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Economical dewatering of tailings for mine backfill with high performance disc filters

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Abstract

Filtration of tailings and paste from ore processing is gaining more and more importance since the recovery of water from the process reduces the intake of the limited resource water. The Boozer disc filter represents the new generation of disc filters, which is currently used in the alumina industry and in the dewatering of coal slurries. The disc filter is moving more and more into applications of tailings dewatering. The paper reports on the operation experience of filtration and dewatering of gold/copper tailings for mine backfill with the disc filter and gives a comparison of capital expenditure/operational expenditure (CAPEX/OPEX) data.

1 Introduction

The treatment of tailings and paste from ore processing filtration and dewatering is becoming increasingly important. Firstly, the recovery of water from the process reduces the input of an important resource – water. This can make the difference between 'yes, we can operate' or 'no, we cannot'. Secondly, the filtered tailings can be dry-stacked, which is safer, cheaper, and environmentally more acceptable. Thirdly, especially with mine backfill, the amount of cement to be added can be reduced, which may save millions of dollars per year.

Typically, filter presses, belt filters and rotary vacuum disc filters are used for this dewatering duty. Among these technologies, in approximately more than 80% of all applications, the vacuum disc filter type is assumed to be the most economical solution with reference to both CAPEX and OPEX aspects – especially, when modern disc filters are used.

2 Typical properties of tailings

Tailings from ore processing are generally non-valuable products which have to be disposed of in an environmentally sound, secure and economic way. Typical properties of tailings, with respect to filtration, can be summarised as follows:

- Very fine particle sizes, mostly in the range of d_{50} = 1 micron up to 50 micron.
- The formed filter cakes have a sticky behaviour and are difficult to release from filter fabric.
- The pH value is often low or high, i.e. tailings often have corrosive properties.
- Solids content is typically in the range of 50-70 wt% due to thickening.
- Clay content depending on orebody can hinder filtration and dewatering.

3 Separation technologies for tailings dewatering

In the dewatering of tailings and paste from ore processing several separation technologies are applied such as filter presses, belt filters and rotary vacuum disc filters which are briefly described below. A comparison of CAPEX/OPEX data of these technologies is presented in Section 5.

3.1 Filter presses

Filter presses are one of the most used solid-liquid separation machines for discontinuous cake filtration and for demoisturing of difficult to filter suspensions. Filtration takes place discontinuously and as a driving force; overpressure is applied by a pump. Filter presses are in use in the mining industry and can filter, dewater and even wash huge quantities of slurries which is why they have been termed the ‘work horse’ of filtration. A filter press is made up from a sequence of filter plates, typically made from polymer, forming contained filter elements. The filter plates are mounted on a supporting frame between the head and the end piece and are pressed together for sealing. Slurry is forced into the filter chambers, under pressure, by means of a pump and the filtrate passes through the filter cloth. The retained solids form a filter cake and filtration proceeds until each chamber is filled with cake. For cake discharge the press has to be opened.

The oldest design is the chamber filter press where the filtration chamber is formed by perforated plates alternating with frames. A disadvantage of the frame filter press is the solids discharge, which has to be manually performed by breaking the cake out of the frames. A more automated operation of cake discharge was introduced, with the chamber filter press which today is the most common filter press design comprising two neighboring recessed filter plates that face each other to form the filter chamber. The filter medium, usually a woven cloth, is stretched over each plate and is pressed into the chamber during operation. Discharge of the cake can be executed more simply than from frame filter presses. However, filter cakes of a certain thickness, i.e. of a certain weight, are necessary to ensure that the cake falls out by gravity. Therefore, often long cycle times are required which can take up to several hours.

A further development of a chamber filter press is the membrane filter press which allows for squeezing the filter cake in the filter chamber from one side by a rubber membrane. Filter and membrane plates alternate with each other. Advantages of this design are that the feed pressure of the slurry can be kept low and a high pressure pump is not needed since the filter cake can be uniformly compressed by the membrane.

Filter presses can contain hundreds of plates of up to 2.5 m in size and have areas of up to 1,000 m^2. They are operated with pressures of up to 16 bar while high pressure filter presses are applied with up to 60 bar. Depending on the filtration properties of the slurry a filter cycle (filling, dewatering, sometimes washing and cake discharge) can take few minutes up to several hours. Detailed information on filter presses can be found in Sutherland (2005) and Wakeman and Tarleton (2006).

With respect to the CAPEX/OPEX comparison presented in Section 5, the following features of filter presses include:

- Reduction of cycle time to achieve high solids throughput requires the use of membrane filter presses.
- Automated operation requires a large number of valves and instruments.
- Cleaning system ensures that feed lines remain operational requires many cleaning and flushing steps.
- Manual check of cake discharge.
- Many components and peripheral equipment may mean high maintenance efforts and high spare parts demand.

3.2 Belt filter

The belt filter type is a continuously or quasi-continuously operating, horizontal vacuum filter. Basically, a belt filter consists of a filter cloth which is moving continuously or with interrupted motion over several rollers. With respect to construction and function, two main types of belt filters exist. The oldest variant is the conveyor belt or carrier belt type which is the relevant version for applications in tailings filtration. The conveyor belt, usually a reinforced rubber belt with grooves and slots for filtrate drainage, moves around the rollers to support and convey the filter belt. The rubber belt slides over a vacuum box which collects the filtrate. Different to this version, the tray type consists of a series of trays underneath the cloth belt. The trays are connected to the vacuum and can either be transported with the cloth, up to a certain position where they return to the starting position, or can be fixed while the cloth belt moves intermittently. Both operation methods of the tray type require that the vacuum is periodically cut off and applied again to allow for return transport of the trays or for the intermittent cloth transport.

On belt filters, the filtration process takes place in direction of gravity along the horizontal cloth belt and typically includes filter cake formation, filter cake washing and cake dewatering by air. Discharge of the filter cake is performed by reversing the cloth belt around a roller of small diameter and can be supported by means of a scraper and/or a reverse flow of compressed air. After cake discharge the filter cloth can be washed from both sides.

Belt filters are applied in many industries from chemicals to mineral processing and are especially suited for easy filtering products that require intensive cake washing, since the washing medium can be applied on the filter cake from the top as a pool. Typical filter sizes range from one up to over 100 m^2. More detailed information on belt filters can be found in Sutherland (2005) and Wakeman and Tarleton (2006).

With respect to the CAPEX/OPEX comparison presented in Section 5 the following features of belt filters shall be mentioned:

- Large space demand as consequence of large foot print per square metre filtration area and relatively low specific solids throughput making many filter units necessary to ensure target solids performance.
- High amount of sealing water required to provide for secure sealing of rubber belt.

3.3 High performance disc filter

The recently developed big diameter disc filters aid seed filtration in the alumina industry and in the dewatering of coal slurries. The disc filter (Figure 1) is now applied to paste dewatering. The main features of the new disc filter are as follows (Bott et al. 2008):

- Minimised pressure drop leading up to 100% higher pressure difference at the filter cloth, compared to conventional disc filters.
- Double capacity, compared to conventional disc filters.
- Filter speed of 6 rpm.
- Easy maintenance.
- Fully automatic operation.

Disc diameters range from 1.7, to 4.2, to 5.6 m. For filtration of large slurry feed rates, such as tailings, a filter with large disc diameter of 5.6 m (L-type) is the appropriate filter size; this is available with one to four filter discs. A more detailed description is given by Hatzenbühler et al. (2013).

These disc filters can be operated in a fully automated mode and thus can react online to changes in the filtration properties of the thickened tailings to maintain the required moisture. Furthermore, modern disc filters are very reliable with regard to cake discharge, no matter how much fines are fed or how the feed solids content changes. The operation, even with high amounts of fines and the constant cake moisture, allows use of tailings for mine backfill without the need to split it into fine or coarse fractions. This reduces the process equipment required, the investment cost and the amount of cement added to the tailings.

3.4 Conditions for use of a disc filter

Tailings operations are suitable for using a disc filter where the following conditions and targets apply:

- If the clay content in the solids is low,
- if mine backfill is processed,
- if the tonnage is >50 t/h and big filter sizes can be applied,
- if a moisture of >18 wt% is accepted,
- if energy efficiency is important,
- if there is a space constrain,
- in third world countries where little know how for operation has to be assumed,
- if amount of flocculent shall be limited; or
- if operation cost shall be minimised.

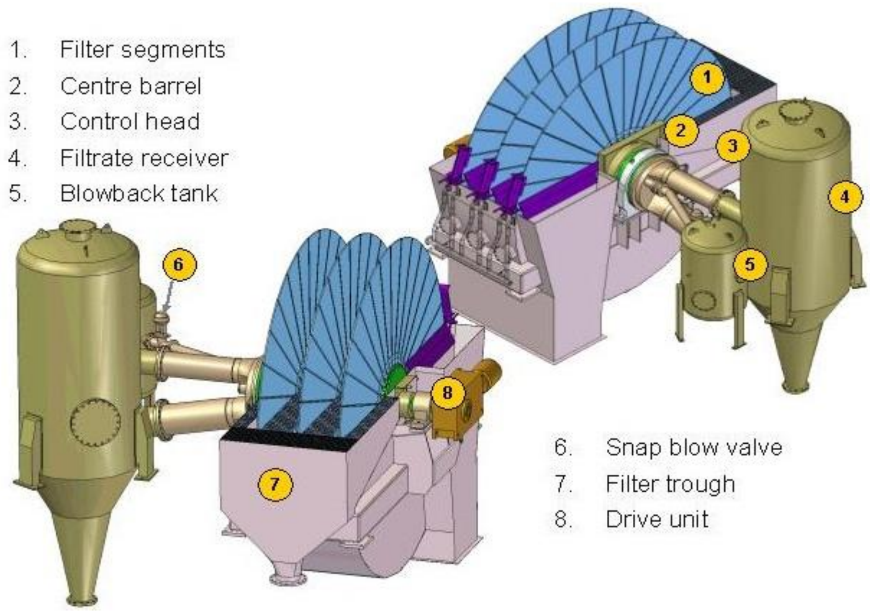

Figure 1 View of a Boozer disc filter with three discs

4 Filtration of gold/copper tailings with the Boozer disc filter

4.1 Filter layout

In the case of a copper and gold mine, the tailings are used for mine backfill. During layout tests the tailings consisted of particles with a mean diameter size of d_{50} of 20-30 microns and were thickened to >50 wt% in a thickener. Filtration tests with two tailing samples, one with a d_{50} close to 20 microns and one with a d_{50} close to 30 microns, were carried out.

Target values for solids throughput was 100 t/h and target filter cake moisture for the process was 23 wt%. The test results showed that the finer sample A reached 650 kg/m²/h specific solids throughput, and the coarser sample B reached 800 kg/m²/h specific solids throughput. It was shown that the required 100 t/h solids throughput can be achieved with one L4 disc filter with 176 m² filter area, which requires a minimum specific solids throughput of 568 kg/m²/h to ensure target solids throughput of 100 t/h. The chosen filter size in fact allowed for a peak throughput of 114-141 t/h, which leaves a significant safety margin in the filter sizing. Depending on the modern design and operational flexibility, this extra capacity can be converted into improved moisture during filter operation (online).

Layout diagram is shown in Figure 2. A more detailed description of filter tests and filter layout is given by Hatzenbühler et al. (2013).

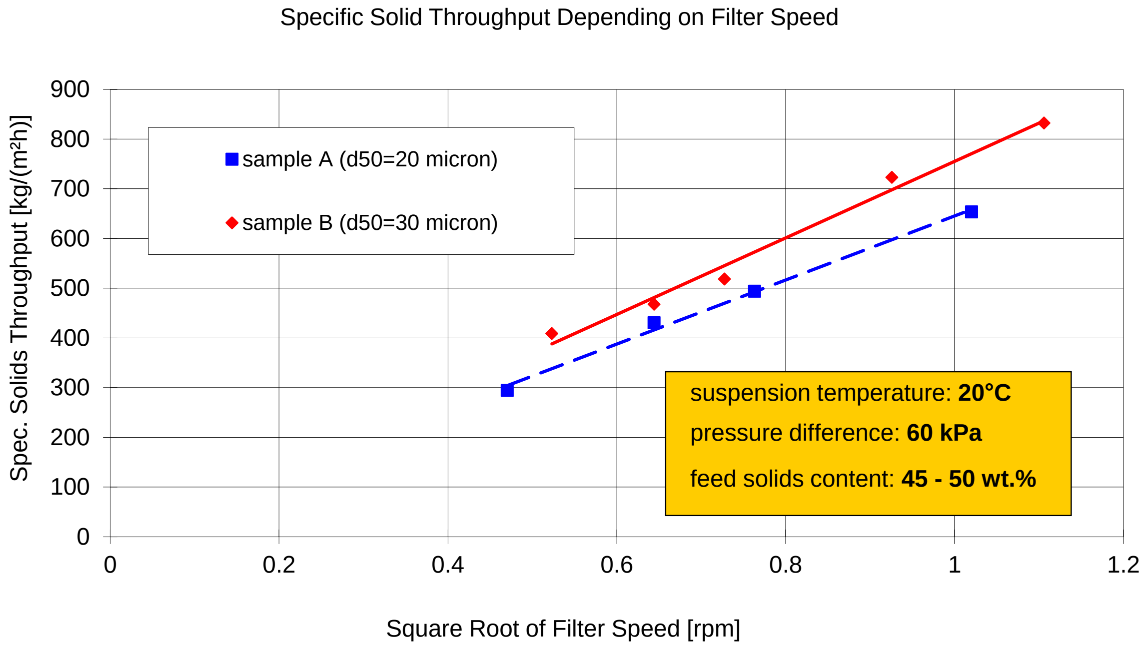

Figure 2 Layout diagram: specific solids throughput versus square root of filter speed; the height of filter cake ranges from 8-15 mm

4.2 Filter commissioning and filter performance after three years of operation

According to the filtration test results, a disc filter with four discs (L4) and a 176 m² filter area was chosen as the appropriate filter size for this tailing filtration application (Figure 3). During commissioning of the filter, the thickener was not in constant operation. Therefore, the filter was fed with feed solids down to 25 wt% and almost no flocculant was added. Due to these harsh conditions, the filter was building a cake of only 3-5 mm thickness. Nevertheless, the filter was discharging almost all of the solids and the moisture content was almost below 20 wt%.

After addition of flocculant, the cake thickness increased immediately to more than 10 mm, sometimes more than 20 mm, and the specific solids throughput was up to almost 1,000 kg/m²/h with moisture contents in the range of 21-23 wt%.

Figure 3 Disc filter with 176 m² filter area (L4) assembled in the gold/copper mine; view of control head side (left); and view of the four filter discs with walkways (right)

After three years of operation the filters are in excellent condition which is a result of the preventive maintenance concept of the plant. Characteristics of the slurry have changed since filter commissioning, with respect to particle size distribution. The mean particle diameter increased from d_{50} = 25 µm to d_{50} = 40 µm which effected an increase of filter solids performance to solids throughput rates higher than needed. As a consequence, flocculant dosage could be reduced step-by-step and currently the filter is operated without flocculant.

Filter performance achieved:

- Solids throughput rates of 110 t/h.
- Residual cake moisture of 19-22 wt% (Table 1).

5 Comparison of investment and operational cost

A comparison of investment and operational cost highlights the benefits of modern disc filters over other technologies in tailings dewatering such as the horizontal belt filter type and filter presses. The data shown in Tables 1 to 3 refer to the operational data presented in Section 4.3. Slurry data and filter data for the disc filter, belt filter and filter press are shown in Table 1. For a solids throughput of 110 t/h, a disc filter with a 176 m² filter area is required or alternatively one filter press with 500 m² or five horizontal belt filters of 140 m² each would be necessary for this dewatering task.

First of all it is important to use the different filtration equipment in the most efficient way in order to minimise both CAPEX and OPEX. For the filter presses the frame conditions for efficient use are:

- Reduction of cycle time to achieve high solids throughput (use of membrane).
- Apply cleaning system to ensure feed lines to remain operational.
- Allow for manual check of cake discharge.

For the horizontal vacuum belt filter the frame conditions for efficient use are:

- Belt speed high with approximately 12 mm cake thickness (minimum for cake discharge).
- Consider cake scraper and constant cloth wash.
- Consider flocculant dosage for improved performance and clean filtrate.

For the vacuum disc filters, the frame conditions for efficient use are:

- Operation speed high with approximately 6 mm cake thickness.
- Use of high speed disc filters with improved cake discharge to ensure reliable discharge of thin filter cakes.
- Consider flocculant dosage for improved performance and clean filtrate.

Accordingly, the basis for the layout calculation of the required filter sizes for this technology comparison is the minimum cake thickness that can be discharged from the disc filter ($h_{C,\ min}$ = 6 mm), or the belt filter ($h_{C,\ min}$ = 12 mm), respectively, and the minimum cycle time for the filter press ($t_{cycle,\ min}$ = 10 min.).

Table 2 shows the investment cost for the three dewatering technologies, whereas Table 3 presents the operational cost. The total investment cost, including cost for filter units, receivers, drives, auxiliary units and building cost amounts to AUD 3.82 M for the disc filter which is far less than the investment cost of AUD 5.4 M for the filter press, and AUD 16.5 M for the belt filter (Table 2). Additionally, the disc filter has the lowest operational cost, including maintenance and spare parts cost, which amounts to AUD 0.49/t whereas the operational cost for the filter press and for the belt filter type sum up to AUD 0.69/t and AUD 0.78/t (Table 2). This leads to annual cost savings in filter operation of about AUD 173,000 compared to the filter press, and about AUD 245,000 compared to belt filter operation.

Table 1 Slurry data and filter data of disc filter, filter press and belt filter for filtration of 110 t/h of tailings for mine backfill (d_{50} = 40 µm)

Slurry and filter data		Five horizontal belt filter	One Boozer disc filter	One filter press
Filtration area per unit	m^2	5 × 140	1 × 176	1 × 500
Specific solids throughput	kg/m^2h	160	625	220
Solids content in feed	wt%	50	50	50
Flocculants	g/t	0	0	0
Cake moisture content	%	19-22	19-22	15-18
Solids throughput per filter	t/h	22	110	110
Cloth change	sets/a	5 × 0.5	1 × 12	1 × 4
Power (filter, hydraulics, compressor, vacuum, pump, etc.)	kwh	5 × 100	1 × 300	1 × 400
Required filter units for 100 t/h	-	5	1	1

Table 2 Investment cost including filter units, receivers, drives, auxiliary units and building cost (cost basis in EUR, currency translation: 1 EUR = 1.5 AUD)

Investment cost		Five horizontal belt filter	One Boozer disc filter	One filter press
			Per filter unit	
Filter cost with receivers and drives	AUD	5 × 900,000	1 × 1,125,000	1 × 2,100,000
Auxiliary units with necessary vacuum pumps, compressor, hydraulics, etc.	AUD	5 × 150,000	1 × 450,000	1 × 600,000
Building cost with piping and electrical installation per unit	AUD	5 × 2,250,000	1 × 2,250,000	1 × 2,700,000
			For all units	
Total investment cost	**AUD**	**16,500,000**	**3,825,000**	**5,400,000**

Table 3 Total operational cost and specific operational cost (cost basis in EUR, currency translation: 1 EUR = 1.5 AUD)

Operation cost		Five horizontal belt filter	Boozer disc filter	Filter press
Power consumption total	kW	3 × 100	1 × 300	1 × 400
Specific energy cost	AUD/kWh	0.15	0.15	0.15
Operation hours	h/a	8,000	8,000	8,000
Filter cloth exchange	sets/y	5 × 0.5	1 × 12	1 × 4
Specific cost for cloth	AUD/m^2	60	30	150
Annual energy cost	AUD/y	600,000	360,000	480,000
Annual cloth cost	AUD/y	21,000	43,200	39,000
Flocculent	AUD/y	0	0	0
Maintenance and spares	AUD/y	60,000	33,000	90,000
Total operational cost/year	**AUD/y**	**681,000**	**436,200**	**609,000**
Specific operational cost	**AUD/t**	**0.78**	**0.49**	**0.69**

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