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THE IMPROVEMENT OF DISC FILTERS IN THE ALUMINA INDUSTRY

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In the European Bayer process disc filters are utilized to separate the seed hydrate from the spent liquor. The principal demand on this operation is a high specific throughput. A simulation program , based on the filtration theory, has been developed to compute the filtration rate of the disc filter and the uniformity of the filter cake thickness for different types of filter.The results indicate that the effective submergence of the discs has a significant influence on the filter capacity. An increase of the apparent submergence to 50% or more, leads to a wider cake formation angle. The filter speed can be increased significantly. A complete cake discharge is achieved. A modification containing all of these, leads to considerably higher throughputs. Furthermore the filter cake thickness becomes more uniform and the subsequent dewatering is more efficient. Examples of industrial filter plant improvements are given.

INTRODUCTION

In the production of aluminum hydrate the filtration process involves the separation of hydrate crystals from the caustic sodium aluminate solution. The hydrate crystals are recycled as seed to the precipitators and the filtrate is returned to act upon bauxite. The principal demand on this operation is a high slurry throughput, as the plant's production strongly depends on the filters' capacity.

Should the already installed units operate at their designed capacity but an additional throughput is required, then further filtering area must be added, or the existing units modified. The following demonstrates how the operation of disc filters can be improved and their capacity increased.

SIMULATION OF THE FILTER PERFORMANCE

A simulation program has been developed to analyse the various steps of the filter cycle and thus the disc filter performance. With this program, the effects of design and operation alternatives can be simulated. The results are valuable for both the design and the process engineer. One objective of the programm is to optimize the filter performance as well as to predict the influence of physical parameters (design, operation, product) without prior testwork. Thus the program is a valuable tool when increasing the filter's capacity by modifying its design and operation (1).

The program scheme is shown in Fig. 1; this mainly consists of three blocks. In block 1, all the physical parameters (such as geometry of the filter, product properties and operating conditions) can be found in the data bank or they are requested from the user as input data. Some parameters,for example the filter geometry, are already known. Others, like the cake resistance, have to be obtained experimentally.

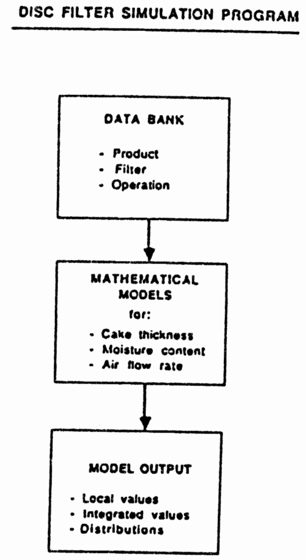

Fig. 1: Schematic of the simulation program

When the input is complete, the program executes the calculation in block 2. The models used here yield various values, such as:

- cake thickness
- moisture content
- air flow rate .

The results are presented either in a table or as a graph. As can be seen from the model output in block 3, the values for cake thickness (throughput), moisture content etc. are calculated for each point on the segment, which will be explained later. Thus the distribution of the values over a segment as well as their integrated mean can be determined. Some of the graphical results will be presented further on.

The model for cake formation is based on the filtration equation for incompressible cakes, whereas those for the dewatering and the air consumption are semi-empirical. The mathematical equations representing the model for incompressible cake formation are given in (2), whereby the influence of the hydrostatic head and the filter medium resistance are not neglected. The model assumes that the cake is discharged completely. More details of this are given in (3). Furthermore it is assumed that there are no hydraulic and pneumatic restrictions within and outside the filter.

In this paper the discussion is to be limited to modifications concerning the increase of the slurry flow rate and the solids throughput respectively. The cake formation rate for a continuously operating rotary filter may be given by the simplified equation:

$$\dot{m}_s = (1-\varepsilon)\cdot\rho_s\cdot\left[\frac{2}{\eta R_c}\cdot\kappa\;\Delta p\cdot\frac{\alpha_1}{360}\cdot n\right]^{0.5} \qquad (1)$$

where the concentration factor is given by:

$$\kappa = \frac{c}{(1-\varepsilon)\;\rho_s\cdot c} \qquad (2)$$

Analogeously to the cake formation rate the slurry throughput:

$$\dot{V}_{susp} = \frac{1}{c}\cdot(1-\varepsilon)\cdot\rho_s\cdot\left[\frac{2}{\eta R_c}\cdot\kappa\;\Delta p\cdot\frac{\alpha_1}{360}\cdot n\right]^{0.5} \qquad (3)$$

is obtained.

As can be seen (apart from the product parameters which can be considered as being invariable) the specific throughput can exclusively in its root dependence be changed by variation of the pressure difference within the filter segment, cake formation angle and filter speed. The possible throughput increase, however, is limited by the pressure difference for vacuum operation and also by the minimum cake thickness necessary to guarantee complete cake discharge.

To increase the filter capacity we can conclude from equation 3 that for invariable product parameters the following must be increased:

- pressure difference
- cake formation angle and
- filter speed.

The various possibilites to realize this as well as the limitations of the necessary modifications will be discussed in due course.

VACUUM SYSTEM

The vacuum pump is the most important accessory to vacuum filters, as it is the source of the filtration driving force and, in many installations, the item of greatest operating expense. In order to regard the effective vauum, however, we have to consider the whole vacuum system, i.e. the filter, the piping system, the filtrate receiver and the vacuum pump.

Figure 2 schematicly shows such a view of a filter station. Normally the vacuum pump yields a pressure difference that should be fully effective in the filter sector if there are no hydraulic and pneumatic resistances (bottle necks). Outside the filter and under practical plant conditions, even with well designed filtrate receivers there is frequently hydrate carryover into the vacuum pumps. Caustic as well as solids, inevitably, enter the vacuum system. The carryover occurs when the filter cloth is worn or the filtrate removal system is not functioning correctly.

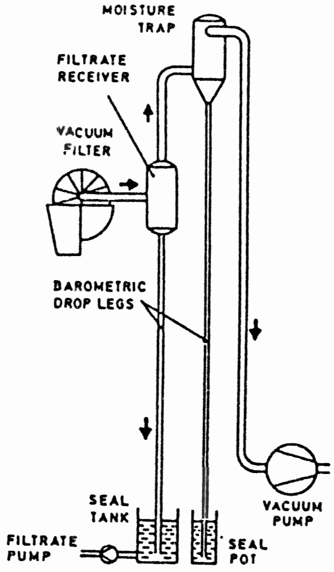

Fig. 2: Schematic diagram of a filter station

Moisture traps are often additionally used to prevent liquid carryover. The vacuum pump may tolerate such a stress, otherwise it fails and shuts down. In any case the solids deposit in the pipes, reduce the effective diameter, thus increasing frictional losses. With a barometric discharge, the drop leg may clog with solids.

As can be seen from eq. 1 the throughput increases with the pressure difference. Concerning vacuum filtration, the pressure difference obtained under normal conditions is about 0.3 bar to 0.5 bar. This depends on the product properties (permeability, particle size) as well as the vacuum pump capacity. The finer the solids, the higher the vacuum. The effect of increasing the vacuum is illustrated in fig. 3. The influence of the hydrostatic head, which cannot be neglected in this case, is also demonstrated. An increase from 0.3 bar to 0.5 bar increases the throughput by 28%. On the other hand, the throughput decreases rapidly with a vacuum drop. This may occur due to incrustations within the pipes (the pressure drop due to frictional loss increases by the inverse value of the diameter to the power of 5), leackage at the filter valve or reduced vacuum pump performance. It was observed in various filter plants that there was a significant pressure drop due to frictional loss caused by pipe incrustation or ineffective vacuum pumps. As a first step to improve the pressure difference, the whole vacuum system has to be checked in order to

- minimize frictional loss
- avoid leackage
- obtain optimum vacuum pump performance .

At this point it is necessary to recall that the existent pipe geometry was designed for the original throughput. If the throughput is to be significantly

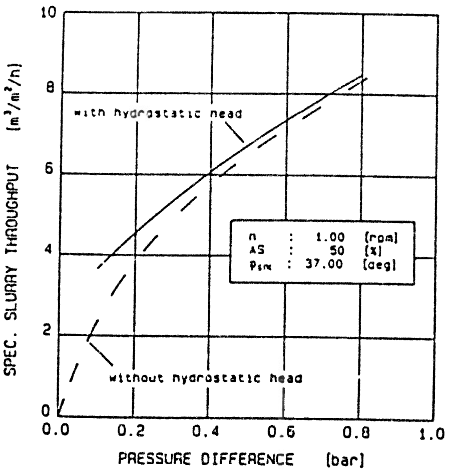

Fig. 3: Variation of throughput as a function of the pressure difference

increased, the entire piping system has to be checked regarding frictional loss increase due to the new and higher flow rates. Because the pressure drop increases with the square of the flow rate (for single phase flow), the piping system outside the filter will probably have to be redimensioned.

CAKE FORMATION

The slurry throughput increases with the cake formation angle (eq. 3). In the model used to compute the cake formation, the filter cloth resistance is included. The fact that the resistance increases permanently during the operation and the cloth needs cleaning with caustic after some hours of operation, is however, not yet included in the model.

Due to the disc filter principle the cake formation angle is not constant but individual for each location on the segment as can be seen in fig. 3 (4). The cake formation angle depends on:

- the bridge block location in the filter valve
- the submergence of the disc and
- the number of segments per disc.

By integration over the whole segment, a mean cake formation angle is computed. The cake formation angle shown in fig. 3, is the minimum value $\alpha_{,min}$ (for the inner location of the leading edge) and the others increasing respectively.

Figure 4 displays on the left a disc filter with 30 sectors and a submergence of 45%. The original bridge block location yields a minimum cake formation angle of 102 degrees.

On the right hand side, the same filter is shown with an apparent submergence of 50%. If the initial bridge block location is maintained, the cake formation angle increases to 127 degrees. The maximum cake formation angle with modified bridge blocks is 168 degrees. The submergence can under same circumstances even be deeper. If the slurry level is not regulated automatically, the vacuum shall start some degrees further to avoid that air is sucked into the segment.

The influence of the apparent submergence on the throughput is demonstrated in fig. 5. The lower 2 graphs represent the simple rise of the apparent submergence (up to 55%) whilst the bridge block location is maintained at the initial position. The upper graphs are computed for the maximum cake formation angle. The broken line represents a conventional filter with 10 segments and the full line representing the same geometry but equipped with 30 segments. The intersection of the graphs determines the minimum admissible submergence. The filter with 30 segments yields a higher throughput when the cake formation angle is maximum (upper curves in Fig. 5). If the initial bridge block location is maintained however, whilst the submergence increases, then the contrary occurs as the mean cake formation angle is higher for a wider segment (lower curves). In practice, the higher slurry level is realized by sealing the center shaft. Various solutions are available, even for conventional filters. The next step would be to adapt the bridge block location to the new submergence as

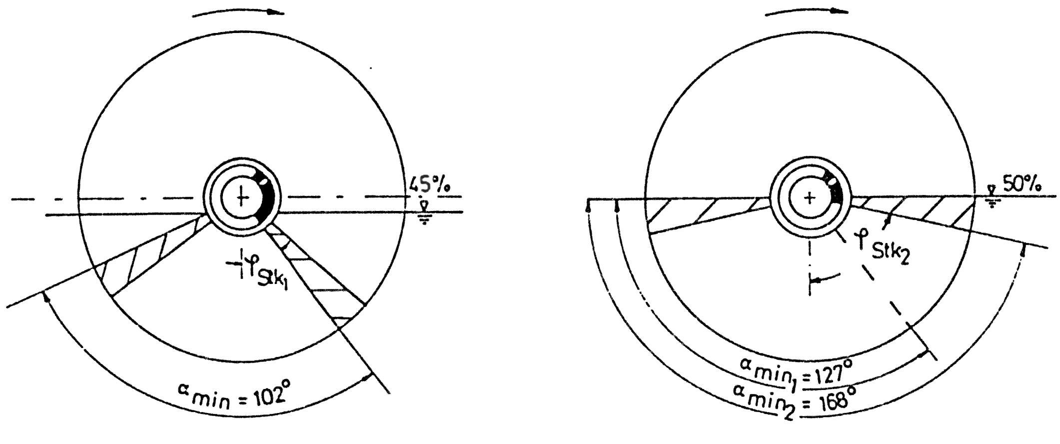

Fig. 4: Minimum cake formation angle for different bridge block locations and submergence of the disc

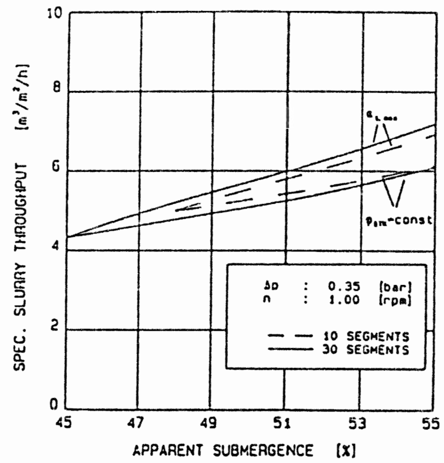

Fig. 5: Throughput as a function of the submergence

filtration can start earlier. Thus the throughput is again increased.

It was observed that with a deeper disc submergence, the vacuum tends to increase as the dewatering area is reduced. This will also increase the cake formation as well as the dewatering potential, thus compensating far the reduced cake dewatering angle. The moisture content will not necessarily become higher. Furthermore, the moisture content is not important unless the discharged cake sticks to the chute. In the model, the vacuum is considered constant for the different levels of submergence.

As an additional effect of raising the submergence a more uniform cake formation is achieved, as the difference between the minimum and maximum cake formation angle on a segment is reduced. The improved uniformity of the cake thickness yields a more efficient dewatering.

FILTER SPEED

As shown in eq. 3, the throughput increases with the filter speed. Normally, the filter speed varies by about 1 to 2 rpm. The vacuum and the cake formation angle can only be increased to a certain extent. The filter speed, however, can often be doubled or trippled with ease, thus rendering a production rate increase of 41% and 73% respectively, according to eq.3. Even conventional filter designs tolerate a higher speed. The only operation limit so far, is the minimum cake thickness necessary for a clean discharge. This minimum varies between 5 and 10 mm depending on the efficiency of the air blow back, the type of segment, the filter cloth etc. (5). Well designed filters operate with air pressure down to 0.1 bar and 100% discharge.

For the two filters shown in figure 6 the production rate increases with the filter speed as given by eq.3. In the same diagram it can be observed how the cake thickness decreases. Raising the filter speed results in a significantly higher throughput. Filter speeds up to 6 rpm have already been realized on an industrial filter, which is equipped with 30 segments and has been working very satisfactorily (6). On other conventional filters, the speed has been increased up to 3.5 rpm. The specific throughput of the modified filters was often more than double, compared to the situation encountered before the "tune-up". In fig. 6, the difference between the initial slurry flow rate and that after the improvements, indicated above, are demonstrated. The improvements obviously include the increase of the pressure difference and the cake formation angle as discussed above.

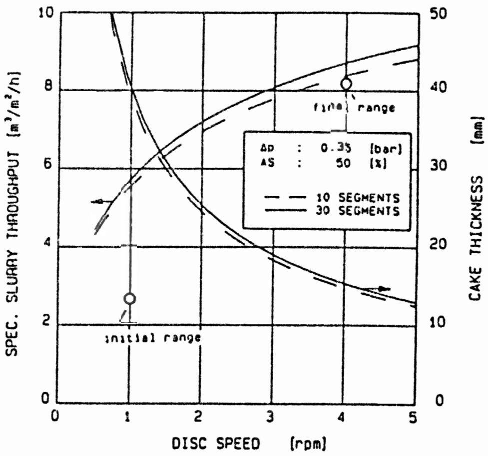

Fig. 6: Throughput and cake thickness as a function of the disc speed

So far, the increase of the filter capacity has been discussed. If, however, there is no need to raise the plant's capacity, the improved filter throughput allows the plant to be operated with less filters, so that considerable operating expenses for the vacuum pumps may be saved. Again, it was oberserved that the vacuum increases with the filter speed because the air breakthrough in the cake is delayed, thus the cake formation and the dewatering additionally improves.

FEED CONCENTRATION

Up to now, the slurry properties, and therefore the feed concentration, were considered invariable. This was necessary in order to discuss the design and operation parameters independently. In practise, however, this assumption is hardly valid, as due to the process conditions, during the leaching and the precipitation, the feed concentration often varies. Thus the cake thickness and the throughput vary as well.

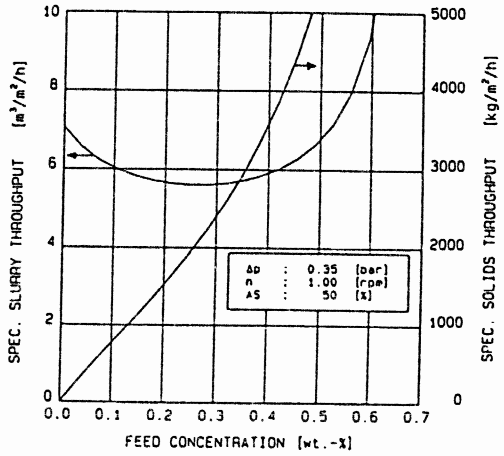

Fig. 7: Slurry and solids throughput as a function of the feed concentration

The feed concentration affects the cake thickness, the filtrate and the slurry flow rate and hence the filter performance. Normally, the feed conentration varies between 20 wt.-% and 40 wt.-%. In this range the slurry flow rate is relatively invariable, whereas the solids flow rate increases rapidly from 1500 $kg/m^2/h$ (20 wt.-%) to 3500 $kg/m^2/h$ (40 wt.-%). The cake thickness increases proportionally with the solids flow rate. This means that with higher feed concentrations the filter speed can be raised until the minimum admissible cake thickness is achieved. As a consequence, the throughput increases as demonstrated above. If on the other hand, the feed concentration decreases, the filtrate flow rate will increase. The higher filtrate flow rate causes a higher pressure drop in the filter and the piping system and the filter performance drops due to insufficient hydraulic capacity. Furthermore, the cake thickness decreases and thus the filter speed must be reduced in order to obtain the cake thickness necessary for a complete discharge. The lower filter speed in return reduces the filter capacity. A high feed concentration is therefore advantageous for an efficient filter operation at full capacity.

CONCLUSIONS

The developed program is a valuable tool for the simulation of the effect of design, operation and product parameters. The filter capacity can be increased significantly by modification of some parameters. As a prerequisite, the vacuum and filtrate system must be able to cope with the expected flow rate. Hydraulic and pneumatic resistances should be minimal to avoid frictional loss. The cake formation is increased by raising the submergence of the disc up to 50% or more and the respective adaption of the bridge block location to obtian a maximum cake formation speed. A high feed concentration is advantageous for the filter performance. Thus several industrial disc filters have been optimized accordingly and the filter capacity increased by 100% and more.

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NOMENCLATURE

AS	apparent submergence	%
c	feed concentration	g/l
c_G	feed concentration	wt.-%
h_c	cake thickness	mm
$\dot{m}_s$	solids throughput per unit area	$kg/m^2/h$
n	filter speed	rpm
Δp	pressure difference (vacuum)	bar
Rc	cake resistance	l/m^2
Rm	resistance of filter medium	l/m
$\dot{V}_{susp}$	slurry throughput per unit area	$m^3/m^2/h$
α_1	cake formation angle	deg
ε	porosity	-
κ	concentration factor	-
η	viscosity of liquid	Pa.s
ρ_l	density of liquid	kg/m^3
ρ_p	density of slurry	kg/m^3
ρ_s	density of solids	kg/m^3
γ_{STK}	bridge block angle (see fig.4)	deg