Advanced Process Control and Optimization of Alumina Calciners

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Abstract

Alumina calciners are one of the greatest energy consumers in an alumina refinery plant. Due to the high temperature needed to remove the hydroxide of the aluminum hydroxide structure, the fuel consumption is extremely high. Regarding this, an accurate process control is essential to achieve an efficient process with low variability, better fuel consumption performance and competitive production costs. The present paper presents the application of advanced control software based on fuzzy logic in Companhia Brasileira de Alumínio (CBA) calciners. Fuzzy logic has the ability of considering multiple variables and the software acts to avoid disturbances. In this way, it was shown in preliminary tests that CBA could improve the calciners performance, reducing the variability of the calcination temperature by 21%, which represents a 0.66% reduction in the specific fuel consumption.

Keywords: Process control, fuzzy, alumina calciner, process optimization.

1. Introduction

Companhia Brasileira de Alumínio (CBA) is located in Alumínio, 74 km from São Paulo city, and it is one of the biggest integrated aluminum plants in the world. CBA started to operate in 1955 and it belongs to Votorantim Group. The aluminum production capacity of the plant reached 417 kt in 2017 and uses a traditional low temperature Bayer Process.

The Bayer Process, developed in 1888 by the chemist Karl Josef Bayer, is the most used process in aluminum industry for refining ore bauxite into smelting grade aluminum oxide. There are four main stages in the Bayer Process: digestion, clarification, precipitation and digestion [1].

Calcination is the last stage of Bayer Process, where the aluminium trihydroxide ($Al(OH)_3$), formed and separated in the preceding process stages, has its hydroxides removed, forming the aluminum oxide (Al_2O_3) and water. The reaction occurs at high temperatures, around 960 °C, and is presented below [1]:

$$2Al(OH)_3 \rightarrow Al_2O_3 + 3H_2O$$

In CBA, natural gas is the second largest cost for the alumina production. Also, calcination has an important influence on the product quality. Because of that, an optimized operation of the calciner is crucial from the economic point of view of the whole alumina refining plant. In CBA, two fluidized bed calciners are responsible for the calcination process. A generic schematic diagramme of a fluidized bed calciner is shown on Figure 1, with the calcination stage (Circulating Fluidized Bed Furnace and Recycling Cyclone) highlighted in gray [2]:

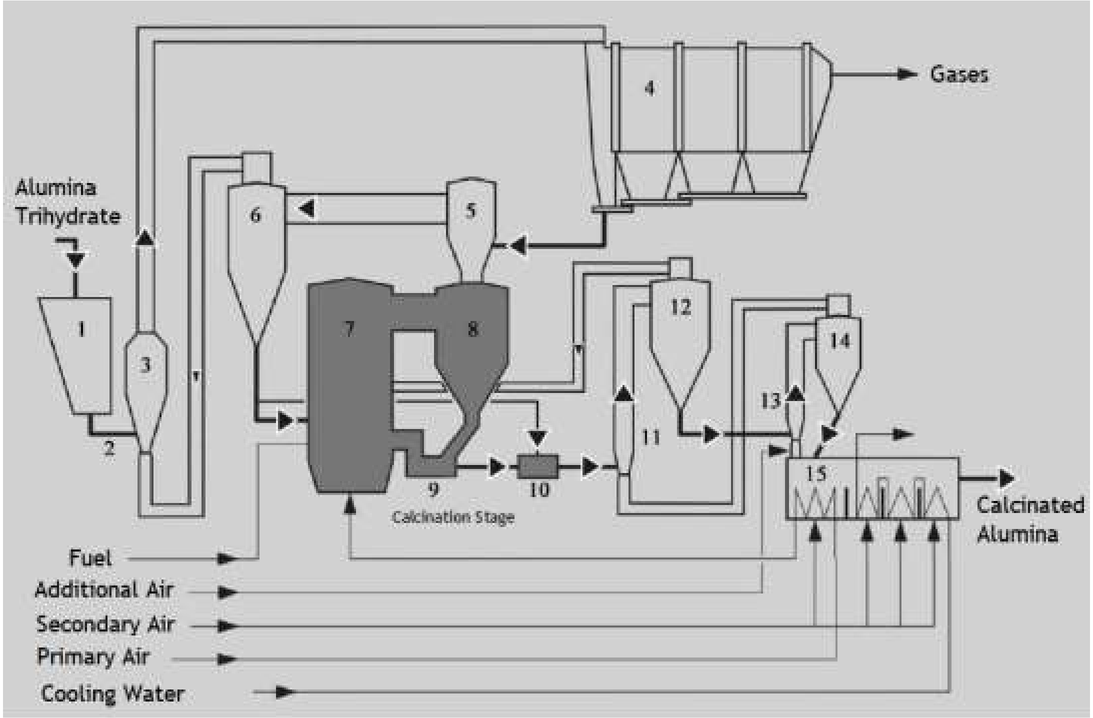

Figure 1. Generic schematic of a fluidized bed calciner, with the calcination stage highlighted.

The feed is fed from the feed bin (equipment 1 in Figure 1) via a feed screw into the first venturi preheating stage (equipment 3, in Figure 1). After passing a series of cyclones the material is fed into the CFB furnace (indicated by the number 7 in Figure 1) by a chute. The fuel (in CBA´s calciners natural gas) is fed by gas lances and controlled with a valve into the CFB furnace. Primary and secondary air are fed by eight blowers (three for the primary air and five for the secondary air). The material is calcined and recirculated in the CFB system, a special discharge device is responsible for discharging product alumina to the cooling stages.

As there are a plenty of heat transfer and chemical reactions (combustion and calcination) occurring at the same time in the CFB furnace, a successful control system must deal with many variables at the same time, as an actuation in one manipulated variable, may have a direct influence on more than one process variable and one process variable may suffer influence from more than one manipulated variable.

The combustion reaction of the fuel is responsible for providing the heat necessary for the calcination of the aluminium trihydroxide into smelter grade alumina, so it is important to control the flow of fuel and air to keep the calcination temperature stable and close to the setpoint. However, the bottom temperature and the secondary air temperature may also interfere with the calcination temperature, as they reflect the amount of heat retained with the recirculated solids and the amount of heat provided to the calciner by the air. That said, it is important that the control system can stabilize all these variables to achieve a stable heat flow in the calciner, optimizing its energetic efficiency and fuel consumption leading to important economic savings on the equipment operation.

1.1. Fuzzy Logic

Fuzzy logic is a powerful artificial intelligence method, as explained by Franco [3]:

This great improvement was mainly achieved by the change on the control logic of the product discharge from the CFB furnace. Before the advanced control the main objective of the control of alumina discharge was to maintain the bottom differential pressure on the setpoint set by the operators. The differential pressure corresponds to the inventory of the fluidised bed furnace and also indicates if there areproblems with the discharge like lack of material inside the calciner (if this diferrential pressures is too low) or obstruction by excess of material at the bottom (if this differential pressure is too high). With this strategy, the bottom temperature was only a result of the control, and not a controlable variable. However, with the advanced control capacity of dealing with multiple variables at the same time, it was possible to create a strategy that optimizes the bottom temperature and keeps the differential pressure inside its limits, leading to the stabilization mentioned above.

Finally, on Table 3 are presented the results comparison regarding the specific fuel consumption of the calciner.

Table 3. Results for the Fuel Consumption.

Control Strategy	**Mean (m^3/t feed)**	**Standard Deviation (m^3/t feed)**
Leaf ON	80.12	1.27
Leaf OFF	80.66	1.92

The data above shows the economic benefits of the advanced control application, by showing the 0.66% reduction on the mean of the specific fuel consumption on the calciner as well as a 34 % reduction in its variability. With that reduction the economic gains derived from the stability of calcination and bottom temperatures could be measured, validating the benefits of the application of the advanced control provided by Leaf.

3. Conclusion

By anticipating disturbances and integrating the main control loops of the calciner, it was possible to achieve a more stable and optimized operation of the process, leading to operational and economic gains.

A more stable process leads to an increase in the product quality, since the calcination reaction is affected by temperatures changes, so a stable temperature improves its yield. Also, in the long term, a more stable process can reduce the costs with maintenance and the deterioration of the equipment.

The reduction of 21 % in the variability of the calcination temperature (maintaining the temperature at the desired value of 960 °C), along with the reduction of 61 % in the variability of the bottom temperature stabilized the process. This stabilization summed with the increase of 0.4 % in the mean of the bottom temperature resulted in reduction of 0.66 % of fuel consumption, derived from a better energetic efficiency of the calciner.

4. References

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