Moisture Reduction and Enhancement of Filtration Processes for Alumina Trihydrate and Red Mud Slurries

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ABSTRACT

Filtration processes are used extensively throughout the Bayer process. A variety of filtration devices and methods are used across the industry with a range of process slurries, most notably those containing alumina trihydrate and red mud, being filtered. While a number of filter aids for both trihydrate and red mud have been used in the industry over a number of years, recent advances in product development have identified a new class of filter aid (FilterMax^{TM}) which acts to increase the porosity of the solid filter cake. It is effective on both trihydrate and red mud slurry with application delivering both improved filter performance (flow rate) as well as a reduction in moisture content of the final cake solids. As a result, the FilterMax products can be effectively used to improve filtration outcomes across a broad range of process areas.

In addition, a parallel development has identified and developed a new class of alumina trihydrate dewatering aid (PowerDry^{TM}). This new product provides a step change in performance above existing dewatering aid technologies and operates using a mechanism that is substantially different to the FilterMax material. When used together, the mechanisms of FilterMax and PowerDry complement each other and enable cake moisture to be significantly reduced. Potential energy savings that calcination of low moisture trihydrate would deliver are discussed, together with potential and delivered benefits of FilterMax use across a range of trihydrate and red mud applications.

1. INTRODUCTION

A critical part of the Bayer process is the separation of solids from process fluids by filtration. Across the circuit there are a number of areas where filtration is utilized to either remove unwanted solids from valuable liquor, such as in security filtration of settler overflow slurry, or to separate and utilize solids from process slurry. Examples of this latter type include filtration steps used in seed deliquoring, alumina trihydrate product dewatering in preparation for calcination and red mud filtration prior to disposal.

All these filtration processes can derive some benefit from enhanced throughput and additives which improve a variety of filtration operations have been previously developed (Malito, 1996; Barham *et al*, 2000). Such products have been well accepted and utilized within the industry for many years, particularly in pressure filter applications such as security filtration.

In addition, the use of dewatering aids designed to reduce residual moisture of filtered solids are well known and extensively used throughout the industry and have been applied to trihydrate (Mura, *et al*, 1998) as well as bauxite (da Silva, *et al*, 1997.)

More recently our work has focused on combining these properties with the aim of enhancing throughput and minimizing residual moisture for those applications which utilize and collect solids for further processing.

Specifically a new range of high performance filter aids has been developed for use in both trihydrate and red mud applications. At the same time, a dewatering aid formulation based on a new alternative chemistry family has been identified and developed. Together, these new technologies aim to expand and enhance the possible performance of filtration operations across the Bayer process.

2. EXPERIMENTAL

2.1 Trihydrate Filtration Rate Test Method

Trihydrate seed slurry (1 L) was heated at 60ºC in a 1 L Nalgene bottle. The slurry was then dosed with water (untreated) or FilterMax and mixed by shaking for 60 sec before pouring into a Buchner funnel that contained a Macherey-Nagel BWS filter paper. The slurry was allowed to settle for 5 seconds prior to turning on the vacuum. The time was recorded from the start of the vacuum to when all the free liquor had been removed from the cake surface. The filtration rate was calculated using the time recorded

and the known volume of liquor added to the filter. The rate was expressed in terms of L/min.

2.2 Alumina Trihydrate Filtration Test

Filtered alumina refinery spent liquor (200mL) and alumina trihydrate (100g) was added to 250mL Nalgene bottles to prepare the slurry. De-ionised water (200mL), for use as the wash water, was added to separate 250mL Nalgene bottles. All of the bottles were then placed in a rotating water bath at 70°C for a minimum period of 2h.

Untreated sample: A bottle of slurry was poured into a Buchner funnel (130mm diam., Whatman 540 filter paper) and allowed to settle for 20sec then vacuum was applied. After 40sec the vacuum was removed, the wash water added onto the cake and the vacuum reapplied for a period of 80 sec. The cake was then sampled and the moisture content was determined gravimetrically by drying in an oven at 110°C.

PowerDry treatment: As per the untreated sample except the wash water contained a known volume of PowerDry.

FilterMax treatment: As per the untreated sample except to the slurry, prior to filtration, was added a known volume of a 0.5% solution of FilterMax and mixed in a rotating water bath at 70°C for 60 sec.

2.3 Red Mud Filtration Test

Red mud slurry (0.5 L) was added to a 1 L Nalgene bottle then dosed with either FilterMax or water. The slurry was then shaken for a period of 60 seconds. The slurry was then poured into a container ready for insertion of a filter leaf. The vacuum was turned on and the filter leaf was inserted into the slurry and moved slowly in an up/down motion for a set period of time. The leaf was then removed, upended and held under vacuum for a further set time period. The vacuum was then turned off and the mud collected from the face of the filter leaf. The moisture content of the mud was determined gravimetrically by drying in an oven at 110°C.

3. RESULTS AND DISCUSSION

The enhancement of filtration processes requires consideration of two separate processes.

The first is cake formation facilitated by using the base filter medium (usually cloth) to restrict the passage of solids and promote the formation of a cake. It is clearly critical that the solids should not embed themselves into the filter medium and thereby restrict fluid flow to cause blinding of the cloth.

In the same way, the formation of the filter cake should ideally capture solids, but not prevent the passage of fluid through the cake as it forms. The filter cake is a dynamic medium, building in thickness as the filtration process proceeds.

As a result, there needs to be a balance between cake thickness (which is a function of total solids captured) and cake porosity, which can be determined by the rate of fluid flow through a given cake thickness. The fluid flow rate can be described by Equations 1 and 2. These equations were developed using the hydrodynamic treatment of fluid flow through a capillary tube (Mishra, 1989).

$$\frac{dv}{dt} = \frac{K A \Delta P}{L \eta} \tag{1}$$

$$K = \frac{\varepsilon^3}{5 S^2_0 (1 - \varepsilon)^2} \tag{2}$$

K is commonly referred to as the permeability constant and is a function of cake porosity (ε) and is directly proportional to the rate of the fluid flow (dv/dt). A is the cross sectional surface area of the porous medium, η is the viscosity of the fluid, S_o is the specific surface area of the particles making up the porous cake and ΔP is the pressure gradient across the cake thickness, L.

Under pressure filter conditions, an additional parameter of cake compressibility must also be considered.

The relationships of the various parameters under pressure filter conditions have been well established (Malito, 1996) with key actors being the compressible nature of the cake, which determines the relative flow rate at a given pressure.

A porous structure that resists compression and consequent “blinding” of the cake will result in enhanced filter operation.

While the relationships in vacuum filters differ slightly, the overall concepts remain the same with the effective flow rate of fluid through the cake being directly related to the cake thickness along with the porosity of the cake “structure” that forms. As demonstrated in the

earlier work, a variety of filter aids can be used to influence cake porosity and enhance filtration performance.

In some sections of Bayer plant operations, most notably product trihydrate filtration or seed deliquoring, filter operation is measured by both throughput as well as an additional critical parameter of residual moisture.

In order to provide substantial benefits to the filtration process of this type of operation, factors affecting the second key process – moisture reduction – need to be considered.

Addition of a filter aid which can influence cake formation and result in a more porous cake medium is inherently an advantage. Once all the fluid is removed from the cake, additional vacuum or air application will result in more effective removal of moisture from a more porous structure. As a result, formation of a porous cake will deliver lower residual moisture under the same conditions.

However, the residual concentration of water in the cake, often expressed as the residual saturation, is reached when the pressure drop across the cake is balanced. This is the state when the forces trying to drive out the moisture from the cake are equal to the forces trying to hold the moisture in the cake. Reduction in the residual saturation can usually be achieved by the addition of dewatering aid reagents. Typically, these can either act to increase the contact angle or reduce the interfacial tension between water droplets and particles which results in lower residual cake moisture. Equation 3 details the expression for the residual saturation (S_r) concentration (Mishra, 1989).

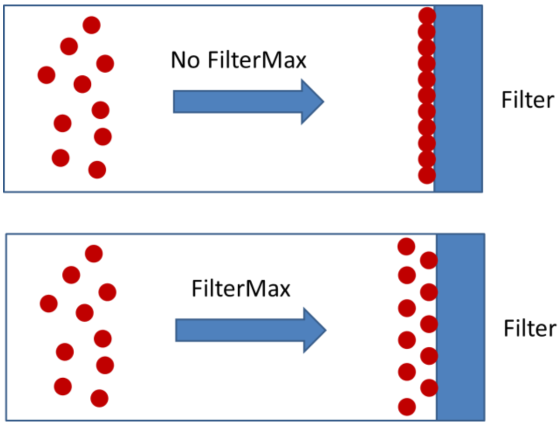
$$S_r \propto \frac{1}{H}\left[\frac{K\, A\, \Delta P}{L\, g\, \Upsilon \cos\theta}\right]^n \qquad (3)$$

From this expression, the cake moisture content can be reduced by increasing the cake permeability (porosity), increasing the pressure drop, increasing the contact angle (θ), decreasing the interfacial tension (ϒ) or decreasing the cake thickness. H and n in this expression are constants.

Figure 1 is a schematic representation of the mechanism of dewatering using (a) a filter aid and (b) a dewatering aid designed to increase contact angle.

The use of filter aid results in a more porous cake which in turn enhances both fluid flow through the solids bed and results in lower residual moisture. On the other hand, use of dewatering aid affects whatever residual moisture remains on the surface of particles.

(a)



(b)

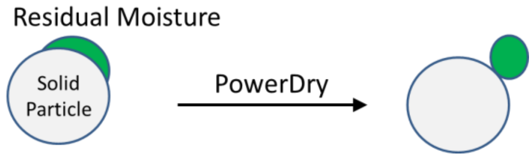


Figure 1. Schematic representation of the mechanisms of (a) FilterMax filter aid and (b) PowerDry dewatering aid

It is believed that these are the mechanisms by which a new range of products enhance filtration operations. Specifically FilterMax filter aids increase cake porosity when added to either trihydrate slurry or red mud slurry which feeds a filter.

Conversely, PowerDry has been identified as highly effective in lowering residual moisture in trihydrate. It is believed to act on both increasing the contact angle and reducing the interfacial tension.

The application and utility of these two product types, either alone, or where appropriate together, has been investigated.

3.1 Filter Aid for Alumina Trihydrate

When added and mixed with trihydrate slurry prior to filtration, FilterMax filter aid influences the nature and structural properties of the cake as it forms. The consequences of this are shown in Figure 2 where filtration rates of a series of simple filtration tests on trihydrate were determined.

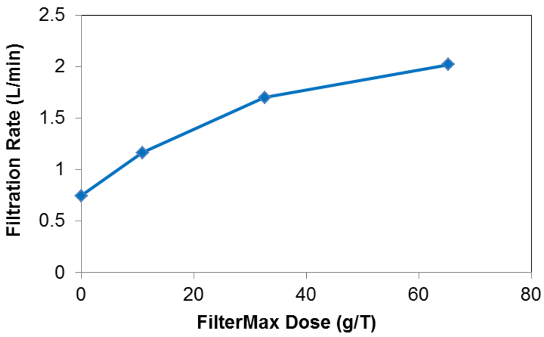


Figure 2. Filtration rates of filtered trihydrate slurry treated with various doses of FilterMax.

There is a clear increase in filtration rate observed when the slurry is treated with FilterMax, which is likely to have resulted from the formation of a much higher porosity cake. Application of FilterMax to trihydrate slurry in a plant situation would enable the operator to significantly increase filter throughput or significantly reduce residual cake moisture or both.

3.2 Filter Aid for Red Mud

Red mud filtration is practiced extensively across the industry. In many cases the resulting red mud filter cake is subsequently removed for disposal such that any additional moisture constitutes a direct loss of soda from the plant operation.

Figure 3 shows a plot of preliminary data showing percentage residual moisture reduction in red mud filter cake after treatment with FilterMax at a range of doses. Again, a clear dose response is evident demonstrating an effect on red mud cake formation.

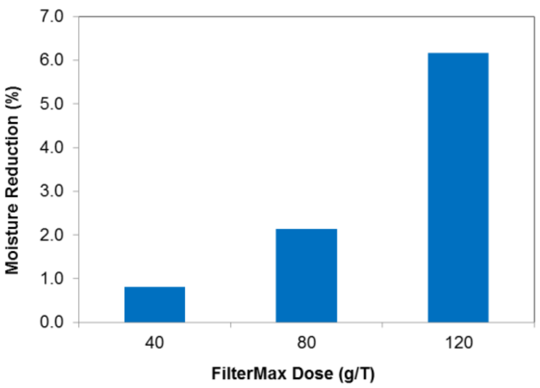


Figure 3. Dose response of FilterMax showing the impact of increasing dose on percentage moisture reduction in red mud filter cake.

3.3 Dewatering Aid for Trihydrate

Conventional dewatering aids used in the alumina industry are typically based on either fatty acid or alkyl sulfosuccinate chemistry. Unfortunately neither of these chemistries is ideal with both having significant downsides. Fatty acids are known to have undesirable downstream effects while alkyl sulfosuccinates generally possess an unpleasant odour which can be problematic. In developing an alternative dewatering aid for use in the alumina industry the need to avoid and overcome these shortcomings was a clear aim. The new PowerDry dewatering aid product is highly effective while possessing none of the adverse properties of existing products. The performance of the PowerDry material as assessed in laboratory tests is plotted in Figure 4. Again, a clear dose response is evident.

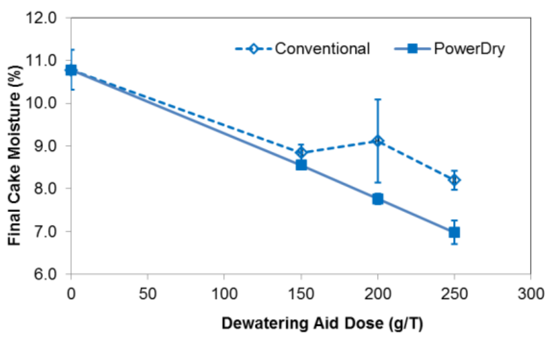


Figure 4. Dose response of PowerDry dewatering aid compared to a standard, commercially available alkyl sulfosuccinate dewatering aid. The impact of increasing dose on residual moisture in trihydrate filter cake is shown.

3.4 Combination of New Technologies

Given that the FilterMax and PowerDry technologies operate using different mechanisms, it was considered possible that each would separately affect moisture removal in different ways to deliver an overall moisture well below that possible from use of either technology when used alone. A test was conducted using simulated trihydrate product filter feed. This test was used to assess the impact of PowerDry dewatering aid alone, FilterMax filter aid alone, and PowerDry and FilterMax when used in combination.

The results are plotted in Figure 5 and show a clear, continuous dose response of the combination, delivering lower residual moisture levels than either single technology

at any dose. One of the difficulties in completing such test work is that a baseline measure of the residual moisture in the untreated sample cannot be determined until all testing is completed. Ideally a lower "starting point" would have been selected for such a test program.

Clearly the combination of different mechanisms is effective in first delivering a more porous cake which is then more amenable to removal of water by the action of the dewatering aid.

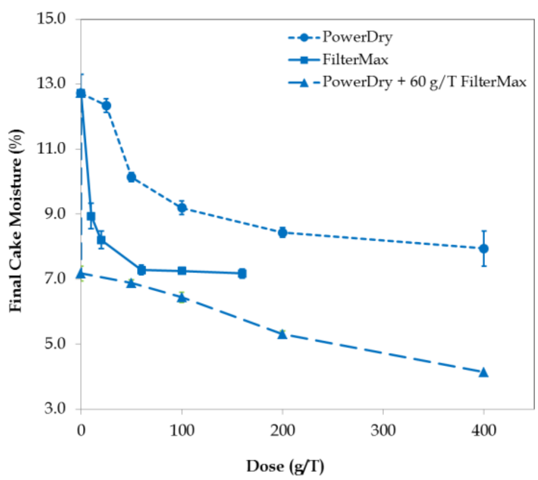


Figure 5. Residual moisture resulting from filtration slurry treated with, PowerDry alone, FilterMax alone and PowerDry and FilterMax in combination.

Such a combination of mechanisms will enable operators to significantly reduce moisture in trihydrate product to levels previously considered to be uneconomic. The lower moisture in product feed to calcination has the potential to substantially reduce energy costs related to initial drying of product in calcination.

Conceptually such a dual technology program is likely to be relatively simple to implement under plant conditions. Figure 6 shows a schematic of one possible application system using a combination of PowerDry and FilterMax.

In theory the balance of these two programs could be manipulated to deliver the optimum cost effective program to deliver the minimal moisture content at maximum throughput.

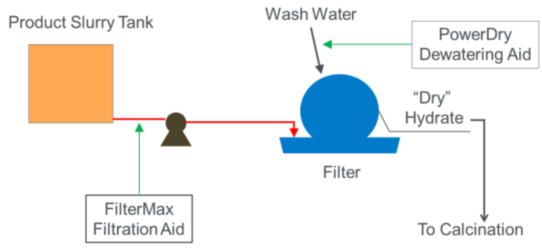


Figure 6. Conceptual application of both FilterMax and PowerDry products to minimize residual moisture content of product trihydrate

4. CONCLUSION

Filtration is a critical operation across a range of processes in all Bayer circuits. Enhancing the efficiency of any filtration process can be achieved by creating a more porous filter cake. This can be accomplished by addition of FilterMax filter aid to the feed slurry of the filtration operation. FilterMax is effective on both trihydrate and red mud solids and can deliver substantial reductions in residual moisture content of the resulting cake from filtration of product trihydrate, seed slurry or red mud for disposal.

An alternative mechanism to reduce residual moisture is utilized by the new PowerDry dewatering aid which has been developed. This product acts to both increase the contact angle and reduce the interfacial tension between the particles and the water phase making it easier to remove the residual moisture when under vacuum. The new product is highly effective as a dewatering aid for trihydrate and possesses none of the undesirable properties of existing dewatering aid programs.

The different mechanisms and application requirements of the two different technologies means that a combination of both PowerDry dewatering aid and FilterMax filter aid can be easily applied and will result in substantial reductions in residual moisture content well beyond that available through the use of either, or any technology alone.

5. REFERENCES

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