Vessel Diagnosis in the Bayer Process Using Ferromagnetic Tracers

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Abstract

In the Bayer process, having a good knowledge of the residence time distribution (RTD) of thickened slurry and pulp flows can help achieve a more efficient operation, diagnose problems such as channeling and dead zones, or evaluate the effectiveness of operational parameters. A tracing procedure and apparatus was developed by Rio Tinto in partnership with the Université du Québec à Chicoutimi to monitor slurry displacement patterns. The principle of the apparatus is the detection of a solid ferromagnetic tracer by inductance coils. The RTD obtained is then analyzed with a proprietary Rio Tinto deconvolution method to understand the different flows inside the vessels. Iron powder is usually utilized as a tracer for its compatibility with slurry of bauxite residue. However, magnetite has been successfully tested as an alternative tracer since it can be used at higher temperature and higher caustic concentrations than typical Bayer washer circuit conditions. The tracing technique was validated at plant scale for the diagnosis of slurry behavior in deep thickeners, stirred tanks, and pipes.

Keywords: Residence time distribution; tracer; flow; diagnosis; ferromagnetic; tanks; pipes.

1. Introduction

In the Bayer process, a number of steps are required to allow alumina extraction such as pre-desilication, digestion, settling, clarification, thickening, mud washing circuit, slurry transport in pipes, etc. The industrial facilities used are quite large and many were constructed at a time when process conditions were different from today. Moreover, the general decrease in bauxite quality results in processing larger volumes for a consistent alumina production rate, which requires a better equipment performance. In this context, a better understanding and optimization of these process steps become crucial. Having a good knowledge of the RTD of slurry and/or thickened slurry flows can help to achieve a more efficient operation as well as diagnose channeling and dead zone problems in operating facilities, or evaluate the effectiveness of various operating parameters.

Tracers are widely used to diagnose the behavior of continuous flow chemical reactors [1-2]. In these techniques, the reactor RTD, from which many physical parameters can be computed, is obtained by measuring the tracer at the reactor outlet. Analysis of the RTD can be useful in diagnosing the reactor’s behavior. To be applicable to industrial facilities, this technique requires an easily measurable tracer that is compatible with the physical and chemical process environment. Tracing techniques have been used previously to simulate liquid flow in settlers [3-4] and thickened slurry behavior in thickeners [5]. Research on an on-line electromagnetic iron tracer detector capable of measuring RTD in industrial equipment has been published previously [6-8].

This paper presents a tracing apparatus developed by Rio Tinto in partnership with the Université du Québec à Chicoutimi [6-8]. This apparatus was used at plant scale to validate slurry behavior in the last deep thickener of the mud washing circuit, in a pre-desilication stirred tank, and in the pipe connecting the refinery to the Residue Management Area (RMA). Two types of tracers were used to carry out measurements in different operating conditions.

2. Tracing Technique

2.1. Ferromagnetic tracers

It is difficult to carry out RTD measurements in the Bayer process because of its aggressive chemical environment. Furthermore, the Bayer process is a two-phase system (solid and liquid) and the tracer must therefore be adapted to represent the real flow to be measured. The use of a ferromagnetic tracer allows the continuous monitoring of the slurry displacement with an on-line electromagnetic inductance measurement method. Because of the differences in Bayer process operating conditions, two tracers were used to carry out the measurements. The first was iron powder, which is used in the mud washing circuit under low caustic soda and relatively low temperature conditions. The second one was magnetite powder that can be used at higher temperature and higher caustic soda concentrations than normally found under typical red mud washing circuit conditions. Indeed, iron powder can be reactive under such conditions, potentially leading to iron oxides and hydrogen gas evolution. As the tracer must remain intact, the use of a final oxidation product that is ferromagnetic, like magnetite, is required. Indeed, both tracers show a good chemical resistance for the time span required to measure RTD under the specific trial conditions. Moreover, they are not toxic and may be easily disposed with the bauxite residue after use. Ground and digested bauxite has a particle size distribution ranging from less than 6 to ± 100 microns. It was previously shown [6] that a ferromagnetic powder with an appropriate average diameter can simulate the slurry displacement. In addition, iron oxide particles are already present in bauxite, so there is no contamination of the process. The large magnetic permeability of iron or magnetite allows the detection of the tracer by electromagnetic techniques. Consequently, the ferromagnetic powder is an ideal tracer to monitor slurry displacement in the Bayer process [3].

2.2. Tracers injection and measurement

The quantity of tracer injected into a vessel is evaluated using the instrument’s limit of detection (LOD, in g/L) and the volumeof slurry inside the vessel. The suspension (Bayer liquor with tracer powder) is injected rapidly at the usual inlet to generate a pulse. Operational parameters such as rake torque, agitator speed, feed flow, underflow, bed level, recirculation flow, etc. are recorded by the plant’s DCS (Distributed Control System).

2.3. Detection method

The detection method consists of injecting a given amount of tracer at the inlet of the vessel and detecting it at the outlet with an inductance coil. In fact, a magnetic field is generated around the coil by applying an electric current. When the ferromagnetic particles cross the coil, the permeability of the medium is modified, which causes variation of the magnetic field [6-8]. The electromagnetic detector is principally built with two inductance coils. The first one is used to measure the ferromagnetic tracer in the slurry flow. The second one acts as a reference coil and measures any extraneous signal originating from the electromagnetic environment. The final signal is obtained by subtracting one from each other and represents the global RTD. Figure 1 shows a picture of the detector. The latest generation of detectors includes two identical and larger coils, a temperature controller on the reference coil to mitigate temperature variations and a better and stronger electrical circuit. The electrical circuit is encased inside an easily transportable suitcase.

Calibration curves are obtained by circulating a suspension containing known amounts of ferromagnetic tracer through the measuring coil. As the calibration of the instrument can be

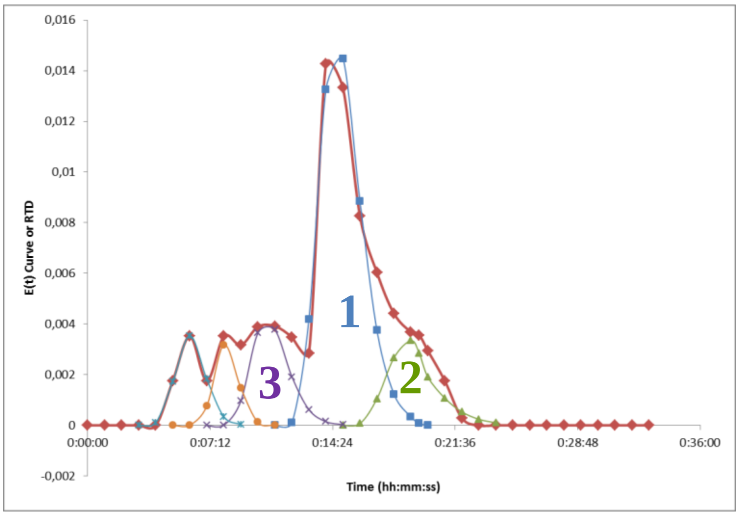

Figure 8. Tracing curve obtained for the pipe between the last mud washer and the RMA.

The global RTD was decomposed into five individual peaks indicating the presence of five types of flows in the pipe. The first major peak (Figure 8, Peak 1) represents 54% of the global area, the major part of the mud flowing inside the pipe through this pathway. Its τ_i (0.25 hr) is near that of the global curve. Its shape is similar to a PFR flow, which is expected. Peak 2 represents 16% of the global area with a 0.33 hr τ_i, longer than the global residence time. This means that this portion of the flow was delayed, possibly by a restriction like an elbow, a bend or scale accumulation for instance. In addition, the flow associated with Peak 2 is much closer to a CSTR behavior, which could indicate a turbulent zone. Peak 3 represents 13% of the global area with a 0.20 hr τ_i, lower than the global residence time. Its shape indicates a piston behavior. It can be assumed that this portion of the flow has a laminar behavior and is situated in front of the main flow in the pipe. Simulations at lab scale are necessary to validate these hypotheses, however, the main purpose of this measurement, to validate the RTD in pipes using the tracing technology, was achieved.

4. Conclusion

A tracing technique using a ferromagnetic tracer to understand the flow patterns in three different vessels proved very effective and easily applicable in an industrial environment. It was also shown that the RTD decomposition method is applicable for analyzing the slurry behavior in a deep thickener, a stirred tank and pipework. Moreover, it was previously shown that this method is able to detect and quantify some common problems like bypass or dead zone and, in this respect, may be used for troubleshooting purposes [7-8]. The apparatus is robust and may easily be used in plant facilities. This technique may be adapted to various other types of mineral industries to assist in the comprehension and/or the diagnosis of industrial vessels. It could also be helpful in the evaluation of tank aging in order to optimize the cleaning schedule, or in the evaluation of plant modifications. In the current depressed economic context of the mining and mineral industries, equipment that helps to understand, improve or diagnose an industrial process at low cost can be very advantageous.

5. References

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