Dry Stacking – Filtration of Bauxite Residue with Filter Presses

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Abstract

This paper is divided into two sections. The first one describes and compares a range of bauxite residue materials from alumina refineries around the world. In particular, the paper compares the physical and chemical characteristics of the materials in slurry form and discusses the results of filtration tests on the different materials. Specifically, we focused our attention on the moisture content and yield stress values of the filter cake to determine the suitability of the cake for dry stacking. The second section details a number of case studies analyzing information coming from some of the largest residues dewatering and dry stacking projects where Diemme Filtration (Aqseptence Group) was involved. Each case study contains tests and operating data from the site as well as various pictures that show the components of the filtration and stacking systems. The main aim of this paper is to demonstrate that the adoption of the dry stacking technology for greenfield sites and retrofitting the technology to existing operations reduces the footprint of the storage area and minimizes the risks associated with residue storage.

Keywords: bauxite, dry stacking, bauxite filtration, filter presses.

1. Introduction

The safe management of mineral tailings is still one of the main challenges of the mining industry. The risks associated with tailings dams have been well demonstrated by recent failures causing significant harm to people and the environment. These incidents are not confined to any particular continent or country and cannot be classified as a third world problem. Tailings dam failures have occurred at sites owned and operated by prestigious mining companies with the highest management standards. There is inherent risk in the technology and that risk varies with the particular conditions of the location. Topography, climate, seismic activity and proximity of residential areas can increase the risk significantly.

The risk of a tailings dam failure (major or minor) should be accounted for in the overall economic evaluation of a mining operation as well as the cost of rehabilitation of the dam at the end of the mine life. Comprehensive and meaningful comparisons between tailings management technologies for a proposed mining operation must take these risks and closure costs into account. When this comparison is conducted correctly, those technologies that may have a higher initial capital cost may also be found to be the most economic over the life of the mine because the risks and closure costs are included in the analysis.

Over the last ten years the alumina industry has gradually embraced pressure filtration and dry stacking of bauxite residue. In fact, the technology has become the preferred method of managing bauxite residue (red mud).

2. Mineral Tailings Management

2.1. Conventional Tailings Dams

Where feasible, dams or ponds have been used as the standard method of dealing with mineral tailings slurry. Many factors influence the successful operation of a tailings dam (Figure 1). Settling of the solid particles in the dam does not always occur uniformly or completely and recovering water for use in the mine is often inefficient.

Figure 1. Tailings dam

Decanting the supernatant is often critical in meeting the design life and total tailings capacity of the dam so when poor supernatant quality prevents this, it is a serious problem. If the design relies on evaporation to concentrate the slurry, this is highly reliant on the prevailing weather. Climate change may have introduced another complication to the selection criteria for an appropriate tailings management system.

As we have witnessed, even in recent years, tailings dam failures have the potential to be very destructive and are a significant risk to a mining operation and its owner. Raising the height of tailings dam walls to extend the operating life of the dam is expensive and usually increases the risk of dam failure and damage to the mine personnel, the environment and any nearby residents.

2.2. Paste Thickening

Paste thickening has been used in mineral tailings management since the development of high-density and paste thickeners. The technology has been used in greenfield situations but it has also been retrofitted to existing operations as a way of extending the life of a conventional tailings dam.

Figure 2. Paste thickeners

The equipment usually has a high capital cost. The technology relies on a relatively high dose of polyelectrolyte and is sensitive to changes in feed slurry solids concentration and consistency of chemical composition. Without sophisticated process control and/or frequent operator attention, paste thickeners (Figure 2) are not well suited to operations with variable feed conditions. The other disadvantage is that although the underflow from paste thickeners is denser than that from a conventional thickener, it cannot be stacked without a retaining structure (or without employing mud farming techniques).

2.3. Vacuum Filters

Where a higher degree of water or liquor recovery is required, the tailings (bauxite residue) needs to be filtered. The same process may be applied so that the resulting filter cake can be dry stacked in cases where wet storage is not ideal (for reasons of climate, topography, seismic activity or if mandated by national or local authorities). Vacuum filtration has historically been used in some operations (particularly vacuum drum filtration – see Figure 3).

Figure 3. Rotary-drum vacuum filter (RDVF)

There are three main configurations of vacuum filters: vacuum disc filters; vacuum drum filters; and vacuum belt filters. The selection of one of these three configurations can depend on the particle size distribution of the feed slurry, whether the cake needs to be washed, the available footprint of the installation and personal preferences.

Figure 4. Travelling-belt vacuum filters (TBVF)

Top-fed vacuum filters (such as travelling-belt vacuum filters, see Figure 4) are better suited to slurries with large particle sizes and are more suitable for cake washing applications (although cake can be washed on other types of vacuum filters). Bottom-fed vacuum filters such as drum filters take up less footprint for the same filtration area and are more suited to fine particles. Vacuum disc filters are also better suited to slurries containing smaller particles and this type has a significantly smaller footprint (in relation to the filtration area). It is important to remember that slurries containing very fine particles and any clay-like materials are not well suited to vacuum filters at all. In many cases, the cake is thixotropic and may not be easily stackable.

It is important to remember that vacuum filters work well for large particle sizes but if there is any variation in the particle size distribution of the feed slurry solids, a thorough testing program is recommended. Where the workable particle size spectrum overlaps with that of pressure filtration, it should be noted that the resulting cake moisture content is usually much lower for pressure filtration. The cake moisture target must be considered carefully before any selection is made.

2.4. Hyperbaric Filters

Hyperbaric filters (Figure 5) are a development of vacuum disc and vacuum drum filters. In this case, the filter is housed in a pressure vessel so that a higher pressure drop over the filter medium (and eventually, filter cake, are possible. The pressure drop applied across the filter media and cake can be significantly higher than that achieved with vacuum filters but typically it is limited to about 4 bar, restricted by the pressure vessel design limit (usually no more than 6 bar).

Figure 5. Hyperbaric filter

Theoretically, the continuous nature of hyperbaric filters could be considered an advantage but their complexity equates to high capital cost and expensive maintenance. The relatively low pressures achievable with a hyperbaric filter and its limited process flexibility in comparison to the modern filter press means that it has a narrow band of applications (such as filtering slurries at temperatures above 95 °C).

2.5. Plate Filter Presses

Modern plate filter presses (see Figure 6) are used in many parts of hydrometallurgical process plants. The adoption of this technology for concentrate dewatering applications was a turning point.

Figure 6. Plate filter press

Tailings dewatering applications required very large filter presses to make this technology economic. The key to making filter presses economic for large-scale filtration applications is minimizing the number of trains (reducing the number of ancillaries such as drip trays, cake conveyors, feed pumps). In theory, for a particularly large dewatering duty, the larger the filter presses, the lower the total cost of installation. Of course, there will be a limit to this but it is not yet clear exactly where this limit is. The size limit is determined by material restrictions for the filter plate design, transport considerations, site-specific installation constraints and operating and maintenance complexities.

For mineral tailings slurries, the cake moisture content typically achieved with plate filter presses is between 15 and 30% by weight. Importantly, it will be lower than the best result of all the competing dewatering technologies. The cake discharged from plate filter presses is highly stable and stackable (see Figure 7). Typically, the cake does not rehydrate significantly when it rains.

Figure 7. Bauxite residue filter cake

A dewatering plant using plate filter presses is compact (has a relatively small footprint) and is easily installed in difficult terrain. The water recovery is very high and, if required, the filter cake can be washed in the filters with very high product recovery (or contaminant removal) using a minimum of solvent. This particular advantage has been employed to replace counter-current decanting thickener (CCD) circuits with specially-configured plate filter presses. The development could be considered as an efficient method for soda recovery but its suitability relies on good permeability of the filter cake after dewatering. The permeability of the filter cake of different bauxite residues ranges widely so detailed test work is required before this technology should be selected for a particular refinery.

3. Range of Bauxite Residues

Diemme Filtration has tested the chemical composition, particle size distribution and filterability of many different bauxite residues from all over the world. We shall briefly examine the extent of variation and how this affects the filterability of the residues.

3.1. Chemical Composition

The main solid components of bauxite residue are oxides of iron, aluminium, silica, calcium, sodium and titanium. The fraction of each component varies greatly. Haematite (Fe_2O_3) is usually the largest component and typically makes up between 25 and 50 %. This is followed by alumina (Al_2O_3) which can range between 15 and 30%. Silica is typically between 5 and 15%. Soda (Na_2O) can comprise between 3 and 15 % of the solid phase of the residue. TiO_2 and CaO usually make up less than 5% each. These figures are typical only (quoted from the results of Diemme Filtration tests conducted over the last 20 years).

The mineralogy of a bauxite residue can affect the filterability of the slurry. The physical nature of minerals such as muscovite (for example) can reduce the filterability. Muscovite is a hydrated phyllosilicate and particles of this material tend to have a plate-like shape and form filter cake with a relatively low permeability.

3.2. Particle Size Distribution

As one might expect, a slurry with a high proportion of large-sized particles is more likely to filter faster and yield a drier filter cake than a slurry with a large proportion of small particles. Bauxite residue slurries vary greatly in their particle size distribution. Looking at the particle size distributions of the many bauxite residue slurries tested at Diemme Filtration, the typical range is as follows.

Almost all the particles of all samples (P100) pass 1 mm but some of the samples had very few particles larger than 150 microns. In general, the majority of samples have only a small component of particles greater than 20 microns in size. The P80 for most bauxite residue samples is less than 15 microns (and often smaller, sometimes only 5 microns). The P50 for most samples is less than 2 – 3 microns. The P20 is typically less than 1.5 microns and the remaining 10% is usually below 0.3 microns. It may be worth noting that the largest variations in bauxite residue particle size are the top 10 % and bottom 10 % of the distribution.

3.3. Filter Cycle Time and Cake Moisture Content

From experience we know that variations in the bottom 10 % of the particle size distribution can strongly affect the filterability (filtration time and cake moisture content). However, as noted in 3.1 above, particle shape can also play an important role in filterability.

To what extent do these variations affect filter sizing for a bauxite residue dewatering plant? Examining the tests results of bauxite residues tested by Aqseptence Group, there is a surprising range of the filter cycle time required to form a filter cake of the same thickness using a similar feed pressure. The filter cycle time (including filter technical time) typically ranges between 15 minutes and 40 minutes. The cake moisture can range from 25 % w/w to 40 % w/w.

With regard to the cake moisture and the suitability for dry stacking, it's very important to stress that the geotechnical tests should be performed on actual filter cake samples produced in a filter press. If the tests are performed on a simulated cake, made by adding water to the dry residue powder the results will be very different. Diemme Filtration has witnessed this on many occasions. For example, geotechnical tests on a simulated cake sample for a recent bauxite residue filtration and stacking project indicated that the moisture target be 24% or less of the total weight of the cake. When the actual filter cake was used in the same tests, the target was revised to 34% moisture.

4. Case Studies

4.1. Slurry Characterization and Filtration Tests of Two Different Bauxite Residues

To demonstrate how the sizing and configuration of plate filter presses might be affected by the chemical and physical properties of different bauxite residues we will present two case studies.

The differences in the particle size distributions are illustrated in Figure 8, below.

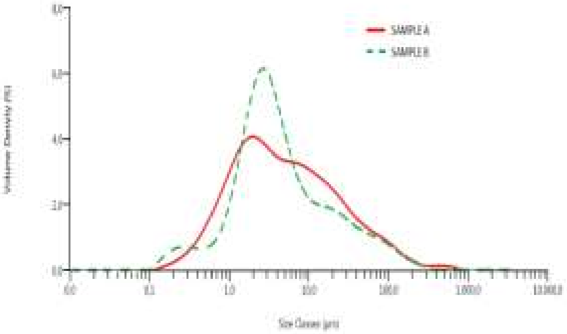

Figure 8. Particle distributions (A&B)

The chemical compositions of the two residues are shown in the table below (Table 1).

Table 1. Chemical composition (A&B)

	A	B
Wt % Al_2O_3	27.2	16.8
Wt % Fe_2O_3	26.5	48.1
Wt % SiO_2	15.1	6.79
Wt % CaO	4.56	4.97
Wt % Na_2O	4.34	13.9
Wt % TiO_2	3.04	4.36

The bauxite residue slurries for the two examples have approximately the same suspended solids concentration (35 % w/w) and the filter feed temperature is the same (40 °C).

Filtration tests on the two samples yielded significantly different results. Residue A has a slower filtration rate than that of residue B, using a fixed-volume chamber and the resulting cake moisture content is higher. Residue B forms a more permeable cake so benefits from the displacement of interstitial liquor by blowing compressed air through it.

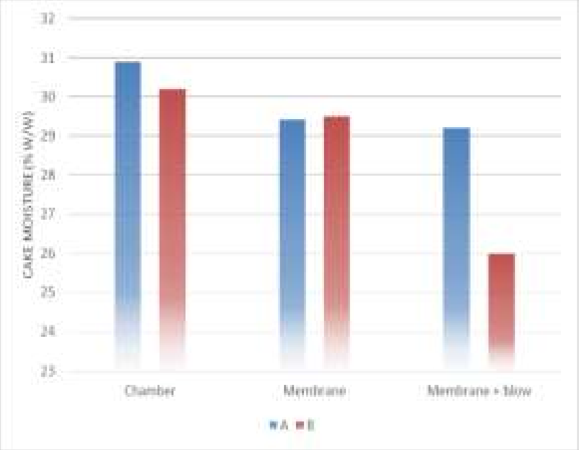

Figure 9. Filtration test results (cake moisture)

The different results are caused by a combination of particle size and particle shape differences between the solid phases of the two residues. This calls for a different approach for each case when configuring the filters for dewatering.

4.2. Filter Sizing and Configuration for Residue A

Figure 10. 6 x GHT2500.P18, residue A

Table 2. Filter Specification

Filters installed:	6 GHT2500-P18
Plate shifting:	Single (1-by-1)
Filtration area:	1750 m^2 each
Cake volume per cycle:	30 m^3
Plate pack configuration	Fixed volume, recessed
Cake thickness:	35 mm
Number of plates:	184

Table 3. Process Conditions

Duty:	6000 t/day, DS

Filter cycle time:	30 minutes
Cake specific weight:	2.00
Bulk density of cake:	1.5
Cake moisture content:	30 % w/w
SS conc. in feed:	40 % w/w
Filter cake production:	179 m^3/h

4.3. Filter Sizing and Configuration for Residue B

Figure 11. 4 x GHT2500-F22, residue B

Table 4. Filter Specification

Filters installed:	4 GHT2500-F22
Plate shifting:	Fast (multiple)
Filtration area:	925 m^2 each
Cake volume per cycle:	22 m^3
Plate pack configuration	Variable volume
Cake thickness:	50 mm
Number of plates:	101

Table 5. Process Conditions

Duty:	6000 t/day, DS
Filter cycle time:	20 minutes
Cake specific weight:	2.00
Bulk density of cake:	1.5
Cake moisture content:	26 % w/w
SS conc. in feed:	35 % w/w
Filter cake production:	174 m^3/h

5. Conclusion

Aqseptence Group’s experience with bauxite residues and their filterability and suitability for dry stacking has proven that even though pressure filtration is now the preferred method for dewatering these materials, the chemical and physical differences in each bauxite residue mean that careful consideration of the configuration and design of the filter presses is important. To get the best results and the most economic dewatering plant, careful and thorough test work is required.

To summarize, to determine the best and most economic filter configuration for a particular bauxite residue, it is desirable to:

- Complete a thorough chemical analysis of the slurry;
- Accurately measure the particle size distribution of the solid phase of slurry;
- Perform a wide range of filtration tests, and include fixed-volume and variable-volume plate pack assessments;
- Understand the mineralogy of the resulting filter cake to better predict its filterability;
- Choose the filter configuration that best suits the application, with careful consideration to the targets.