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Light Metals 2013 *Edited by: Barry Sadler*
TMS (The Minerals, Metals & Materials Society), 2013

IMPLEMENTATION OF LOGIC CONTROL BY DCS TO MEASURE THE CAUSTIC CONCENTRATION IN SPENT LIQUOR

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Keywords: Caustic balance, DCS control and decrease variability

Abstract

In Hydro Alunorte over the years several regression studies have been conducted in order to determine the caustic concentration in spend liquor tanks that feed digestion unit based in temperature, conductivity and density values. A new control is done through multivariable control logic implemented in DCS based on caustic balance in spent liquor storage area. The logic control displays caustic concentration and flows from flash cooling, evaporations and digestion to calculate the soda solution flow required to keep the process parameters. They are part of the instruments control refractometer (PLA), thermocouple and flow meter, which allow the instantaneous measurement of the concentration caustic. The main improvements are stability in caustic control parameters in order to reduce the variability of 53%, reduction in caustic solution consumption, number of analyzed, reduced operator exposure and increase yield

Introdution

The challenge to any alumina refinery is to minimize the cost of production per tonne of alumina, consistently with safety and environmental considerations. This translates to maximizing the production of alumina (plant flow and yield) and minimizing the soda costs per tonne of alumina.

Caustic soda is a product of the transport process bayer. Its concentration has a direct impact on the liquor yield. Also governs the solubility of hydrate, in all parts of the process: digestion, mud filtration, filtration and precipitation. It is therefore essential to maintain control of the caustic concentration plant defined. Regarding the volume of liquor, caustic inventory is affected by a number of production factors, where the outputs are identified as silica reactive, soda in mud and sand soda, at TCA, in alumina and others.

Thus, caustic concentration control is made through evaporation system and adjust of soda solution from tanks that was in caustic cleaning. Adding more caustic to the circuit then was lost or not consumption will increase amount of caustic inventory. However, the caustic concentration is affected by volume variations, caused dilutions on the circuit.

Process Description

The process for obtaining alumina from bauxite ore was developed and patented by Karl Josef Bayer in 1888. Typically, depending on the quality of the ore, between 1.9 and 3.6 tonnes of bauxite are required to produce 1 tonne of alumina.

Bayer process is cyclical and involves many unit operations, like digestion, solid – liquid separation and crystallization.
Overall, bauxite ore is digested in caustic solution concentrate in temperatures ranging from 145° to 270°C, depending on the nature of the ore. Under these conditions, most mineral species that contains aluminum is dissolved, forming sodium aluminate, soluble, as shown in equations (1) and (2).

$$Al(OH)_3 + NaOH \leftrightarrow NaAlO_2 + H_2O \quad (1)$$

$$AlO(OH) + NaOH \leftrightarrow NaAlO_2 + H_2O \quad (2)$$

The portion of the ore that is insoluble in caustic solution after digestion (red mud) is removed by sedimentation and filtration process and pregnant liquor polished is send to the precipitation. The hydrate precipitate is removed, washed and sorted. Alumina is then obtained by calcinations of hydrate.

Test Tanks Area

The test tanks was designed for storage spent liquor from the white side to feed digestion unit, avoiding the loss of production as a result of operational problems in the process from the supply system spent liquor, or because due to maintenance requirements of the equipment of that system.

The test tanks also possible, by mixing, smooth variations in the concentration of stream liquor from the plant. The caustic concentration of stream feed digestion is also controlled through this area.

The liquor level in the tank test is maintained between the maximum and minimum limits, by adjusting the flow hydrate thickeners tanks through Flash Cooling area.

The caustic solution tank has capacity to store 5.450 m³. This tank was provide to control volume plant by receiving soda solution from caustic cleaning system. Caustic solution added to the process to compensate loss from reactive silica consumption and others.

Caustic Concentration Control

The spent liquor feeding tanks tests comes from the Flash Cooling area with caustic concentration of 283 gpl caustic, about 40% of the liquor is sent to the evaporation system. The evaporation system of lines 1 and 2 was designer with 10 stages evaporated at a rate of 128 m³ / h with a nominal flow rate of 560 m3 / h. The system of line 3 was designer with 10 stages at a rate of evaporated 64 m³ / h with a nominal flow of 450 m³ / h and the system of lines 4 and 5 of evaporation made up of 12 stages with a rate of evaporated 150 m³ / h with a nominal flow of 700 m³ / h. Units evaporations are designed to provide an increase of the caustic liquor poor concentration of 45 gpl.

The Figure 1 shows block diagram of the process.

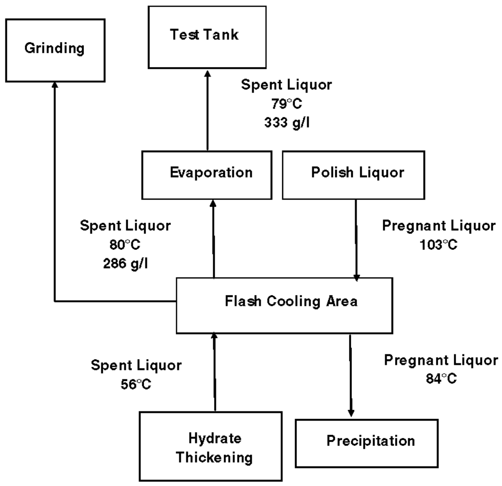

Figure 1 – Test tank area flow simplified block diagram.

Caustic Concentration measurement online

The system to determinate caustic concentration online is conposed for following instruments: refractometer, thermometer, flowmeter and manual valves.

The flowmeter indicates spent liquor flow for the system. This flow must be such to allow a flow of approximately 14 m³ / h (speed of solution of approximately 1.8 m / s) to minimize scale formation on the prism of the refractometer, plugging of nozzles washing prism and obstructions in circuit.

The refractometer shows on Figure 2 (mark PL&A, model AL-6337), was used to obtain the refractive index online. The refractive index (RI) is defined as the angle deviation of the light when crossing a way, this deviation is proportional to the solids concentration or density of the liquid in the alumina industry that enables precise analysis of molars ratio. Figure 2 shows the equipment.

Figure 2 - Refractometer PL&A, model AL-6337, installed online.

The measured value of each instrument system is transmitted to the DCS (Digital Control System), as a signal 4 to 20 mA. This signal is read every second and can be integrated for a certain time to eliminate oscillations reading instruments or signals transmissions. The integration time is approximately 10 seconds to eliminate variations in readings.

The methodology of multivariate linear regression on data from refractive index and temperature of the spent liquor was used to obtain mathematical models that enable the prediction of caustic concentration with adequate precision.

The equation 3 determinate caustic concentration, using constants obtained by applying linear regression of the data supplied by the equipment and laboratory analysis.

$$NaOH \text{ (g/L)} = a_1 * IR + a_2 * T + a_3 \quad (3)$$

Where,
Cáustico = concentração de soda cáustica da solução em g/L;
IR = índice de refração da solução;
T = temperatura da solução;
a_i = constantes do modelo de regressão para soda cáustica.

Controller to adjust caustic concentration by DCS

The controller to adjust caustic concentration was developed using the programming language FBD (Function Block Diagram) and ST (Text Structure), defined in IEC 61131-3, the Digital Distributed Control System (DCS) Industrial IT 800xA, for lines 4 and 5 and AMPL (proprietary language ABB) in Advant Controller AC450 case for lines 1, 2 and 3.

The controller was divided in four modules control logic, which are: Flow / evaporation, caustic Balance, PID control and interlocks.

Flow / Evaporation: It is the module responsible for caustic flow inlet the spent liquor storage area (40% for evaporation and 60% directly for storage area through Flash Cooling system);

Caustic balance: It is the module responsible for determining the caustic concentration calculated (Virtual Instrument);

PID controller: It is a mathematical model, which uses proportional gain, integral and derivative, to perform control and reduce the error (deviation between the measured variable and setpoint). The PID controller is composed for error subroutines, feedBack, feedforward and correction.

Error: Calculates the difference between the process value and setpoint;

FeedBack: It's a negative feedback system that uses the proportional gains, derivatives and integrals to compensate for the error and decrease the influence of this process.

FeedForward:. It is the module responsible for performing the prediction of process behavior based on several variables that influence, anticipating disruption and reduce the influence of those in caustic control add.

Interlocks: the module is responsible for ensuring the safe operation of process control caustic areas 18A, 18B and 18C.

Results

Figure 3 shows the profile of the caustic concentration on spent liquor comparison between the laboratory analysis and measuring online. The hypothesis test confirms that the datas has a normal distribution and have equal variances and means. The laboratory results confirm the trend information monitored by DCS. Figure 4 shows the Box plot graphic of the statistical evaluation.

However observed that the process is not capable to look to the specification limits. Values below the lower limit of 295 gpl impair digestion chemical yield and above can cause high losses of gibisita circuit and loss of yield in the area by auto precipitation filtration pregnant liquor. Values above the upper limit 301gpl impair precipitation chemical yield.

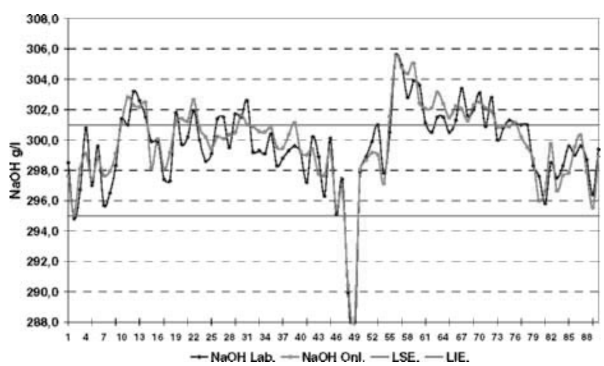

Figure 3 – Caustic concentration profile between PLA and laboratory analysis.

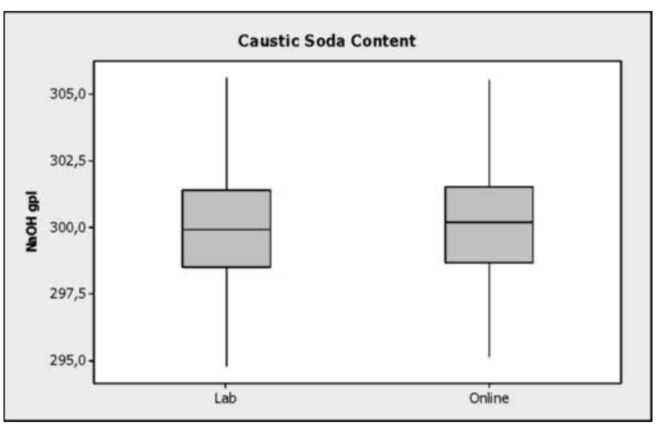

Figure 4 –Box Plot graphic.

Figure 5 shows the time series graphic with caustic concentration profile in the spent liquor storage before and after the implementation of the control. The results show a reduced standard deviation of 4.1 to 2.2 (53.6%), increased 1gpl caustic concentration in the test tank (298g / l to 299g / l), increased by 0.36 T / m³ digestion chemical yield.

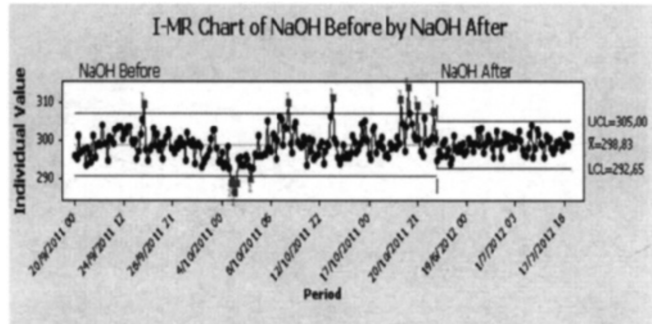

Figure 5 – Time series graphic with profile caustic concentration before and after the controller.

Conclusion

The control was implemented successfully, achieving standard deviation results in the order of 4.1 to 2.2 (53.6%), an increase of 1 g / l in caustic concentration in the test tank (298g / l to 299g / l), an increase of 0.36 t / m³ in digestion chemistry yield. Seeing this profile, is possible to ensure the ratio A/C in digestion blow off control stability due to variability reduction parameter ensuring the balance caustic and operability of pregnant liquor filtration area ensuring auto precipitation control.

Improved volume control avoiding excessive soda consumption on the process to control caustic concentration in spent liquor storage area.

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