coal waste. Physically they may have clay and sands and generally they are fine (usually less than 0.5 mm in the upper size limit). For simplicity, this section will discuss tailings originating from a flotation tailings circuit.

Chemically, copper tailings may contain acid-generating potential from the depressed pyrite in which a variety of changes could occur. Heavy metals and potentially hazardous non-metals such as arsenic and selenium may be present, both in the solution and solids portion of the tailings. In some applications there is a limit to how much solution can be recycled for re-use in the hydrometallurgical processes.

High levels of pyrite containing sulphides could result in the generation of acidic water which may require a separate TSF. This can be prominent in a cleaner circuit where pyrite is depressed and reports as copper tailings. Slightly acidic water would then have the potential to leach other metals and cause even lower pH water, which would result in mine operations becoming unacceptable.

Conventional technology has been to use thickener systems and pump solids at between 50 and 65% w/w to a TSF.

Extensive test programs and large demonstration plants are currently being designed to better understand the processes and properties of dry copper tailings. Recent work conducted in Australia has found that clays, in particular those with particles finer than 10 µm, play a major role in the settling and dewatering rates of thickeners and filters. The journey of clay particles through the various stages of crushing, milling and flotation undergo delamination, fracturing into nano-sized particles from 200 µm down to 2–5 µm. These ultra-fine particles, some in the form of platelets, have aspect (length to diameter) ratios which can be lodged in apertures of filter cloths under high pressure.

With the use of horizontal belt filters, interesting possibilities may be able to offer distinct advantages in the overall schemes of waste management. In this respect, 'dry tailings' appear to be very attractive and can probably be achieved using less water within the circuit, resulting in smaller amounts of wastewater for treatment and disposal. Typically, horizontal belt filters use less water for cleaning than plate and frame filters.

4.3 Introducing coarse particle flotation

The primary objective of CPF is to recover coarse (>150 µm) value-bearing composite particles that are lost to conventional flotation tailings, without the need for additional upfront power input for particle size reduction to improve mineral liberation. The conventional rougher scavenger circuits at some concentrators are not effective at recovery of particles above 200 µm. The conventional flotation circuit recovers a high proportion of the target mineral, in this case chalcopyrite, in a particle size range of 15 to 150 µm. (Contigo et al. 2007). However, at very fine (<15 µm) and very coarse (>150 µm) sizes, the losses can be seen to increase as shown for the rougher scavenger tailings samples in Figure 1 (Mehrfert 2017).

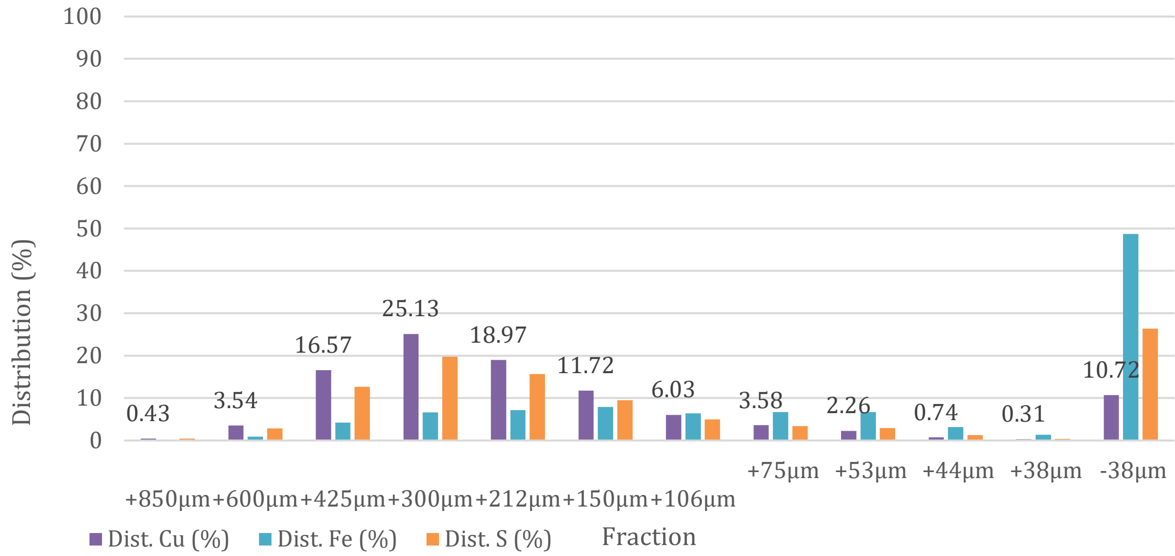

Figure 1 Rougher scavenger tailings – metal distribution by size fraction

A CPF separator developed by Eriez (HydroFloat™ separator) to maximise the flotation recovery of coarse particles has been successfully installed in copper concentrators. (Kohmuench et al. 2019). It operates on the principle that different particle sizes require different turbulence regimes to facilitate recovery (fine particles require turbulent mixing while coarse particles require quiescent mixing). The CPF cell consists of an aerated, fluidised bed. Deslimed feed is directed into the top of the unit while water, air and frother are introduced separately and directly into the fluidised bed. Flotation takes place either immediately upon particle–bubble contact or when enough bubbles have adhered onto particles to prompt eventual transfer to the overflow concentrate launder. The inclusion of CPF in a copper concentrator has many process advantages, with further advantages in the dewatering and handleability of the tailings discharge. A coarse sand material with P_{80} between 300 to 500 µm would allow screen dewatering technology (McPhail et al. 2019) to prepare a sand material suitable for TSF placement.

Sand disposal offers significant benefits when compared with conventional tailings disposal alternatives. Where waste rock is added to the sand, co-disposal options provide the following benefits:

- A reduction in the tailings volume at the TSF.
- A reduction in the overall waste storage footprint.
- A faster rehabilitation when approaching mine closure.
- An increased recovery of water from the sand dewatering system.

Almost all fine dewatering methods employed involve the addition of thickeners followed by filtration systems. Hydrocyclones have become popular for reducing the volumes required to be dewatered.

5 Particle size distribution

Tailings consist principally of ground-up rock with a variable size distribution, mixed with water to different pulp densities. The water may contain many dissolved chemical constituents of varying concentrations.

The constituents are potential pollutants. The ease with which the tailings dewater will depend largely on the following three factors:

1. The average D_{50} particle size of the solids.
2. The percentage of 10- µm particles.
3. The composition of the clay-sized particles (smectite, montmorillonite, illite or kaolinite).

Dewatering ease will generally increase with an increase in average particle size, a decrease in the percentage of very fine material and lower clay contents, particularly smectite- and montmorillonite-type clays.

Much can be done to improve the dewatering properties of the tailings by better understanding their composition and moving to better technology specifically designed for the particle size generated. Coarser grinding is now finding favour in copper and gold mines across Australia via coarse particle flotation.

Dewatering methods for tailings can be ranked in approximate order of the decreasing ease with which the water is removed.

1. Gravity drainage is generally employed for free-draining tailings where the material is greater than 0.2 mm and less than 10% finer than 45 µm. Screens are now employed for CPF tailings.
2. Hydrocycloning plus gravity/screen drainage dewaters the coarser fraction of tailings. Fine tailings in the overflow must be separated and further treatment is required.
3. Vacuum filtration using disk, drum or belt filters creates high hydraulic gradients over thin layers of cake to improve dewatering efficiency.
4. Centrifugation is typically used for fines dewatering of coal flotation tailings, however, recovery can be problematic.
5. Pressure filtration using either belt or filter presses increases hydraulic gradients through thin cakes and this can be used to dewater the finest of tailings. High pressure feeding and air makes pressure filtration an effective and flexible dewatering device.

Items 3, 4 and 5 have been reviewed in previous technical papers. Cake formation: three tailings filtration technologies using pressure (Meiring 2021) provided evidence that higher pressures in dewatering technologies have generally been found to deliver drier cakes.

Illustrated in Figure 2 are the gradings for six different tailings products.

1. The copper tailings cyclone underflow is sufficiently coarse and is relatively free draining. It can be placed in the field at its discharge moisture content and, with adequate under-drainage, will behave as a granular waste and be stackable in a pile which has a 3:1 side slope.
2. The second copper tailings sample is a little finer for over 50% of its grading curve, but contains a much higher percentage of clay fines, indicated by the high tail. These tailings are being belt filtered to approximately 35% moisture content and are 'sloppy' when handled by earthmoving equipment.
3. The sulphide tailings sample, despite being considerably finer than the two copper tailing samples, has, on average, a much lower clay content. Due to its lower clay content, it can be economically belt filtered down to 18.5% moisture content. The product has a high SG and at this moisture content is still fairly 'sloppy' when handled by earthmoving equipment.
4. Fine coal waste (coarser) and fine coal waste (smectite) samples are both relatively fine and have high clay contents. Test results on these show that the coarser sample can be effectively and economically dewatered using either a belt press or a filter press, while a centrifuge or a drum

vacuum filter would not be suitable. Unlike the coarser sample, the waste with smectite contained a substantial amount of clays and was extremely difficult to dewater by any method. There is also reason to believe that the smectite samples could break into further nano-sized ultra-fine particles as they undergo delamination and fracture into layers.

5. Lastly, the CPF tailings (curve depicted on the left-hand side) presents a completely coarse size fraction that can be considered for more straightforward dewatering and disposal. Coarse tailings streams present a unique opportunity to demonstrate alternate dewatering technologies such as screens in a lower-risk environment while still delivering a robust economic case. Please note that the benefits of the coarse grind (lower milling costs and greater throughput) to enhance CPF must be considered.

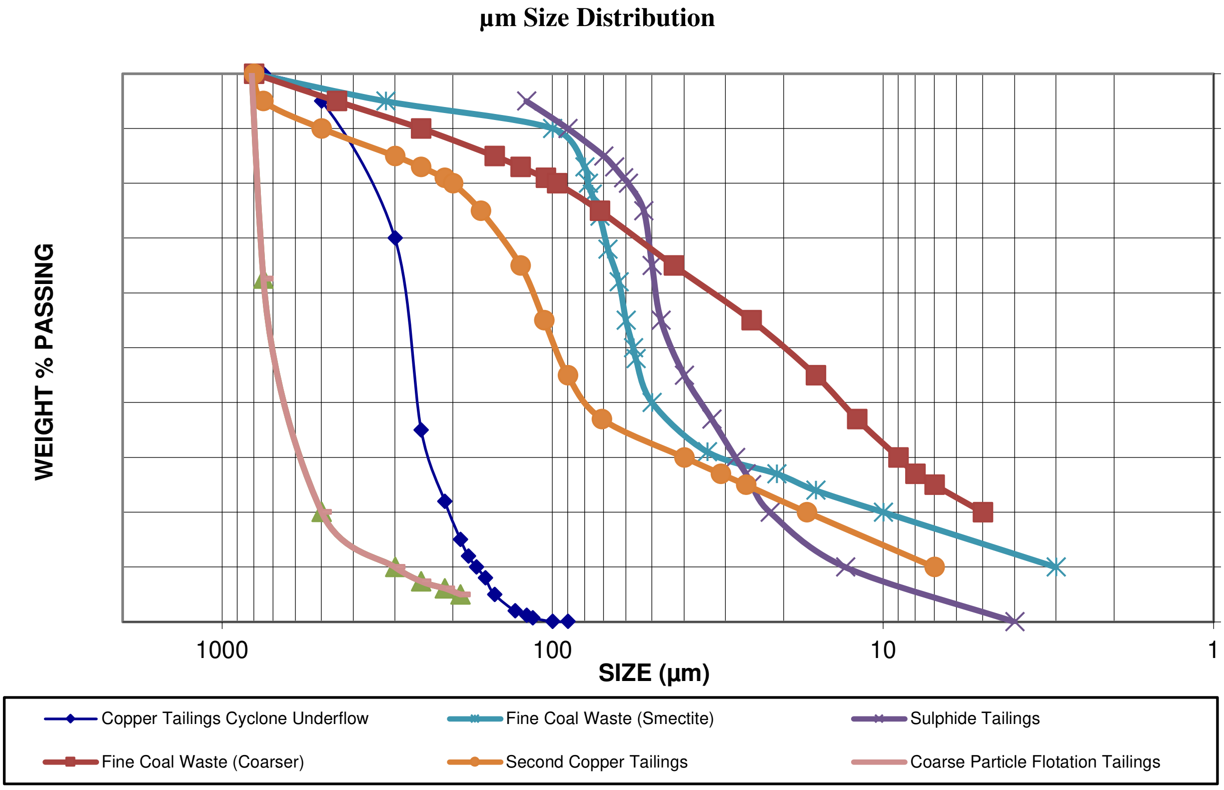

Figure 2 Different tailings gradings for six products

An initial assessment of tailings dewatering ability can be made based on the above. While benchmarking remains useful for concept level studies, the final selection of equipment and process method must be done on pilot- or demonstration-scale equipment from which final scale-up data can be developed.

The sample 'life span/time' is an important consideration when working with tailings as the characterisation of the samples can change over time. This is particularly prevalent when clays are involved, as they can fracture and change owing to water, pH, chemistry and handling.

6 Dry tailings handling

While dewatered tailings are at times not dry, they possess a residual moisture content which can vary from 8 to 40% of total weight. At these moisture contents the filtered tailings vary in consistency from a thick slurry to a granular non-cohesive cake or a cohesive cake with little free water. The handleability of these products varies tremendously.

For the purposes of this paper, tailings are considered to be 'dry' if they have been dewatered sufficiently that they can stand in a substantial pile and be handled by conventional earthmoving equipment without liquifying. Non-cohesive tailings would generally attain this state at relatively low moisture contents of 10% to 20%. Cohesive tailings could have moisture contents in excess of 35% and still be considered 'dry'.

As the moisture content of the tailings increases it tends to become sloppier. At moisture contents a little above the 'dry' level , it may stand in a slumped pile, but it would tend to flow and slop about as soon as it is disturbed or vibrated. This change in properties on disturbance is due to a reduction in shear strength brought about by an increase in the pore water pressures developed in the tailings as it is disturbed or sheared. At yet higher moisture contents the tailings become a slurry with viscosity dependent on the solids concentration.

Our interest in the handleability of the tailings by conventional earthmoving equipment is effectively in the range where it behaves as a solid waste through to a sloppy product. Sloppy tailings products can be, and are being, loaded from settling lagoons, sludge dams etc. by front end loaders and hauled by truck for co-disposal with rock waste. The sloppier the product the more inefficient are the loading and transportation. Tailings slop from bins, buckets and trucks pours out of truck tailgates. A large amount of energy is expended loading and hauling water rather than solid product. Spillage on haul roads causes a mess and increases the maintenance costs . Since the sloppy tailings will not support the loading and transporting equipment, a 'firm roadbed' is needed. At one coal plant, for example, dewatered tailings is dropped onto coarse reject material to enhance the trafficability of the dry cake.

Concerns relating to the handling of the tailings can be grouped in three major areas:

1. Handleability: the methods by which it can be dewatered, transported and deposited.
2. Trafficability: the issues that will be encountered by equipment moving on placed material during loading or following placement in the disposal area.
3. Stability: the stability of the placed material and therefore the geometry to which it can be placed or the containment that it may need.

A convenient measure of the sloppiness of a tailings product can be made using the Atterberg Liquid Limit Apparatus or viscometers. The liquid limit is not a function of the moisture content and cannot predict the behaviour of the field moisture.

Recent management advancements include the use of computerised modelling like METSIM®. This general-purpose process simulation system is designed to assist the engineer in performing mass and energy balances of complex processes that can be used to link the performance of a thickener to that of a filter or vice versa.

METSIM® uses an assortment of computational methods to effect an optimum combination of complexity, user time and computer resources usage. Tailings models use LOOKUP to change the cycle times on filters based on the thickener underflow solids content, feed clay compositions and previous filtration duties.

7 Recent advancements in technologies

Over the past 10 years a number of advancements have been made in technologies.

7.1 Thickening

1. Paste thickener tank diameters have reached 45 m, resulting in less thickeners.
2. Thickener side wall heights have increased, albeit the constraints have been related to water release dynamics. Retention times have changed.
3. Higher-rated torque mechanical drive mechanisms are now available. FLSmidth has recently introduced a 'super-duty' drive which, at 16.4 MNm, is the largest drive gearbox on the market. That said, the torque for centrally driven rake systems will become limited and periphery driven

rake systems will need to be considered. With a periphery driven system, torque can be driven at much higher ranges, nearing 100% of the drive mechanism rating. Typically, after installation, vendors would recommend that the rake function at normal operating torque, which is a fraction of maximum operating torque. It is also worth noting that torque increases with the tank diameter to the power of two and that smaller diameter thickeners would not undergo high torque.

4. Mechanical drive mechanisms are no longer sized using thickener duty K factors. The industry has moved to a more conservative approach using maximum operating torque plus a safety factor. Typically, extra heavy-duty thickeners had a K factor of 150 – 300, which has now been replaced with 'multipliers' added to the K factor as high as 2. These equate to K factors close to 600.

5. Higher underflow density results in higher water recovery. An example is that for 4,398 t/h feed and thickener underflow at 55 wt%, the underflow contains 1,230 m3/h more water than thickener underflow at 65 wt% solids. This is equivalent to 10.8% higher water recovery. In terms of pressure filtration rates, less water in the higher underflow solids has a significant influence on the total cycle time.

   It has been estimated that 1% w/w loss in the filter feed density translates to a 2-4% loss in filter throughput, depending on the clay content. High paste yield stress, due to clay content and fines, has driven the rake design to higher torque levels. This has resulted in rakes rotating the bed mass rather than raking the solids towards the inner cone, causing significant downtime. To maximise underflow density and reduce the risk associated with high yield stress in large diameter thickeners, it is recommended that high compression thickener diameters not exceed 60 m.

6. The introduction of pickets within a thickener enhances the release of additional water that may not necessarily have been released in the compression zone. The pickets create shortened paths for trapped interstitial water to escape from the mud bed. This allows for an acceleration within the thickener, reducing the required residence time.

7. New thickener feedwell designs have been trialled, including a feedwell trough populated by a multitude of vertically directed nozzles. These deliver slurry into a flocculation chamber before dispersing through an exit gap into the thickener tank. The trough innovatively ensures flash mixing and highly uniform solids dispersion inside the aggregate growth chamber. Numerical modelling indicates that when quantitatively compared to an equivalently sized diluting Vane Feedwell, the design provides a large improvement in solids hold-up, mixing, exit distribution and more. It has been reported that the first occurrence of a networked bed was observed, underflow densities improved by 6.5% w/w, flocculant consumption reduced by 5%, and overflow clarity largely improved.

8. Polyelectrolytes have changed. The effect of several parameters related to the clay mineral (type, composition), the polyelectrolyte (e.g. synthetic/natural, molecular weight, charge type, charge density, linear versus branched) and the flocculation medium properties (e.g. pH, ionic strength, clay mineral, and polyelectrolyte concentration and type) are now more apparent.

7.2 Filtration: pressure filtration

Over the past 10 years, a number of advancements have been made in filtration technologies.

1. Larger filtration areas with up to 2,788 m^2 plate presses and filtration volumes reaching over 60 m^3 have been achieved (Hawkey et al. 2020). This has been achieved by increasing the plate size and number of filter chambers in the press. Aqseptence Group Srl has designed a pressure filter with dimensions of 4.15 m high by 4.8 m wide. Higher throughput tonnage up to 9,500 tpd is currently being trialled.

2. Filling the filter at a higher pressure (above 2,100 Kpa) surpasses the driving force of a vacuum filter and can be 8–10 times greater than the driving force of a belt press filter. Higher fill pressures have resulted in lower cake moisture content.

3. Higher thickener underflow density feed to the filters results in higher water recovery. In terms of pressure filtration rates, less water in the higher underflow solids has a significant influence on the total cycle time. Cycle times between 12 and 20 minutes are now possible for typical copper tailings. Faster cycle times translate to fewer batches and higher production rates.
4. Filter presses can achieve over 90% availability utilising a method of maintenance 'outside' the filter press. Most maintenance on a filter press is associated with the filter cloth and filter plates . Filter cloth has a typical lifetime of around 3,000 cycles on most mineral flotation tailings. This results in changing the filter cloth on the filter approximately twice per month, depending on how often the filter is operated. Batches of plates can now be removed and replaced with minimal downtime.
5. Testwork comparing actual to laboratory results has proven that large installations achieve similar to better results than laboratory tests (Chaponnel & Wisdom 2018). Some operations have now taken to conducting lab filtration tests on different tailings materials to predict the acceptable moisture content. Cycle times are then corrected for the accepted moisture content.

7.3 Characterisation

The industry has a better understanding of slurry physical, chemical and rheological properties. For maximum water recovery, thickeners need to operate close to the underflow rheology yield stress limit and not density. Much work has gone into rheological clay properties of unsheared and sheared yield stress, which has reduced a significant risk of the operating torque component with thickening.

The characteristics that have the greatest effect on both the filtration rate and cake solids concentration are the type of clays, total clay percentage, proportion of particles finer than 10 µm, the presence of sodium, chlorides and the cation exchange capacity. The dewatering performance of clay mineral-rich samples is dependent on the structure that the solids form when hydrated, which affects their permeability.

The presence of kaolinite or smectite minerals can negatively impact coal tailings filter cake permeability (Meiring 2021). These clays are known to affect drainage and filtration rates while also increasing filter cake moisture and making handleability more challenging.

Parameters that reduce the filtration rate and cake solids concentration include:

- High levels of smectite when not combined with kaolinite.
- High levels of particles that are smaller than 10 µm.
- High total clay content.
- High levels of sodium (Na^+) cation.
- Cation exchange capacity with high total negative charges in the calcium, sodium magnesium etc.

Recently, a gold company assessed tailings containing high silica quartzite fines. A process has been developed to extract and dewater the silica content, which represented over 46% of the tailings. The fine tailings were classified into two size fractions, at a split of 53 µm: the +53 µm fraction to be used for cementitious fill and the -53 µm fraction to be used for 3D printing. Removal of these fractions has produced a new approach for the design of the TSF.

8 Conclusion

A good understanding of the particle size distribution and the associated composition of the tailings material is required for an initial assessment of tailings dewatering ability. The dewatering performance of clay mineral-rich samples is dependent on the structure that the solids form when hydrated, which affects their permeability. Processing technology can influence the flowsheet design and the method of tailings disposal.

The installation of CPF can have a very positive impact on tailings dewatering as coarser particles are easier to dewater then ultra-fines. Production of dry tailings via manipulation of the particle size is technically feasible and economically viable on some operations. There are installations which have demonstrated this conclusively.

Technology and, in particular, larger equipment for dry tailings systems are developing rapidly. The increased filtration equipment sizes are continually improving the filtration tonnages and overall economics. Models are being utilised to manage both the thickener and the filter to deliver manageable dry tailings. It has been estimated that 1% w/w loss in the filter feed density translates to 2-4% loss in filter throughput, depending on clay content. To maximise underflow density and reduce the risk associated with high yield stress in large diameter thickeners, it is recommended to keep high compression thickener diameters at 60 m.

The implementation of dry tailings schemes provides considerable advantages for both the short- and long-term in terms of limiting the environmental impacts and increasing the safety of TSFs. CPF can increase the overall yield of the product and can change the approach to tailings dewatering.

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