Reduction of Energy Consumption Improving the Calciners' Efficiency

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Abstract

Calcination, the last stage of alumina refining, consumes a significant amount of the energy used at alumina refineries. Managing and improving calcinations' energy efficiency is an important lever to minimize cash cost and as well as reduce carbon dioxide emissions. Despite this, the energy required to convert hydrate to alumina is often reported, without the conditions under which the conversion occurred. The development of a mass and energy balance model for calcination can provide a useful assessment of plant data and identify gaps to practical limits and opportunities on calciner energy performance. This paper shows a case study of energy gap analysis using an Aspen based mass and energy model for Alcoa calciners and provides guidance to optimize the energy consumption in calciners.

Keywords: Calcination energy efficiency, Aspen Model, energy consumption.

1. Introduction

At the recovery section of an alumina refinery, gibbsite crystals, $Al(OH)_3$, grow from the clarified Bayer liquor and are subsequently washed and calcined to form smelter grade alumina (SGA).

Due to the high heat of reaction required to perform the thermal decomposition of the gibbsite crystals into alumina, a great amount of fuel is required. Generally, this is one of the higher costs required in alumina production. At the studied case, the fuel used is known as BFO (bunker fuel oil).

Apart from the design of the calciner, there are several parameters which impact energy efficiency. The main motivation for this work was to identify energy efficiency opportunities in the calciner's dynamic combustion process, guided by process modelling, so as to improve and optimize their performance. The challenge of the calciners operating using BFO is to produce alumina at high production rates while aiming for low fuel consumption.

2. Calciners process description

At the Alumar refinery, a system distributes the hydrate feed into calciners of different design, namely Alcoa MKIV and Alcoa MKVII designs. The MKVII calciners have a similar process but have larger capacity and better efficiency than the MKIV calciners.

The total calcination production target is calculated through the operation of the Bayer process. The required fuel oil is then set for each calciner to achieve its individual production target. The main inputs into calciners are hydrate, air, BFO and cooling water. The air is used to transport the hydrate/alumina, transfer heat and combust with the fuel oil in the furnace and pre-heater.

The air-fuel ratio and excess air are important parameters in ensuring that adequate combustion takes place and to achieve the required level of alumina specific surface area. Cooling water is used to control the temperature of the discharged alumina product. A schematic of calciner inputs is demonstrated in Figure 1.

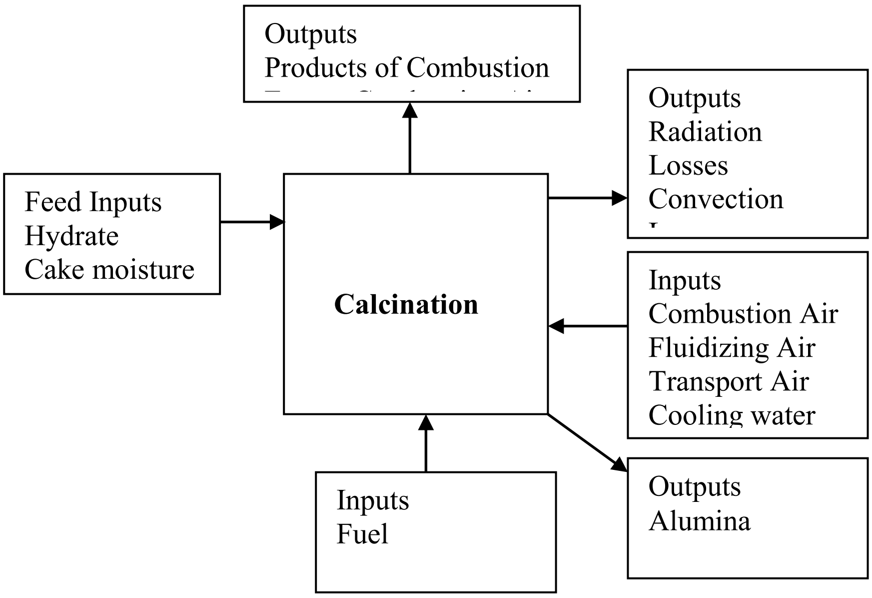

Figure 1. Calcination inputs and outputs diagram.

3. Simulation Details

3.1. ASPEN Plus Model Set-Up

ASPEN Plus is proprietary modelling software being used within Alcoa to mathematically model calciner performance. Model results can be used for optimization of calciner fuel usage, optimizing the process vessels and to identify short-circuiting [1]. Each calciner in the system has a base case of model parameters that should reflect the nameplate operation of that calciner. It was necessary to calibrate the ASPEN Plus model with the calciner configuration and use the modelling results to generate the energy impact.

The process modelling software is a very good way to simulate the real scenario, whereby the input of certain fixed variables are required to determine the energy values.

For the simulation set in question, the main parameters varied were: hydrate cake moisture, production volume, excess air, furnace and duct temperatures, stack temperature, cooler inlet, duct conveying air, pre-heater cooling air, holding vessel and cooler fluidization air, to estimate the impact in energy consumption of MKIV and MKVII calciners. Nine different scenarios were modelled for each calciner design to predict the energy saved.

3.2. Bridge Interface

After the simulation results were calculated by the model, the bridge interface spreadsheet was developed for each calciner. This allowed for a direct comparison of current plant set up to readily determine if calciner operation is optimized to reduce fuel consumption. The energy consumption can be monitored daily for all calciners and any deviation in the bridge represents energy gains/losses.

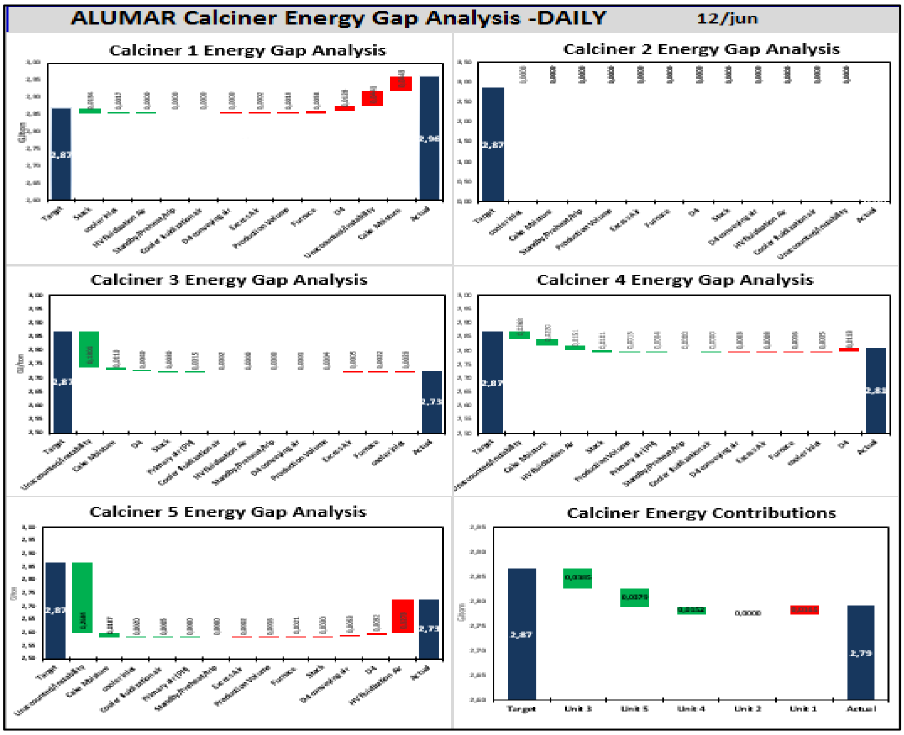

Figure 2. Energy gap analysis.

4. Energy Results

4.1. Air Flow (m^3/h)

The primary factor impacting energy consumption is the air flow distribution [1]. The air needs to be added at stages within the calciner. Nevertheless, the combustion air input not used to cool the alumina, requires additional energy to heat. In the same way, external air added to the hydrate preheating section of the calciner will result in lower stack temperatures which lowers hydrate temperature requiring more energy to be added in the furnace. This will result in more products of combustion [2].

This means that to maximize energy recovery from the alumina, combustion air as holding vessel (HV) fluidization air and pre-heat cooling air, should be maintained at their minimum to allow the maximum level of air passing through all the cooling stages.

The energy impact was determined from Aspen modelling for both the Mark IV and Mark VII calciners for every 1000 m^3/h variation of holding vessel air, conveying air and also pre-heater cooling air.

4.2. Feed Moisture (%)

Filtration and washing of alumina hydrate product is performed on pan filters at Alumar Refinery. The pan filter is well suited to the filtration and washing of coarse particles [3]. Cake moisture has a direct impact on calcination energy because water in the feed consumes energy to evaporate. Energy used for evaporation results in a lower hydrate temperature to the next preheating stage [2].

For each 1% of moisture in hydrate cake the energy consumption is increased by 0.02 GJ/ton of alumina.

4.3. Temperature Profile

The furnace temperature has an important role in energy consumption and alumina product quality control. A furnace temperature higher than desired will result in a high stack temperature and reduced throughput.

The impact on energy from Aspen results were determined for both the Mark IV and Mark VII calciners for every 25 ºC variation of furnace temperature, stack temperature and cooler inlet temperature predicting an energy impact of 0.01 GJ/t ,0.03 GJ/t and 0.01 GJ/t, respectively.

Stack temperature and cooler inlet temperature are the most difficult to control. Influencing factors are excess air, hydrate cake moisture and furnace temperature.

4.4. Overall Energy Reduction

After execution of all the above changes in calciner operation, the main result obtained was the improvement of overall energy efficiency, as shown on Figure 3 below.

Alumar calciners had an energy efficiency around 2.88 GJ/t before the improvements in 2016, reducing to 2.87 GJ/t in 2017 saving 0.01 GJ/t, with the potential to achieve 2.85 GJ/t in the future years.

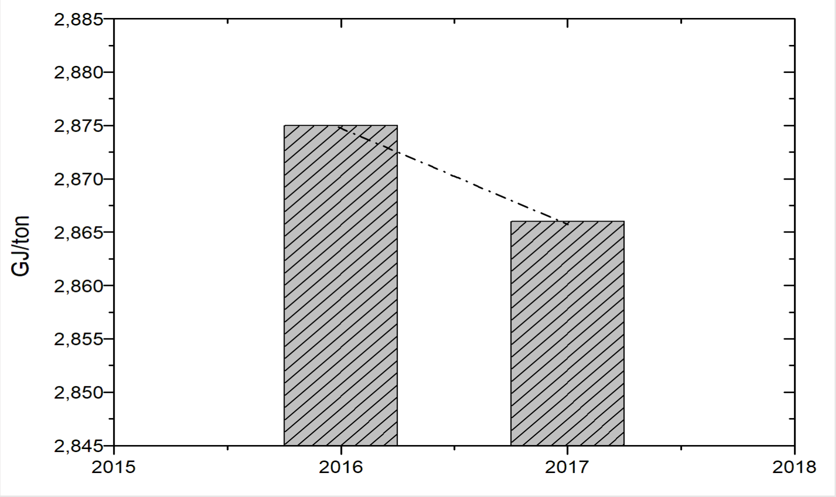

Figure 3. Calciners energy overall reduction (GJ/ton).

5. Conclusion

The energy optimization in Alumar's calciners from mathematical modelling (Aspen) shows the importance to reduce energy losses from all streams, minimizing the exit temperatures through maximizing the proportion of combustion air in the cooling stages, minimizing the furnace temperature and maximizing the heat transfer throughout the calciner. The changes need to have careful evaluation of temperature's, pressures and velocities in calciners. It requires validation through field tests, monitoring the accuracy of the instrumentation and the calciner's thermal profile in critical zones. This was very important to guarantee the success and sustainability after changes were implemented.

6. References

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