

Simulation of Tailings Filtration Performance

Jason Palmer

Metso-Outotec, Australia

ABSTRACT

Tailings filtration is growing in interest with increased pressure on water resources and Tailings storage facility legislation. In greenfield projects limited sample is available to evaluate filtration performance and often composite samples to represent mineral recovery are utilised.

The mineral resource over the life of the mine can be variable and small changes in clay or other material can have significant effects on the filterability.

This paper looks at methods to predict filterability of a tailings stream with changes in mineralogy. Based on initial testwork and historical database information, mineralogy and particle size data can be analysed in HSC SIM to predict the rate and achievable moisture. Together with plant model information, alternative dewatering strategies can be evaluated to determine the capital and operating costs.

INTRODUCTION

Mine planning and realisation start with geology, detailed information on mineralisation is usually collected in the early stage of a project. As the responsibility shifts from mine planning to mineral processing, the focus moves from the major body of the resource to the desired mineral or final concentrate.

In the past, the properties of tailings where disposal is in a wet tailings dam were often a minor consideration. With a shift towards filtered tailings, the properties and the variability of the tailings takes on more importance.

MODELING OF CAKE FILTRATION

Multiple theories have been developed to describe cake filtration. Many early models describe the flow of liquid through the cake using a capillary analogy to explain and predict filtration performance. One of the simpler and reliable theories is the Darcy equation (equation 1) where the rate Q is proportional to the cake resistance, area, pressure and viscosity of the slurry to be dewatered. This explains the formation of a filter cake from a slurry.

$$Q = K \frac{A\Delta p}{\mu L} = \frac{A\Delta p}{\mu R} \quad (1)$$

$$V = \frac{\pi \times r^4 \times \Delta p \times t}{8 \times \mu \times L} \quad (2)$$

$$\alpha_{av} = \frac{5 \rho_s SSA^2 (1-\epsilon_{av})}{\epsilon_{av}^3} \quad (3)$$

(1),(2),(3)refer to the nomenclature at the end of the document

Hagen- Poiseuille's (equation 2) formula further relates the filtrate flow to the particle size or more specifically the diameter of pores in the cake. The value r is the pore diameter and is difficult to measure. A relationship to the particle size is more useful.

In equation (1) the Kozeny constant K depends on the structure of the cake, and it is typically assumed to be 5.0 for randomly packed incompressible beds (Grace, 1953; Tiller, 1953). Equation (1) can be further modified and written in terms of average specific cake resistance, to give Equation (3). Equation (3) now clearly shows that the relationship between the average specific cake resistance and specific surface area should be quadratic if the cake porosity remains constant.

The use of equations (1) and (2) for predicting the values of filtrate flow or cake resistance is reasonable. The applied pressure in filtration has a direct influence on the packing structure of the bed, thus influencing also several other parameters in the equations (Häkkinen et al., 2008). Sperry (1916) and others added a second resistance for the filter media to improve the models, however, all

are based on the assumptions, the state of the cake with the compressive stress and assumed the particles' diameters are within an order of magnitude.

To compare the predictability of capillary based models we can look at filterability of different slurries where viscosity and void fraction are kept constant and specific surface is compared to cake resistance. Specific surface itself is quite complex to measure accurately with some variability depending upon the measurement procedure. Particles with porous structures show very high surface areas and measurements that consider mean diameters give better comparison to filtration tests. Despite selecting samples with relatively homogeneous materials, as shown in Figure 1, some material correlated well and others not. As a methodology for analysing unknown samples the theoretical approach has some limitations. When extending this approach to tailings with diverse compositions and clays with large surface areas compared to their mean diameter, theoretical modelling from specific surface should be used with caution. Where the model can be compared to filtration data, the model can be refined, and the accuracy greatly improved.

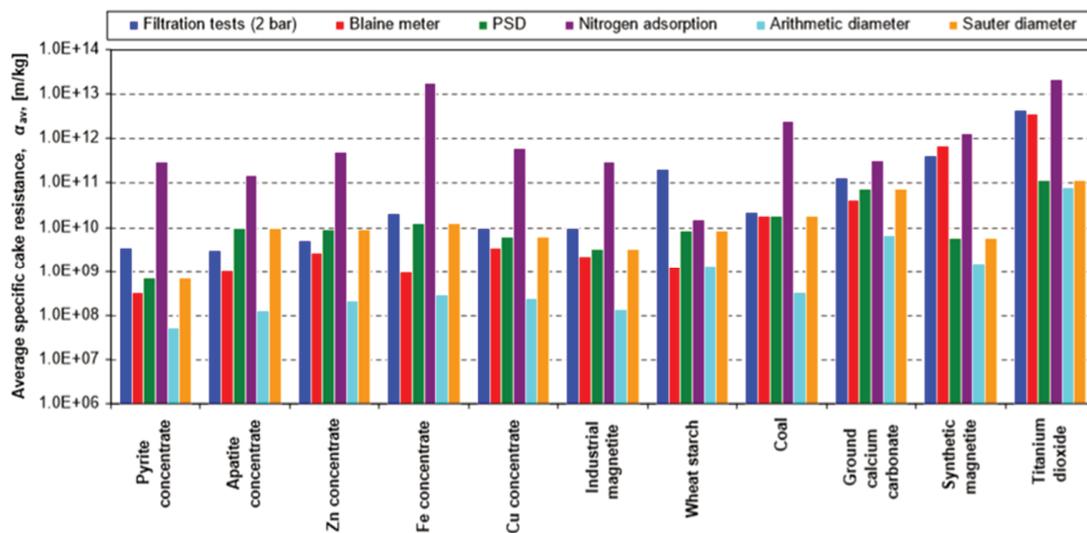


Figure 1 Filterability vs specific surface area

In industrial filtration operation, there is significantly larger variability of type and slurry particle sizes than in laboratory experiments. When the major particles retain to form a cake, a fine material (slimes and clays) penetrates the cake, moving with filtrate forming non homogenous cakes. Ignoring the effect of fine particle retention could lead to an overestimation of the compression effect on cake permeability, since a small amount of fine retention may significantly blind a cake.

Rheological models take compressive yield stress and the hindered settling rate as functions of the local volume fraction.

In general, the performance of a filtration of non-Newtonian slurry depends not only on the rheology of the dispersion medium of slurry, but also on the properties of the filter cake, such as the porosity

and specific filtration resistance of the cake. Micro structure and Monte Carlo models further help explain filtration behaviour, however definition of particle parameters from mineralogical data is difficult and these were not utilised.

In cake filtration, cake formation and growth is a particle-packing process. Particle packing is never ordered but random in actual filtration. Extensive modelling (Ni 2001) of the solid flow by Discrete Particle Method (DPM) is at the individual particle level, whilst the fluid flow by Continuum Fluid Method CFM is at the computational cell level.

By combining CFM with DPM, studies of cake filtration give results that are comparable to those obtained by the above Monte Carlo method to a large degree, both models exclude van der Waal forces. Once again despite the accuracy and sophistication of these models they do not represent a method to accurately model complex mineral slurries.

To enable simulation in HSC Chemistry® a permeability and cake formation rate proportional to particle size is required and more complex simulations were not used. While effective in analysing test data, few models can predict the expected performance from mineralogical data, and physical testing remains the best methodology for determining filterability and is used as an input to the model where possible.

The filterability is also defined by the equipment selected and the particles in the slurry fed to the filtration equipment. Various factors affect filter performance. Temperature, viscosity, and soluble solids concentration determine the liquid properties whilst particle size and shape, the way they are concentrated will define the resistance to liquid flow through the cake and particle surface interactions and pore size will determine the extent to which gas can displace liquid.

TEST ANALYSIS OF VARIABLE PARTICLE SIZES

The filterability of tailings slurries was experimentally studied to see the differences between the filterability of coarser and finer fractions, obtained from hydrocyclone separation of a tailings stream. A feed sample of 97.3kg was split to an overflow of 29.4 kg and an underflow of 67.9 kg. As a benchmark the filterability of the feed material gave a rate of 3200 kg/m²h. The coarse fraction was significantly easier to filter and capacities up to 9000 kg/m²h were achieved. The slimes fraction was very difficult to filter and at 1000 kg/m²h the slimes requires a similar sized filter to whole tails filtration. (see figure 2)

This dependence of filterability on the fines fraction indicates that a model built on the filterability of the fines fraction as a rate limiting value, with coarser material added as ballast to modify capacity and moisture. In vacuum filters the maximum capacity is not limited by cake thickness, compared to pressure filtration where chamber volume and machine function limit filtration rates with coarse material.

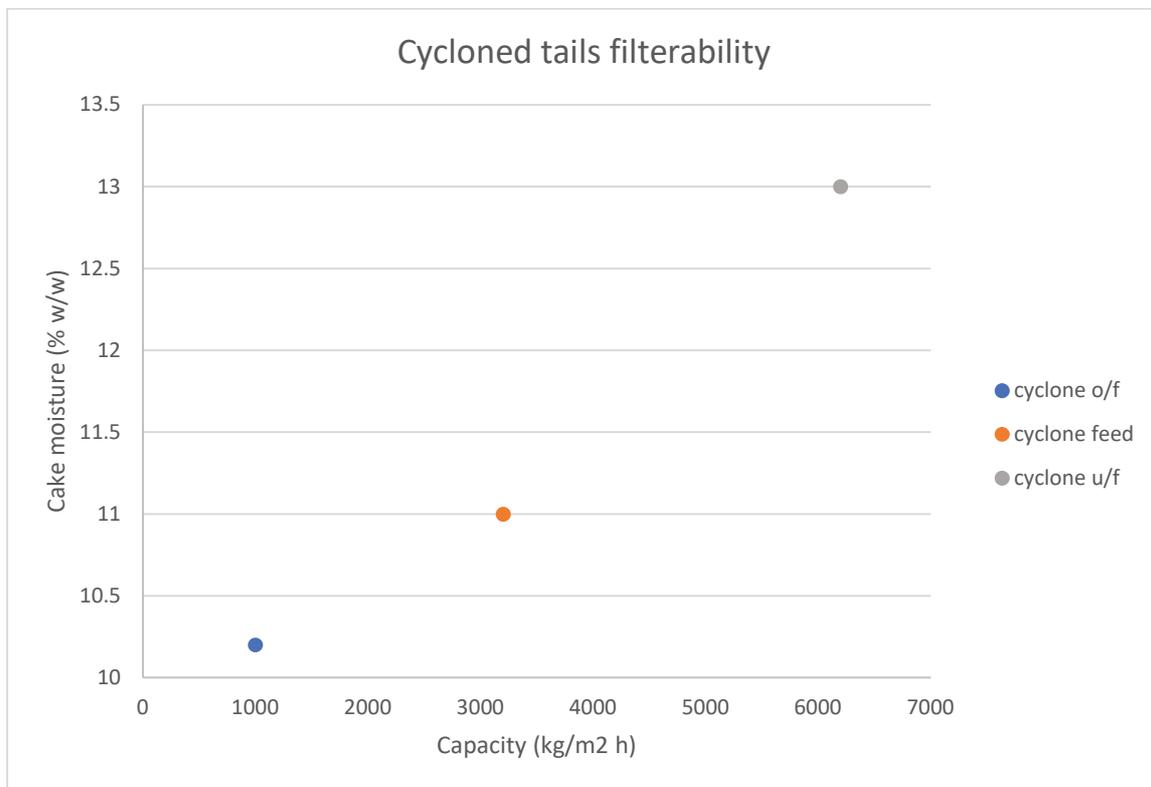


Figure 2 Hydrocyclone separated tails filterability

Filtration models and industrial scaleup

Filtration models for complex mine tailings can be constructed from a combination of theoretical models and laboratory test results. Rather than selecting composite samples as a baseline, samples that represent the more difficult materials should be tested and used for the model. Clays and oxidised materials should be tested if possible.

Where insufficient material exists to conduct filtration testing, specific surface measurements can be useful in predicting cake resistance. Mineralogical analysis data allows data of similar minerals filterability to be used and the rates can be modified to suit the expected ore composition.

The cake resistance, while important, may represent only a small fraction of the industrial scale equipment performance and the model needs to be customised to the preferred filtration technology. In addition to cake resistance models, cake moisture also needs to be considered. Filtered tailings for dry stack disposal need to be dewatered to a moisture defined by geotechnical properties, the required moisture will be below the saturated cake moisture and some form of gas displacement of filtrate in the cake is required to achieve the process targets. Testing is preferred however pore pressure analysis can be useful in selecting the correct filter technology or estimating the achievable filtered cake moisture.

The required differential pressure to exceed the capillary pressure can be calculated using several equations. One equation predicts the pressure from surface tension, as shown in Equation (4), and it is a function of the pore diameter D , surface tension τ and the solid wetting angle θ . Unlike flotation concentrates, tailings generally have a hydrophilic surface and a large wetting angle that increases the threshold pressure. (Wakeman, R.J. and Tarleton, E.S. (2005))

Alternatively, when considering gas flow displacement, the relative permeability models of Lloyd and Dobbs (equation 5), can be applied. This model can be used to predict the threshold pressure required for airflow.

Airflow is an important parameter and the saturated void fraction gives a good starting cake moisture, to relate the final moisture to capacity a decay model taken from filtration data is required. To estimate the required geotechnical moisture extensive testing is usually required, where this is not available plastic limit and liquid limit data can be utilised to estimate a geotechnical stacking moisture.

By combining a model of cake filtration and cake drying with machine parameters, reasonable predictions of filter performance can be estimated. In addition, the gas flow model utilises parameters available in HSC Chemistry®

$$\Delta p = \frac{4\tau \cos\theta}{r} \quad (4)$$

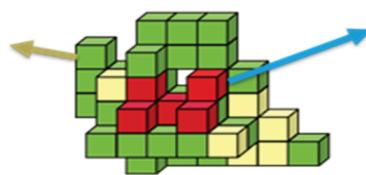
$$P_b = \frac{4.6(1-\varepsilon)\sigma}{\varepsilon d} \quad (5)$$

Filtration models and Geometallurgical characterization

Compared to product dewatering where tailings are filtered, the operating costs can be significant. Filtration models can be included to Geometallurgical models to assist economic evaluation of ores. The results of mineralogical characterization, ore grindability, Bond W_i , and the locked cycle flotation and dewatering tests can be reprocessed with HSC Chemistry® 9 Data module utilizing linear regression analysis and principal component analysis.

Geometallurgical approach Block model information

- Traditional**
Information in a block
- Block ID
 - Location
 - Grade
 - Density (SG)
 - Lithology



- Geometallurgical approach example**
- Resource
 - Block ID
 - Location
 - Elemental grades
 - Mineral grades
 - Chemical composition of minerals
 - Physical properties
 - Hardness
 - Grain size
 - Texture
 - Density
 - Metallurgy
 - Recovery functions
 - Property based parameters
 - Process model & simulation
 - Throughput (t/h)
 - Grade
 - Recovery
 - Operating cost
 - Scenarios
 - Production alternative
 - Metal prices
 - Consumable prices
- Relevant information for processing, environment, economic modeling etc. included in the data structure and block model, and can be utilized throughout the operational cycle.**

20 1/15/2020

Introduction to geometallurgy

CONCLUSION

While filtration testing is the best method of quantifying plant performance, filtration models are also effective tools. Models can be utilised to analyse the effect of variability of ore type and when combined with process simulation and plant economic models, they can help define the optimum solution for planned mineral processing plants.

Identifying the variability within an ore deposit and understanding the mineralogical composition and the metallurgical performance of the various ore types are key requirements for efficient mining and minerals processing plant evaluation.

ACKNOWLEDGEMENTS

The author would like to acknowledge Outotec for their assistance in this paper and for granting permission to publish.

NOMENCLATURE

Q	Filter capacity (kg m ² /h)
K	Filtration resistance
Δp	Differential pressure
μ	Viscosity
A	Filter area (m ²)
L	Cake thickness (m)
V	Filtrate volume (m ³ /h)
r	Pore diameter (m)
ε	void fraction.
SSA	Particle surface area
ρ_s	solids density
P _b	threshold pressure.
σ	solids volume fraction.
d	particle diameter.
θ	wetting angle.
τ	surface tension.

REFERENCES

- Palmer, J. Operational results and future trends of filtration technology in minerals processing, XV Balkan Mineral processing Conference, 2013
- Linan Ni, Modelling and Simulation of Cake Formation In Cake Filtration Process, Faculty Of Science And Technology The University Of New South Wales, Thesis, 2001
- Safonov, D, Häkkinen Blaine surface areas of Hematite samples, Lappeenranta University of Technology 2015.
- Liipo, J., Hicks, M. Takalo, V-P., Remes, A. Talikka, M., Khizanishvili, S., and Natsvlishvili, M. Geometallurgical characterization of South Georgian complex copper-gold ores. The Southern African Institute of Mining and Metallurgy, 2019