Pressure Filter Feeding Methods: Case Study

Maycon Silva*
Vale, Brazil

ABSTRACT

A new trend in Brazilian iron ore beneficiation processes is the concentration of ultrafine minerals. Such minerals are currently disposed in dams or similar structures despite having a high iron content. With the development of new reagents and new concentration methods, it was possible to concentrate this type of material, however, the tailings from the concentration of these materials must still be disposed.

Another upward technique in iron mining in Brazil is the disposal of filtered tailings in the tailings pile (PDR). In order to be able to dispose of ultra-thin materials in the aforementioned manner, it is necessary to perform the filtration using the press filter technology, which is the most suitable to process this type of material.

In press-type filters the dewatering is somehow accomplished through the pressurization offered by the pumping system responsible for feeding the filters. The present work aims to present a case study of filtering of ultrafine tailings essentially addressing the various ways studied for feeding and pressurizing filter presses through variations between available technologies.

To evaluate the best feeding method, pilot scale tests were performed to determine the specific filtering conditions of ultrafine material. Parameters such as pumping time, filtering time and total cycle time were determined from which scale-up factors were applied to enable the sizing of pumping capacity on an industrial scale.

Finally, data from similar systems were used to calibrate the resistance curve of the cake and the AFT Fathom software based on Wilson's theory for mineral slurry handling was used to evaluate possible feed forms. Items such as energy consumption, pumping pressure stability, dewatering efficiency and acquisition cost will be compared.

INTRODUCTION

Filtering Operation Using Press-Type Filters

Filtration using press-type filters uses the pressure difference provided by an external pumping system to dewater the solid material. Pumps of various types can be used to induce the pressure differential, among which the centrifugal pumps can be highlighted in general, in addition to the volumetric pumps commonly called positive displacement pumps.

The material is pumped into the filter and distributed among the various chambers of the equipment. This stage, called feeding, is responsible for a large part of the dewatering, however, the pumping pressure in this stage does not undergo significant increases, being basically the intrinsic resistance to the equipment itself plus the still low filtering resistance.

When the equipment chambers are full of slurry and the material occupies the entire filtering area, there is a gradual increase in the local filtering resistance, leading to an increase in the pump pressure. This stage of the cycle is called the compression of the cake and the volume of water removed from the cake (filtrate) is less than in the stage of filter feeding.

If the material does not reach the required humidity, some filters also have the drying step, which is carried out, in many cases, with the injection of compressed air in membranes parallel to the filter plates, thus performing the last dewatering step. After this stage, the hydraulic cylinders of the filters relieve the chambers sequentially by discharging the properly filtered material. Figure 1 below shows the scheme of the operation:

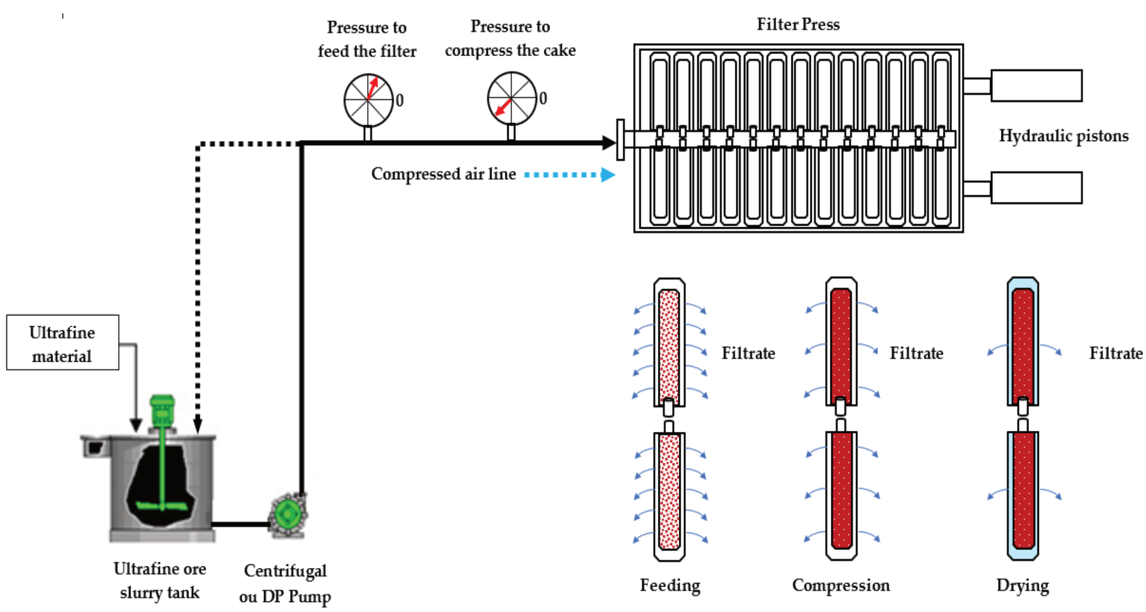

Figure1 Principle of operation of the filter press

Project Characteristics

The project object of this article aims to filter 250.0 tons / hour of material from the concentration of ultrafine to later incorporate into the product of the beneficiation process. To characterize the material and verify the fundamental properties of the filtering process, several exploratory tests were carried out on a pilot scale. The following table presents the results obtained with the execution of the pilot tests carried out with an average supply pressure of 8.0 Bar.

Table 1 Average data of tests performed

Characteristics	Slurry	Feeding	Compression	Drying
	Tank	Filter press		
Average time (min)	-	1.0	0.5	3.0
Slurry Volume Fed (l)	-	19.8	-	-
Filtered generated during step (l)	-	11.64	2.75	-
% Solids (%)	47.0	74.5	86.5	89.7
% Water (%)	53.0	25.5	13.5	10.3
Slurry Density/Torta (kg/l)	1.593	2.44	2.51	2.42
Total ciycle time (min)	7.5			

As the tests were carried out on filters for pilot tests, the feeding, compression and drying times are shorter when compared to the process on an industrial scale, so it was necessary to adjust the total cycle based on some similar operations. After the application of the scale-up factor calculated due to the difference in total volume between the industrial filter and the test filter, the cycle shown in Table 2 is arrived at below:

Table 2 Adopted cycle time

Datas	Feeding	Compression + Drying
Technical time + Dead time (min)	10.0	20.0

From the data of cycle time, unitary filtration rate and information about the desired process such as rate, humidity, among others, the sizing of the industrial filtration was carried out, which remained as indicated in the table below:

Table 3 Industrial characteristics of ultrafine filtration

Datas	Press filtration
Nominal production of the beneficiation plant (t/h)	314.6
Project production (t/h)	377.5
Unit filtration rate (kg/h/m²))	299.3
Filtering area (m²)	1 261.0
Number of filters (und)	3.0

System Modeling Criteria

The total cycle time weighted by the scale factor and by experiences in similar operations was also used to determine the operating conditions of the feed pump. To this end, the following equation was applied, which relates the rate, the pumping time and the number of cycles necessary to achieve the desired production:

$$\dot{Q}(t/h) = \left(\frac{Total\ rate}{Cycles}\right) \times \left\{\frac{60\ seg}{(Cycles \times pumping\ time)}\right\} \tag{1}$$

From the rate calculated using the equation above and knowing the characteristics and physical parameters of the slurry, the operating conditions of the pump are shown in Table 4 below:

Table 4 Feed pump operating conditions

Datas	Feed filter press
Rate per pump (t/h)	188.8
Flow Rate (m³/h)	331.3

Cake Strength and System Modeling

To determine the hydraulic resistance curve of the cake, the ideal method would be to adopt an empirical approach in a process with similar characteristics relating the pressures and discharge flows of the pumps, with the respective energy consumption and after algebraic work, model an equation that relates such quantities with the hydraulic resistance of the cake. However, for the present work, the estimated average resistance value was determined by correlating the flow reductions from the dewatering obtained in the pilot test, with the system curve and the pump curve for each flow reduction. Figure 2 below shows mentioned correlation.

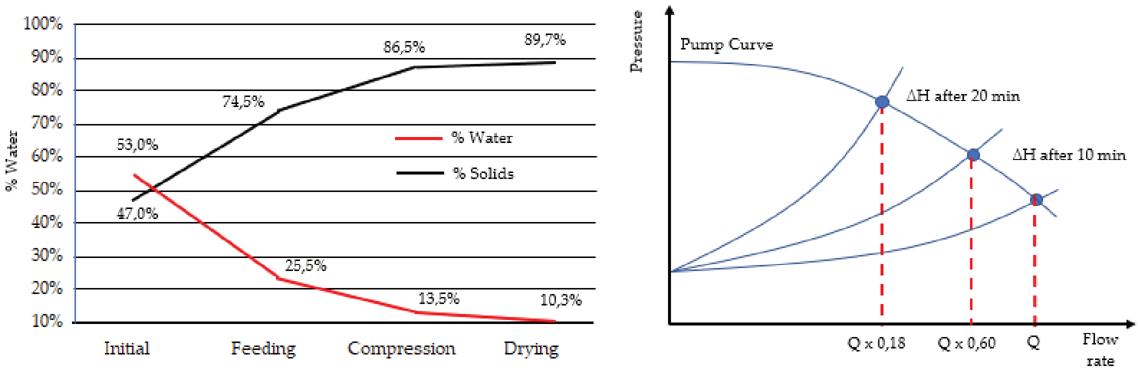

Figure 2 Conditions used for modeling cake strength

To carry out the evaluation, the AFT Impulse software was used to determine the pressures and flow rates during the filtration processes. Figure 3 below shows the model used as well as the calibration of the cake resistance curve.

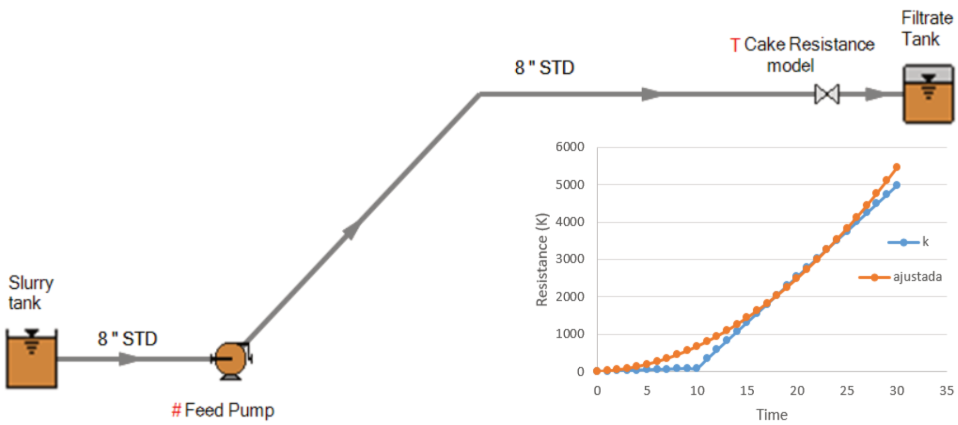

Figure 3 Model used in calculating the system and cake resistance curve

RESULTS AND DISCUSSION

System Evaluation with Centrifugal Pumps in Series and with positive displacement

Pumping by centrifugal pumps is highly dependent on the resistance conditions of the piping. It is noticed a reduction in the flow with the increase of the resistance of the cake, so that the pressure stipulated in the test must be treated as a average condition due to the difficulty of stabilizing the pressure. Figure 4 below shows of pressure and flow variation over the established time.

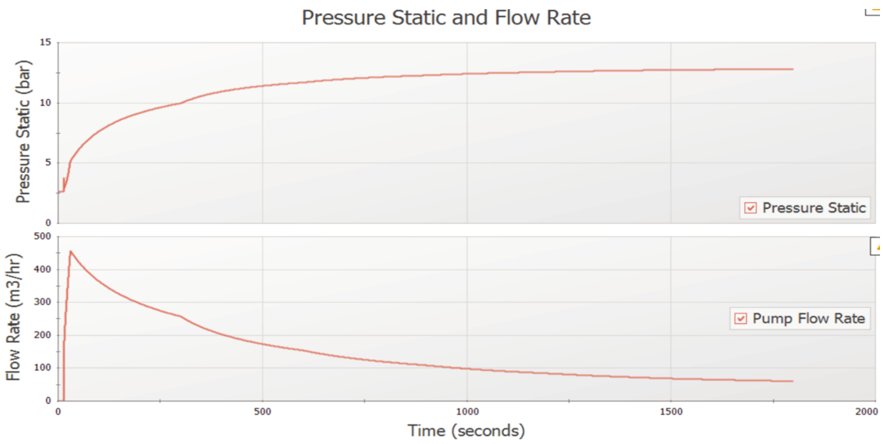

Figure 4 Operating condition of the filter feed centrifugal pump

For positive displacement (PD) pumps the pressure variation condition was also verified, that is, even if positive displacement pumps have a constant discharge pressure for any flow, it is necessary to establish a resistance to provide the pressure increase in the positive pump displacement. The advantage is that the flow rate remains constant during the settlement pressure stabilization process.

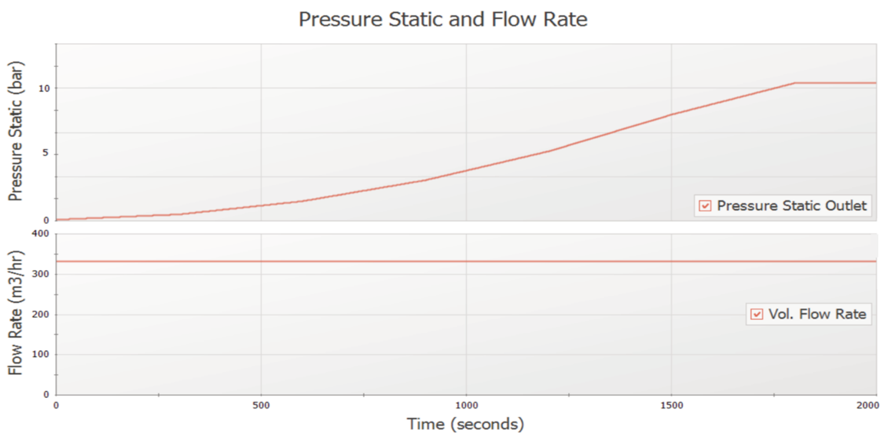

Figure 5 Operating condition of the filter supply PD pump

Pressure and Flow Stability Assessment

The direct implications of the pressure and flow differences shown in the figures above are diverse. Firstly, in installations where centrifugal pumps are used, the pressure is usually higher during the compression period even when is not necessary. This is because with the exponential increase in the filtration resistance the pump approaches the shut off where the pressures are higher as a result of the lower flow rates. In the case of PD pumps, this condition is best addressed because the pump has a mechanical limitation and offers only the necessary pressure as the resistance provides the necessary back pressure and the cycle ends. This condition can lead to lower pressures when using PD pumps. See Table 5 below:

Table 5 Discharge pressure of filtration feed pumps

Pump type	Maximum Pressure
Centrifugal pump	12.4 Bar
Positive displacement	10.2 Bar

Evaluation of total filtration cycle

Another important point is the optimization of cycle time. Comparing the two figures presented above, the flow rate of a PD pump is more stable and does not vary due to the operating conditions of the filter. This leads to faster filling of the filter and a reduction in total cycle time of the order of 7.0%. Even if the centrifugal pump starts the cycle with greater flow, the situation is reversed as the mineral cake offers hydraulic resistance, forcing the flow drop in the case of centrifugal pumps.

Evaluation of Energy Consumption

Evaluating Figure 4 it is possible to notice that the most critical request in the centrifugal pump in terms of required power does not occur at the point of maximum flow. This is because the discharge pressure is not high at this point and the hydraulic performance of centrifugal pumps is higher at higher flow rates. The positive displacement pumps, in turn, in addition to having higher mechanical performance, have a well-established flow throughout the cycle and the discharge pressure reaches its maximum at the end of the cycle when the pie resistance offers the necessary back pressure. Table 6 below shows the expected energy consumption for the two pump models studied in the article.

Table 6 Energy consumption of filtration feed pumps

Pump type	Time	Energy consumption	Drive Installed
Centrifugal pump	250 s	170.6 kW	250 HP
Positive displacement	1 700 s	158.5 kW	250 HP

Evaluation of acquisition cost

Due to their robustness and manufacturing conditions, positive displacement pumps have a higher acquisition value compared to centrifugal pumps. In general, and based on quotations carried out for the present project, in addition to other market references, the value of positive displacement pumps has a cost between 2.36 to 3.82 times the value of a centrifugal pump for a same operational condition.

CONCLUSION

After making the comparisons, it was found that both solutions have the appropriate benefits. Centrifugal pumps have a lower acquisition cost, however, they require a greater quantity of equipment in series or the use of double or triple stage centrifugal pumps, which is not a problem. In addition, centrifugal pumps have a very defined pressure limitation due to the shut-off. This condition demands a dimensioning of the piping with higher pressures when compared to PD pumps. Positive displacement pumps, despite greater pressure and flow stability, have certain limitations for lower rates making it difficult to acquire pumps with lower flow rates, in addition, the lead time for positive displacement pumps, in many cases, is greater than the centrifugal pump. For the project in question, due to the advantages presented, double-stage centrifugal pumps were adopted.

REFERENCES

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