

AA17 – Successful Application and Installation of SWIRLFLOW® Mixing Technology in an Inverted Cone Precipitation Tank at the Hindalco Alumina Refinery in India

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Abstract

Precipitation is a critical process in the white side of alumina refineries where nucleation and crystallization occur to form alumina hydrate product. The precipitation process utilizes a series of precipitation tanks connected via launders or pipes which allow continuous flow for providing the required residence time and temperature profile to achieve good alumina hydrate quality. A variety of tank bottom designs are found in service including flat bottom, with or without fillet, and conical bottom. Conventionally, the tanks are fitted with draft-tube agitator, air lifting or multi-impeller agitation systems with baffles. Hydrate solids formed from precipitation out of the liquor, often deposit on unwanted locations such as the impeller shaft and hub, tank walls and upcoming risers. The mass of the accumulated scale can adversely influence sedimentation and mixing efficiency, lead to expensive cleaning/de-scaling operations, and compromise the tank integrity via draft-tube collapse or tank bottom bulging.

To overcome these challenges, SWIRLFLOW® mixing technology was jointly developed by CSIRO and QAL in the 1990s for use in alumina precipitation tanks. It has now been successfully installed in over 100 tanks of different sizes and duty around the world including tanks with flat, conical or filleted bottoms. This year (2023) at the Hindalco alumina refinery in India, SWIRLFLOW® was implemented in a precipitation tank of different design to those thus far - a tank with a filleted bottom and an inverted cone. This was the first installation of SWIRLFLOW® in India. At the time of writing this paper the precipitation tank has been running well and according to design for 4 months since commissioning, with the SWIRLFLOW® power consumption being within expectations from the laboratory design test work. The design, installation, and commissioning of the SWIRLFLOW® technology in this unusual tank type are discussed.

Keywords: Alumina precipitation tank, filleted bottom, Inverted cone, SWIRLFLOW®, implementation.

1. Introduction

SWIRLFLOW® was originally developed by a joint effort between CSIRO and Queensland Alumina Limited (QAL) as an alternative to the existing draft tube agitation system that was used in their precipitation tanks. Up to the time of writing QAL has successfully replaced draft tubes with SWIRLFLOW® in approximately 30 % of their precipitation tanks, while other alumina

refineries around the world are now conducting plant trials with SWIRLFLOW[®]. Other than the alumina refineries, SWIRLFLOW[®] has also been implemented in a magnetite mixing tank in an iron ore operation [1], a gold CIP (Carbon-in-Pulp) tank, and a neutralization tank in a gold BIOX operation [2].

In alumina precipitation tanks scale formation can occur. Scale deposits on the tank internal surfaces and structures, adding significant weight to the structure which can cause damage including deformation of the tank and collapse of internal structures such as the draft tube, dip tube, etc. Excessive scale growth often results in high maintenance requirements, often tanks need to be taken offline before the scheduled maintenance, in several cases it can lead to unplanned shutdowns [3]. QAL has confirmed that SWIRLFLOW[®] has performed well in keeping the solids in suspension and has allowed the online time for precipitation tanks in the agglomeration stage and the precipitation tanks before and post interstage cooling to be increased.

So far, SWIRLFLOW[®] has been successfully implemented in precipitation tanks with tank bottoms such as conical bottom, fillet bottom and flat bottom tanks [4]. In 2022 the Hindalco Alumina refinery decided to implement the SWIRLFLOW[®] to replace a draft tube agitation system. Draft tube tanks are a known technology and are commonly used in other alumina refineries. The precipitation tank at Hindalco was different in that it has a fillet bottom with an inverted cone as shown in Figure 1. The functionality of SWIRLFLOW[®] is to generate a strong tornado in the center of the tank which provides strong uplifting flow to keep the solids in suspension. The precipitation tank at Hindalco has a bottom fillet which is likely to be more favorable for the SWIRLFLOW[®], however the concern with the central inverted cone at the bottom was whether it would obstruct the tornado, thus causing the tornado to slow down, which could potentially compromise the solids suspension performance.

This paper presents the results of a physical modelling campaign conducted in a scaled-down test rig in the CSIRO laboratory in Melbourne, Australia, to study and assess the performance of SWIRLFLOW[®] compared to the existing draft tube agitator design in an inverted cone tank. This formed the basis for an optimized design for the full-scale implementation as a trial at Hindalco's Muri alumina refinery in India.

2. Experimental Set Up

To design a suitable SWIRLFLOW[®] for the precipitation tank at the Hindalco refinery, a modelling study was conducted on a scaled-down test rig. Figure 1 shows the existing design scaled down, with details of the draft tube, slots and inverted cone. The modelling rig consists of an acrylic, transparent 1.0 m diameter cylindrical tank which was fitted in a square glass tank. The outer tank was filled with tap water to correct for optical distortion from the curved inner tank and to equalize the pressure difference between the inner cylindrical tank and the outer square tank. The impeller was fitted to the desired location on a central shaft which was driven by the motor via a VFD (Variable Frequency Drive) to allow the impeller speed to be changed. The shaft was instrumented with a speed detector and an Ono Sokki torque transducer, which were connected to a computer system that allowed for the impeller speed and torque to be logged. From the torque and speed, the power consumption and power number could be calculated. The modelling rig, as shown in Figure 2, was designed to allow for the option to change from a draft tube configuration to a SWIRLFLOW[®] configuration. The first part of the physical modelling was to study the performance of the draft tube, thus reproducing what was observed on the plant in the laboratory model.

The physical modelling work included making visual observations of the flow patterns in water and assessing the solids suspension performance by measuring the solids sedimentation height across a range of impeller speeds. The basic geometry and operating conditions of the laboratory

and full-scale tanks can be found in Table 1. The modelling was at ambient pressure and temperature conditions (nominally ~20 °C).

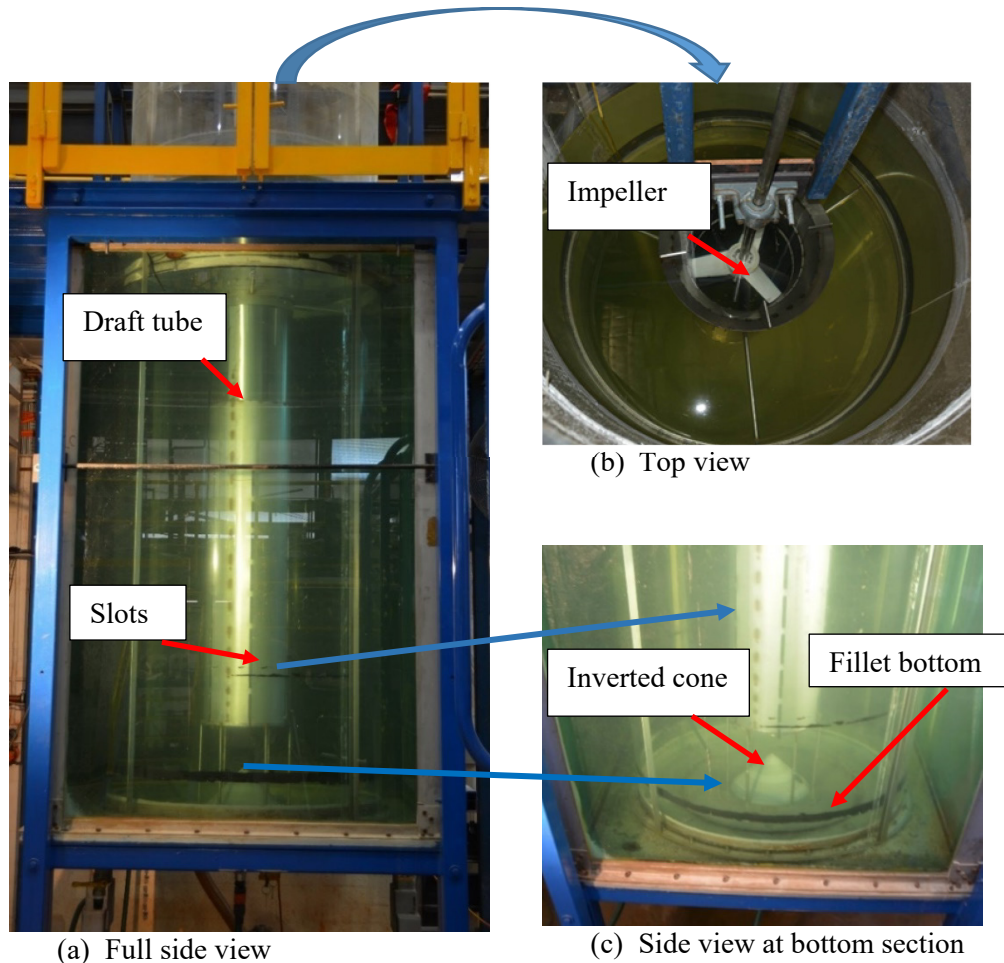


Figure 1. CSIRO laboratory modelling tank, scaled down from the Hindalco draft tube precipitation tank: a) Full side view, b) Top view, and c) Side view at bottom (Note: the blue arrows show where the zoomed in photos were taken from).

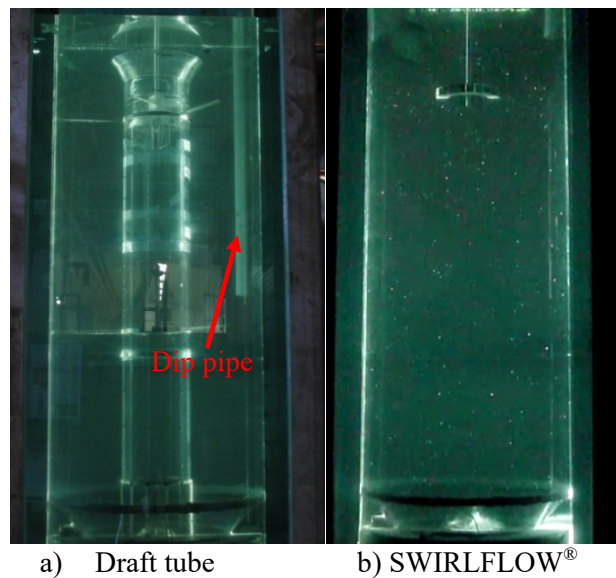


Figure 2. Modelling tanks; a) draft tube, and b) SWIRLFLOW®.

Table 1. Operating conditions for laboratory scale rig and full-scale plant data.

Parameter	Full-scale (Draft tube)	Full-scale (SWIRLFLOW [®])	Laboratory (Draft tube)	Laboratory (SWIRLFLOW [®])
Tank diameter, T [m]	13.4	13.4	1.00	1.00
Liquid level, H [m]	32.2	32.2	2.33	2.33
Tank volume, Vol [m ³]	4900	4900	1.87	1.87
Impeller design	Axial impeller	SF-A	Axial impeller	SF-A
Impeller diameter, [m]	3.73	4.29	0.278	0.320
Bottom clearance, [m]	26.0	30.0	1.94	1.96
Motor power capacity, [kW]	90	90	-	-
Operation Speed, N [rpm]	37.8	16.8	380	200
Tip velocity, [m/s]	7.38	3.77	5.73	3.35
Solids concentration, [g/L]	380	380	450	450
Liquid density, [kg/m ³]	1275.00	1275.00	1000.00	1000.00
Solids density, [kg/m ³]	2500.00	2500.00	2500.00	2500.00
Slurry density, [kg/m ³]	1460	1460	1270	1270
Particle size D ₈₀ [mm]	0.15	0.15	0.15	0.15

The solids suspension performance test was conducted by running the impeller at a speed such that solids were well suspended from the tank bottom. The solid sedimentation bed height was then measured and recorded together with torque and speed as the impeller speed was gradually reduced in steps of 10 or 20 rpm. The studies were conducted with the draft tube and the SWIRLFLOW[®] options to allow for developing an optimized design for the Hindalco refinery precipitation tank.

The synthetic slurry used in the physical modelling was made up of glass beads and Melbourne tap water. The glass particles have a similar particle size distribution (PSD) to the solids in the precipitation tank at the Hindalco alumina refinery, as shown in Figure 3. The specific gravity (SG) and solids concentration were also kept similar to those at the plant. The experimental modelling was conducted at a solids concentration of 450 g/L as specified by Hindalco. This solids concentration was slightly higher than the current concentration at Hindalco as it was important to be conservative for the different tank design to those investigated previously. The modeling tank was filled with at required solids concentration is shown in Figure 4 where the solids bed is shown in the fully settled and fully suspended modes.

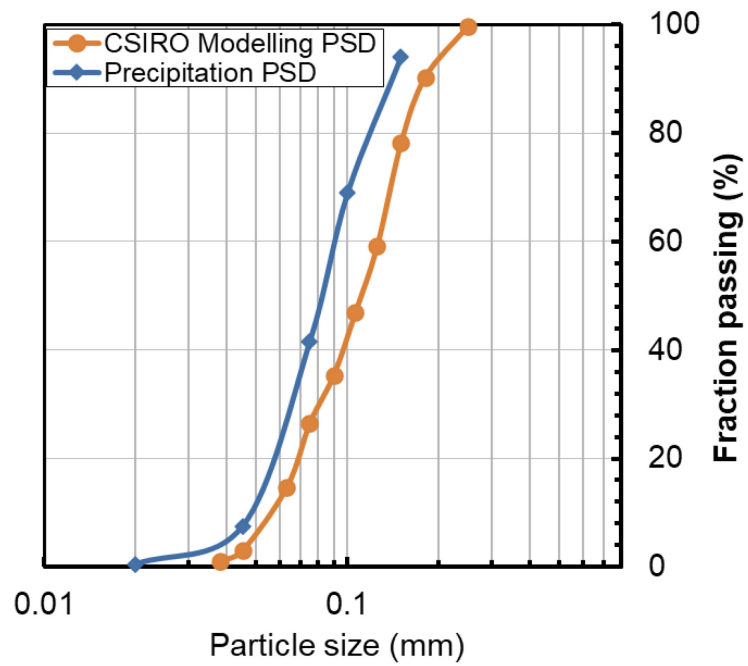


Figure 3. Modelling and plant particle size distribution.

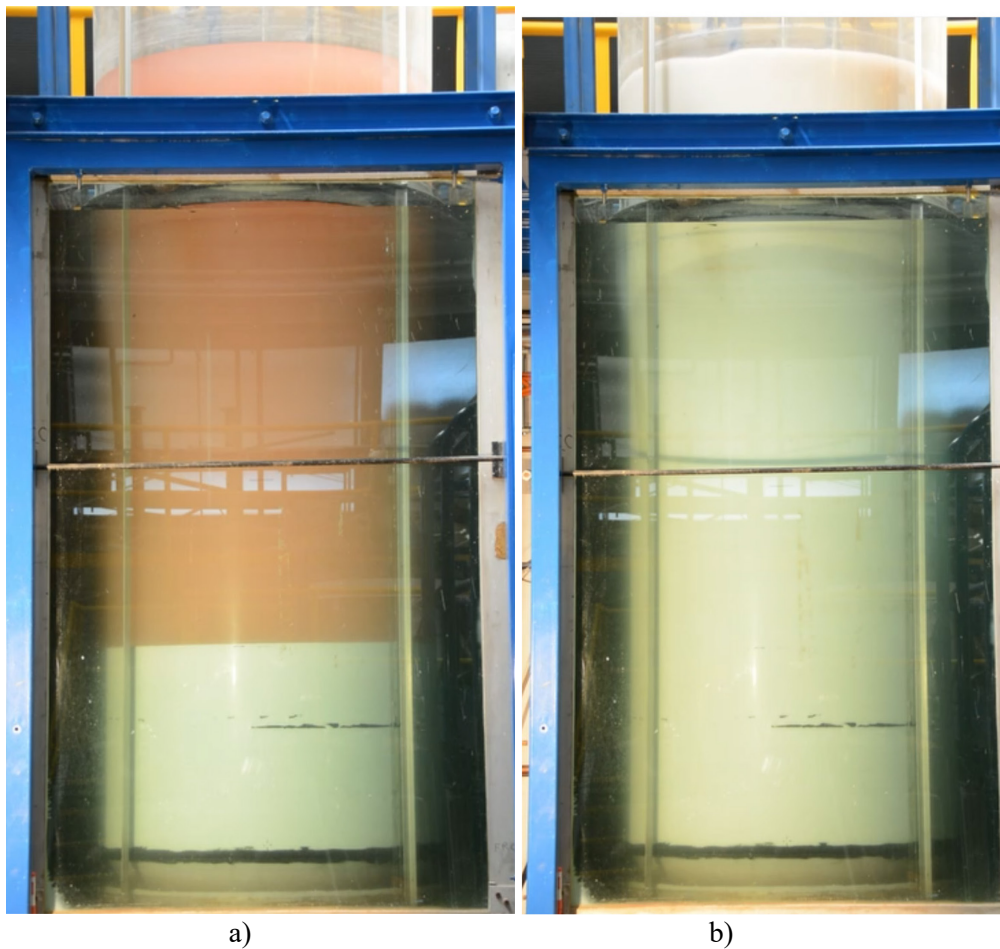


Figure 4. Modelling slurry at 450 g/L; a) solids settled, b) solids fully suspended.

3. Results – Laboratory

3.1 Flow visualization

The central inverted cone on the tank bottom at the existing precipitation tank was initially thought to have an effect of reduced draft tube clearance, which was believed to provide a higher slurry flow velocity at the bottom of the tank. The inverted cone helps to divert the flow to the tank bottom corner which is normally where dead-zones and sedimentation occurs. The combination of a stronger velocity with flow being redirected to the corner can lead to a better overall solids' suspension. In the SWIRLFLOW® configuration however, the inverted cone was an obstacle that was potentially in the way of the tornado, which may cause a disruption to the tornado momentum and could lead to compromised solids suspension performance.

The flow visualization tests were conducted in clear water with plastic beads with visualization provided via spreading a sheet of light across the center of the tank. Examples of the flow visualizations with the draft tube and SWIRLFLOW® running at the same power are shown in Figure 5. The behavior of flow patterns for both the draft tube and SWIRLFLOW® were similar to that observed previously without the inverted cone.

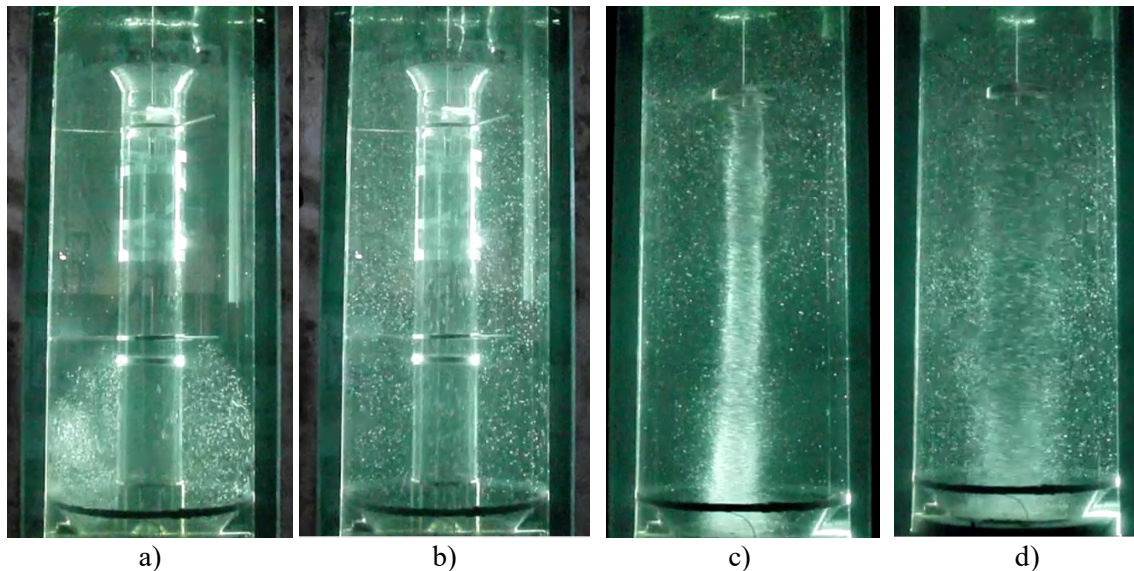


Figure 5. Flow visualisation flow patters for: a) draft tube – starting up, b) draft tube-stable condition, c) SWIRLFLOW® - starting up, and d) SWIRLFLOW® - stable condition.

3.2 Suspension Performance Test

The solids suspension performance of the draft tube and SWIRLFLOW® designs was then compared. The suspension tests conducted in the draft tube design had the dip pipe included as part of the tank's internal furniture, however, with the SWIRLFLOW® the draft tube and all the internal support structures, including the dip pipe, had to be completely removed and only the inverted cone was retained for the modelling.

Figure 6 shows the suspension performance of the draft tube design compared with the SWIRLFLOW® design. The suspension performance is determined via the record of sedimentation bed height H_B (normalized by the liquid height H) vs. power. The sedimentation results clearly demonstrate that the solid suspension performance with SWIRLFLOW® is significantly better than the current draft tube at Hindalco.

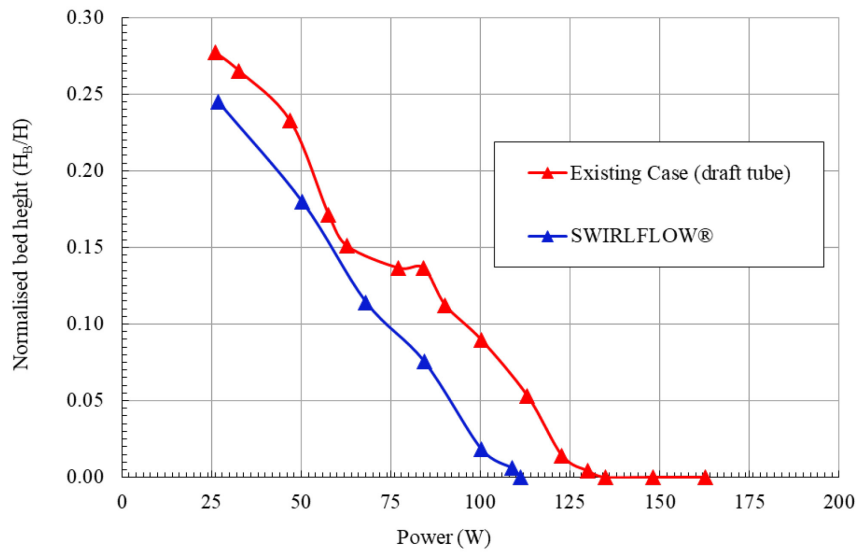


Figure 6. Sedimentation height H_B , normalized by the liquid height (H) vs. agitator shaft power measured in laboratory tank. Solids concentration: 450 g/L.

4. Results - Plant Implementation

At the end of the laboratory test campaign, a suitable SWIRLFLOW® design was developed to replace the full-scale draft tube at Hindalco to achieve better solids suspension. Figure 7a shows the existing draft tube design, which was removed along with other internal support structures, and the SWIRLFLOW® design is given in Figure 7b.

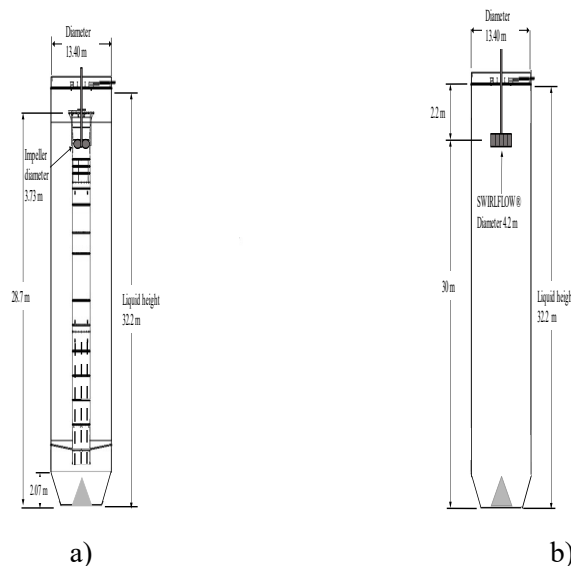


Figure 7. Full-scale precipitation tank at Hindalco; a) existing draft tube design, and b) SWIRLFLOW® design

Subsequent to the installation of the SWIRLFLOW® agitation system in tank (NG3) at Hindalco, the tank was filled with liquor (without solids) before running the SWIRLFLOW® impeller, starting up on the 3rd of March 2023. A few days later the tank was loaded up to the operating solids concentration. Figure 8 shows the SWIRLFLOW® installation at Hindalco with the

impeller is running without complication in air (a), running as liquor was filling (b), and with the liquor filled to the operating level when the SWIRLFLOW[®] was running at its operating speed 16.8 rpm (c).

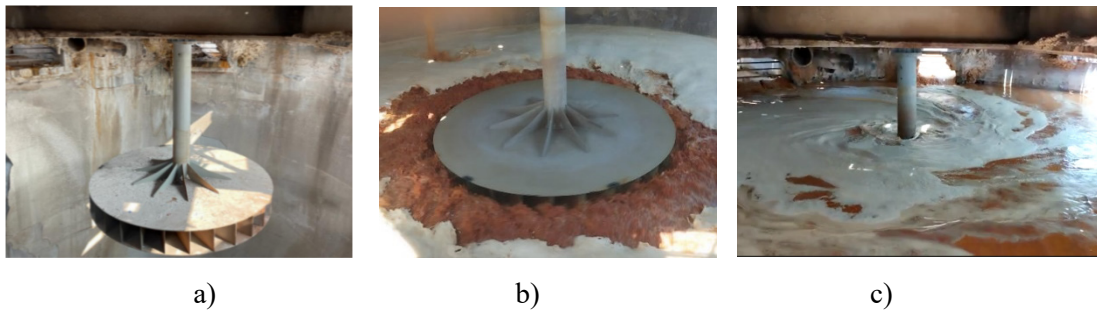


Figure 8. SWIRLFLOW[®] installation at Hindalco; a) before filling, b) during filling and c) with liquor level filled to its operating level.

The nominal impeller design speed was 19 rpm, but a VFD was installed to allow the speed to be adjusted, so that the operating speed could be optimized. The measured inlet concentration was found to be similar to the outlet concentration indicating the tank was fully suspended. It was confirmed by Hindalco that the tank was not caustically cleaned before the SWIRLFLOW[®] installation, the tank wall had approximately 10 mm of scale roughness as well as 0.7 m of sedimentation on the bottom of the tank before the SWIRLFLOW[®] trial started. The thermal scan of the tank shown in Figure 9 clearly shows the solid sediment that was left behind before the trial but also reveals no additional solids were settling out. To monitor the solids sedimentation during the full trial period, the operator will be conducting regular thermal scans.

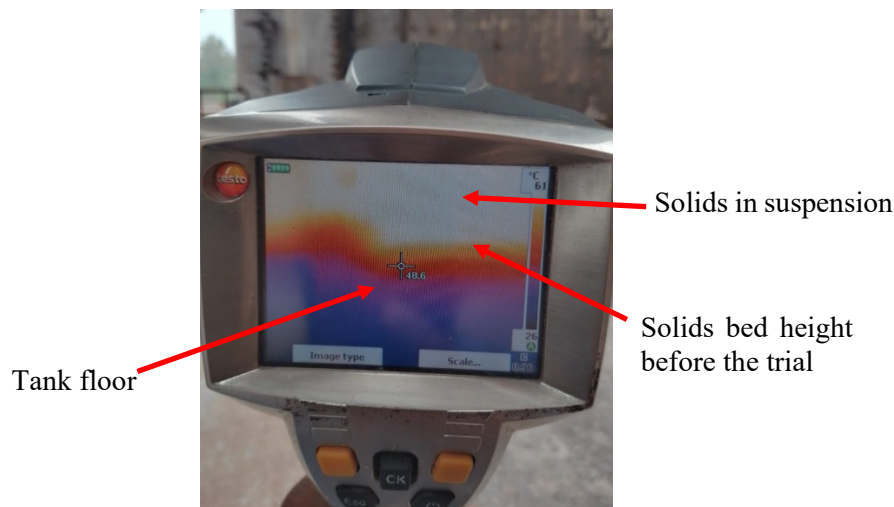


Figure 9. Thermal scan showing initial solids sedimentation on tank floor.

Observations during the plant trial

- The SWIRLFLOW[®] starting up met with some minor challenges that were caused by some gearbox issues (note this issue was unrelated to the SWIRLFLOW[®] itself).
- The existing agitator was not available for the tank to be caustically cleaned prior to the trial.
- During the trial, it was recorded that several unscheduled power failures took place at the refinery. The SWIRLFLOW[®] was successfully restarted and returned the NG3 precipitation tank to full suspension condition shortly after the power failures. In the most

recent power failure, during restarting, it was observed that the resuspension of solids was more effective when the recirculation pump from the tank bottom was also used.

- Up to the time of completing this paper, it has been reported that the SWIRLFLOW[®] was operating very well at Hindalco and in line with design and power draw specifications Hindalco are now considering further SWIRLFLOW[®] installations in their precipitation tank line.

5. Discussion

On previous occasions CSIRO's physical modelling approach was successfully utilized to develop suitable SWIRLFLOW[®] designs for QAL precipitation tanks as well as for other tanks in alumina refineries around the world. A similar physical modelling approach was used here to prepare for the Hindalco SWIRLFLOW[®] implementation. The Hindalco precipitation tank (NG3) was fitted with a central inverted cone in a filleted tank bottom. The modelling was carefully conducted and compared the performance between the existing draft tube set up and the proposed SWIRLFLOW[®] design and the results demonstrated that SWIRLFLOW[®] consumed a much lower power to maintain the same solids suspension than the draft tube. However, the SWIRLFLOW[®] system was designed to have a similar power consumption to the existing draft tube at Hindalco meaning the solids suspension with SWIRLFLOW[®] is expected to be much better than the draft tube.

Besides removing of all internal structures for the SWIRLFLOW[®] implementation, the tank was required to be thoroughly caustic cleaned. Due to an unforeseen situation, the existing agitator was not available for the caustic cleaning and so the tank was left uncleaned for the SWIRLFLOW[®] trial. Despite this the SWIRLFLOW[®] installation went well and remains operating well in line with design criteria. Given its performance in an uncleaned tank we expect that the power consumption in a cleaned tank will be much lower leading to a much longer tank online time.

6. Conclusion

The SWIRLFLOW[®] agitation system was originally developed for precipitation tanks at Queensland Alumina Limited (QAL). The technology has since been successfully implemented in many other alumina refineries as well as for mixing tanks in other commodities. The success of the development and implementations of the SWIRLFLOW[®] technology has been based on CSIRO physical modelling.

Though the Hindalco installation this was the first time that SWIRLFLOW[®] was implemented in an inverted cone with fillet bottom tank, the initial CSIRO modelling showed that it was feasible. The modelling compared SWIRLFLOW[®] with the existing draft tube design and the results confirmed that SWIRLFLOW[®] clearly outperformed the existing draft tube suggesting SWIRLFLOW[®] could be a better alternative for the precipitation tanks at the Hindalco refinery. Though the trial at Hindalco is at an early stage, the observations and the data collected by the plant operators to date confirm good performance in line with the design criteria.

7. Acknowledgement

The authors would like to thank QAL for the joint invention of SWIRLFLOW[®] with CSIRO as well as other collaborations for further optimization of the technology. We would like to thank CSIRO staff Dean Harris and Metso staff Amit Kumar Das, Bilas Kundu for their support during experimental work and the plant trial.

8. References

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