OPERATING EXPERIENCE WITH IMPROVED PRECIPITATION AGITATION SYSTEM

D Stegink[1*], T Davis[1] and J Wu[2]

[1]*Technical Services, Queensland Alumina Ltd, Queensland, Australia*

[2] *Advanced Processing Technologies, Process Science and Engineering Division, CSIRO, Victoria, Australia*

Abstract

CSIRO and Queensland Alumina Ltd have jointly developed patented Swirl Flow agitation technology, which uses high slurry velocity to minimise scale formation in precipitation tanks. The objectives of Swirl Flow agitation are to increase yield, reduce cost and safety risks, and improve operational security.

In a Swirl Flow precipitation tank, a radial flow rotor near the top of the tank draws in slurry along the vertical axis of the tank and discharges the slurry radially with a large tangential velocity component. The resulting high slurry velocities along the tank wall result in a reduced scaling rate, which improves performance through its impact on tank volume and operating factor.

The agitator can be installed and removed by working on the agitator access platform, and as there are no tank internals, there is no need for personnel to enter the tank for agitation system maintenance. This eliminates a high risk activity from the tank's safety risk profile.

To date, 16 cone-bottom precipitation tanks have been converted to Swirl Flow agitation. Based on over a decade of operating experience, the performance of the technology is assessed and compared to conventional agitation technology. Swirl Flow precipitation increases yield through increased operating factor and tank volume, and the low conversion cost makes it the preferred option over replacement of a damaged draft tube. The agitator has superior re-suspension capability, which allows easy recovery from an interruption of power supply; care must be taken to optimise cycle duration.

1. Introduction

Precipitation of alumina trihydrate in the Bayer process requires the use of large agitated slurry tanks. The purpose of the agitation system is to suspend the hydrate solids, provide effective mixing and minimise scale formation. During operation, scale forms on the tank walls and internals, which has to be removed periodically. To this end tanks are bypassed and taken off line periodically for cleaning, which is normally done by dissolving any scale in strong, hot cleaning caustic.

Operating experience at QAL shows that in high velocity regions in precipitation tanks the rate of scale formation is an order of magnitude smaller than elsewhere. This is consistent with scale suppression by slurry erosion, which is more effective at a higher velocity1. Therefore increased slurry velocity can be used to minimise scale formation. A review of the literature on hydrodynamic scale suppression is outside the scope of this paper however further work is being conducted in this area by CSIRO[†] and other research institutions.

Slurry cooling at QAL is done in an interstage cooler installed on each Precipitation row. The interstage cooler operates by flash-cooling, which reduces the temperature and increases the caustic concentration. The changes in temperature and caustic concentration reduce the equilibrium oxalate concentration, which triggers the precipitation of oxalate in the tanks downstream of the interstage cooler. The co-precipitation of oxalate has a marked impact on the morphology of the scale on the tanks walls; upstream of the interstage cooler a slow growing, glassy scale forms, while downstream of the interstage cooler the scale has a sandy nature. The post-interstage scale contains oxalate and grows much faster.

QAL has 106 precipitation tanks, of which 96 were constructed with draft tube agitation and 10 with airlift agitation. In terms of mixing performance and ability to control scale, the draft tube agitators perform better than the airlift; nevertheless, cleaning times of draft tube tanks can be excessive when heavy scale is present. Another disadvantage of draft tube tanks is the need for vessel entry for certain maintenance activities, which is time and resource intensive due to safe work procedures. In case of loss of agitation it can take days or weeks to recover draft tube tanks, as the settled solids interfere with the flow out of the bottom of the draft tube.

Any scale present in a precipitation tank reduces its on-line volume, and the off-line removal of the scale adversely impacts the operating factor of the tank. Both factors reduce the total volume available for precipitation, which in turn reduces the achievable yield. This is the driver for the development of an improved agitation technology. Swirl Flow technology was jointly developed by CSIRO and QAL (Welsh 2002).

2. Agitation Concept

As stated above, the purpose of a precipitation agitation system is to suspend hydrate, provide effective mixing and minimise scale formation. From the fact that fully suspended tanks still form scale, one can conclude that the velocity required to suppress scale formation is well in excess of that required for solids suspension. In conventional agitation systems the design is primarily based on the requirement to maintain suspension; this defines a minimum vertical velocity that is able to suspend the hydrate particles. Power usage considerations prevent the slurry velocities to be increased substantially to minimise scale growth, as slurry velocity is proportional to agitator speed while power usage increases with the cube of agitator speed.

[†] To be submitted to Journal of Mineral Processing: Wu J, Nguyen B, Lane G, Farrow J, Graham L, Short G & Stegink D 2011, "Swirl Flow Agitation for Scale Erosion Suppression"

The concept behind swirl precipitation is quite simple. In addition to the vertical velocity component for solids suspension, it uses a large horizontal velocity to increase the total velocity over the tank wall. This results in superior scale suppression ability. Physical modelling by CSIRO[2] and experience at QAL have shown that for similar solids suspensions performance, a Swirl Flow agitation system can deliver much higher slurry velocities along the tank wall than a draft tube agitation system operating at the same power consumption.

In a Swirl Flow precipitation tank, a radial flow rotor draws in slurry that rises along the tank axis and pumps it radially outwards, while also imparting a large swirl velocity (see Figure 1). As the slurry reaches the tank wall it changes direction and spirals down along the tank wall. Upon reaching the tank bottom, the slurry spirals towards the axis of the tank. In doing so, the swirl velocity increases due to conservation of angular momentum, which requires that the product of tangential velocity and radius remain constant. The fast-swirling slurry then rises along the tank axis and enters the agitator. Note that no guide vane or flow straighteners are used. Figure 2 shows a photo of a swirl agitator installation.

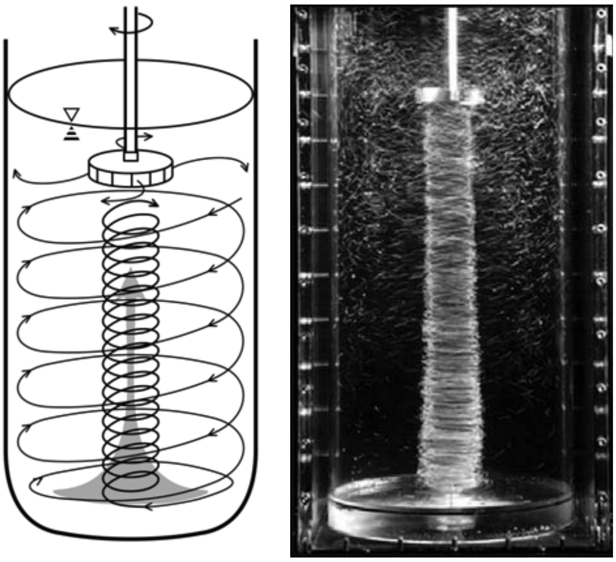

Figure 1 (a) Diagram of flow patterns (b) Flow visualisation of Swirl Flow (Courtesy of CSIRO)

Figure 2 Full scale Swirl Flow installation at QAL

As can be seen in Figure 3, the precipitation tanks are placed in two offset rows, where each tank feeds the downstream tank by gravity overflow. This arrangement allows any tank to be bypassed by blinding off the overflow to the downstream tank and opening up the bypass overflow to the next tank in line (not shown). The swirl direction is chosen to minimise bypass, which is achieved by ensuring the swirl in the tank takes the long path from the tank feed to the tank discharge. In other words, when looking downstream, tanks on the left hand side of a row are swirled clockwise, and tanks on the right hand side are swirled anticlockwise. By the time the slurry has travelled around most of the circumference of the tank the feed slurry has started its spiral path down the tank wall, resulting in negligible bypass.

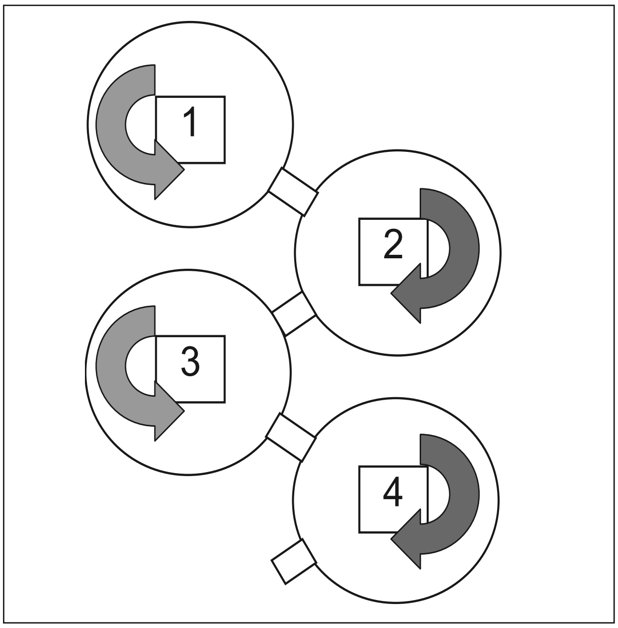

Figure 3 Diagram of a precipitation row with Swirl Flow direction

To date, Swirl Flow agitation has been implemented in 16 cone-bottom tanks in the QAL precipitation circuit.

3. Operational performance

Pilot trials commenced in the late 1990s. These resulted in the selection of the rotor that was subsequently used for all further conversions to Swirl Flow agitation. Operating experience with the early installations led to the selection of a more robust gearbox for this duty.

In the precipitation tanks upstream of the interstage cooler, the scale growth rate is reduced when operating with Swirl Agitation. Due to the smooth surface of the scale, the agitation current remains fairly constant over the campaign duration. Swirl Flow tanks upstream of the interstage cooler have campaign durations that are double those of draft tube tanks. The longer operation and the quick cleaning result in an improved operating factor, and the reduced scaling rate means that the effective volume of the tank is larger. Both result in increased yield.

The scale growth rate in Swirl-agitated tanks after the interstage cooler is also reduced compared to draft tube agitated tanks. However, due to the rough surface of the post-interstage scale, the flow resistance of the scale increases as scale formation progresses. The high swirl velocities are partially dissipated as the slurry flows over this rough scale, which results in a reduction in the swirl intensity of the slurry entering the agitator. This causes an increase in the power demand for the agitator.

A typical pattern of agitation current§ for a post-interstage Swirl Flow tank campaign is shown in Figure 4. The campaign starts off with an induction period, during which no noticeable scale is formed and the agitation current remains constant. This is followed by a period in which the scale growth increases the roughness of the walls, which causes the current to increase steadily. If the tank is kept on line long enough, the agitation current levels off and becomes unsteady. At this point the flow resistance due to the scale has increased to the point where the

2 Wu 2010, confidential report to QAL, October 2010

solids suspension ability of the rotor is compromised. The tank should not be operated beyond this point. As the pattern of the agitation current over the campaign is well defined it can be used to monitor tank performance and determine the optimum campaign duration.

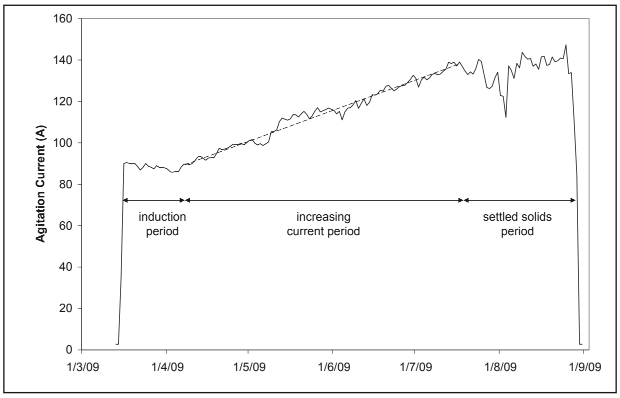

Figure 4 **Agitation current for a post-interstage Swirl Flow agitator**

Due to the influence of other process parameters it is impractical to quantify the impact of Swirl Flow precipitation on yield via direct measurement. Instead, process parameters such as operating factor, scale volume and natural cooling are measured and their impacts on yield calculated. The data shows increases of up to 5% in operating factor and 50% in natural cooling, as well as 2% reduction in the scale volume.

As a conversion to Swirl Flow agitation is cheaper and quicker than draft tube repair, it is now standard practice at QAL to replace severely damaged draft tubes with Swirl Flow agitation. This is done in all cone bottom tanks except the two tanks immediately downstream of the interstage cooler. Plant trials have shown that the technology is able to substantially reduce scale growth, however due to the high scaling rate in these tanks the induction and increasing current periods are too short to achieve a competitive operating factor.

Recovery from a loss of suspension situation in a Swirl Flow tank is straightforward. After the operator restarts the agitator, the liquor re-establishes its normal flow pattern, and the solids are re-suspended within a couple of hours without further operator interventions. By contrast, draft tube tanks typically require air injection, back-flushing with spent liquor and/or external recirculation during the recovery process.

In the early installations some mechanical issues were encountered, such as under-designed gearboxes and couplings. These have long since been resolved and the Swirl Flow installations operate quite reliably. Some of the earlier agitators that have been in operation for over ten years are showing some signs of wear, but no loss of performance or mechanical integrity is evident. To date, no agitators have required repair or replacement.

4. Safety aspects

The internals of draft tube agitated tanks require periodic maintenance, for which personnel need to work inside the tank. To ensure the vessel entry is done in a safe manner, the tank needs to be isolated, a vessel entry permit put in place and a stand-by person present. These safety requirements add to the scope, duration and cost of the maintenance activity.

A Swirl-agitated precipitation tank does not have any tank internals. During conversion, all mixing boxes are removed from the tank overflow to the next tank and draft tube supports are cut out and ground flush. Furthermore, the agitator can be installed and removed using a crane and maintenance personnel stationed on the agitator platform. As a result there is no need for vessel entry.

Due to the high slurry velocities there is a risk of splashing. This is minimised by terminating all feed pipes above the slurry surface.

5. Discussion

If the campaign of a post-interstage tank is extended too far, the flow resistance in the tank will increase to the point where full solids suspension is lost. From this point on, the amount of settled solids in the tank will gradually increase. This reduces the active volume of the tank and causes delays in emptying the tank for cleaning, both resulting in lost yield. So while Swirl Flow agitation provides superior scale suppression due to the high slurry velocities, it is at the same time more sensitive to the presence of scale. By comparison, a draft tube agitator in a similar duty operates with significantly more scale near the end of its campaign without a noticeable change in agitation current.

Due to Swirl Flow agitation's sensitivity to the presence of scale it is very important to ensure that at the end of each campaign the tank is cleaned back to bare metal. With reference to Figure 4, any residual scale after cleaning will result in the loss of the induction period. Furthermore, the increasing current period will be shortened as the starting agitation current will be elevated due to the roughness of the residual scale. This means that the achievable campaign duration is compromised by incomplete caustic cleaning.

Monitoring of agitation currents to determine when tanks are due for cleaning is essential. For this purpose a graph of daily average agitation current over the last three or so campaigns is most useful.

6. Conclusions

Swirl Flow agitation has been in use at QAL for over a decade. It has delivered improved yield through higher operating factor and reduced scale growth, improved resuspension ability, reduced maintenance cost and lower risks to maintenance personnel.

Damaged draft tubes in cone bottom tanks are being routinely replaced with Swirl Flow agitation. The agitation upgrade is less expensive, requires a shorter outage and delivers ongoing process benefits.

Care needs to be taken not to exceed the maximum campaign duration, which leads to operation with settled solids and extended outages for tank cleaning.

7. Acknowledgements

The authors would like to acknowledge the longstanding collaboration between QAL and CSIRO to develop Swirl Flow agitation.

References

Welsh M 2002, "Method and Apparatus for Mixing", US Patent 6,467,947 B1