Increased Operational Flexibility in CFB Alumina Calcination

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Keywords: Automation, Operational Flexibility, Outotec® SmartFeed, Burner Management, Alumina Calcination,

Abstract

Operational flexibility with regards to production rates and fuel usage in alumina calcination is becoming increasingly important in today's market. Outotec has a range of technologies, which can be retrofitted in old plants, or offered as options in new developments, that are aimed at improving the plant flexibility and performance, while maintaining product quality.

Process stability is critical for product quality and energy consumption and also to reduce material and refractory wear, increasing the operational life of the calciner. In the Outotec® SmartFeed product, the feed and fuel control is automated to reduce temperature fluctuations in the circulating fluidized bed (CFB) furnace. A feed forward function, build into the fuel controller, takes into account any changes in feed rate or hydrate bypass level and adjusts the fuel correspondingly and in advance.

Additional operational flexibility and improved service life can be gained through Outotec's Burner Management System concept. This system is designed to reduce the downtime of the calciner and to allow maintaining the temperature in the CFB furnace during shutdowns by keeping the pre-heat burner in operation continuously.

Introduction

Traditional single loop controls have some limitations in providing adequate response when there are multiple process interactions [**1**]. Alumina calcination is one such example, where temperature control in the CFB furnace and oxygen level in the off-gas is controlled by varying variables such as fuel flow, feed flow, air flow and furnace discharge. At the same time the control system has to be capable of handling different process conditions and fluctuations that occur naturally or due to process upsets. Process upsets may include feed moisture changes, load changes, pressure and temperature fluctuations.

The temperature stability in the calcination process has a direct influence on product quality and energy consumption. There are also some indirect influences for example on refractory lifetime, improved availability and ease of operation.

Process description

The main components of the Circulating Fluidised Bed calcination process are: two preheating stages, a calcining stage and two cooling stages. The entire residence time from when the raw material is fed into the process to the point when the product is discharged from the end is roughly thirty minutes. CFB calciners typically operate in a range from 900 to 1000°C, depending on product quality demands. A schematic illustration of the process is included in figure 1.

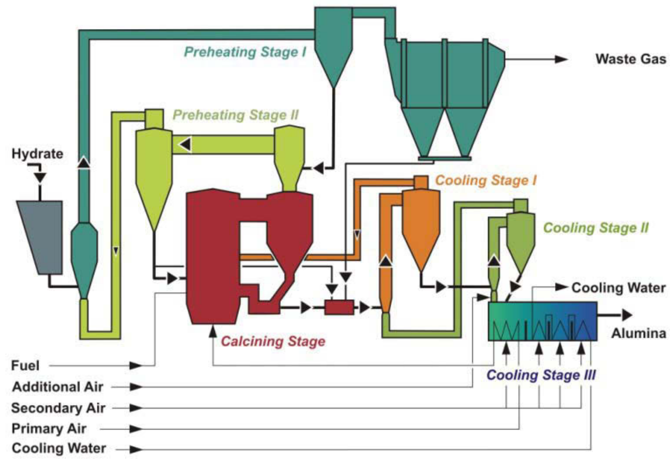

Figure 1. Schematic diagram of a Circulating Fluidised Bed calciner.

The CFB calciner makes use of a multi-stage venturi preheating system to recover the waste gas heat by preheating and drying the gibbsite feed prior to reaction. The main calcination reaction is carried out in the CFB reactor. The energy for the calcination process is supplied by direct combustion of either oil or gas. Energy in the hot alumina is also recovered in a multistage cooling system (which includes a pair of cyclones and a fluidized bed alumina cooler). In a further design evolution of the CFB technology some of the energy in the hot alumina from the CFB furnace can also be used to directly react part of the gibbsite from the first preheating stage (in a so-called "hydrate by-pass"). The CFB technology can be scaled up without consequences for product quality owing to the recirculation of solids in the CFB which results in an even temperature distribution and homogenous product quality also at large capacities. Recent experience, with large calciners, has shown that the calciner design has a large influence on the product quality (e.g. particle breakage). Continuous industrial operation with the hydrate bypass demonstrates that no detrimental impacts on product quality are observed (in particular, no traces of gibbsite detected in the product) [**2**]. The efficient use of heat exchange technology and the implementation of the "hydrate by-pass" and the inclusion of a hydrate dryer (which uses heat from the fluid bed cooler) brings the total energy consumption down to a world record low 2.7 kJ per kg of alumina (LHV) produced [**2**].

Outotec process systems

As illustrated in figure 2, there are generally three process levels which can be adapted to a calcination plant. The first two levels for process control are the field instruments and the basic Distributed Control System (DCS). On top of these two basic levels an Expert System can be implemented to optimize the utilization of the plant. In this case the Outotec SmartFeed and

Burner Management System (BMS), described in this paper, are considered as Expert Systems that can be implemented on most existing calciner to enhance plant performance and stability. With increased stability also an increase of safety can be expected.

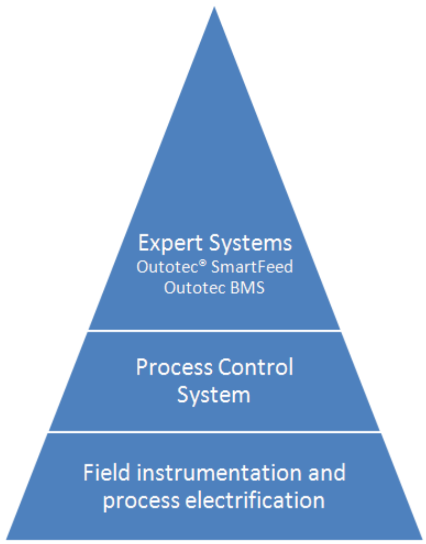

Figure 2: Outotec process expert systems for an alumina calcination plant.

Outotec® SmartFeed

SmartFeed, is a sophisticated proprietary control logic [3], to control the feed condition and further maintain the fuel efficiency on any calcination plant. Additionally, this system can be used to control the maximum fuel availability and control the level of excess oxygen to ensure complete combustion. It can be retrofitted to most CFB calciners to improve the operation performance and stability and thus safety. The installation process is fast, and the software upload to the process control system can be done during operation with subsequent fine tuning also during operation.

The SmartFeed is built-up on the feed forward control principle, which compared to the conventional feedback control corrects errors and/or process parameters deviations before they occur, making the control panel operator's task significantly easier by ensuring continuous operation of the furnace at any desired set-point. Further the SmartFeed allows quick responses of the system to outside disturbances such as loss of feed or quick load changes. The quick response allows to transfer the furnace into a hot standby. Regulatory purges and times for reheating of furnace are avoided and shorten unplanned downtimes significantly.

During normal operation furnace temperature is kept stable by variation of fuel at stable feed rates of hydrate. Any changes in feed and / or disturbances in solids flow within the system, which might influence the heat balance in the furnace are detected and the fuel flow adjusted in time to ensure stable furnace temperature.

An inbuilt **Air Flow Optimizer** adjusts the supply of combustion air flow to maintain optimum stable excess air levels. The air flow optimizer takes into account the requirements for the air not only to support the combustion, but also to ensure reliable solids transport at low operating loads of the plant.

In cases where fuel flow is limited, e.g. no more air available from process air blowers or limitation in fuel supply a **Feed Optimizer** will be enabled to maximize hydrate feed based on the available fuel flow. If the actual fuel consumption is less than the maximum permitted fuel rate, the Feed Optimizer will increase the speed of the feed screw gradually. Consequently, the required amount of fuel will increase in order to process the additional feed. Shall the opposite occur the Feed Optimizer will reduce the speed of the feed screw in order to maintain process temperatures at the desired set-point.

In order not to exceed the minimum air to fuel ratio an **Oxygen (O_2) Limiter** can be enabled. This feature monitors the measured O_2 content in the off-gas against a predetermined minimum limit revising the maximum fuel allowance if required. This feature is especially useful when an Air Flow optimizer cannot be easily applied to the controls of blowers without installing significant additional instrumentation for retrofit.

Outotec is able to test the parameters of fuel and feed subject to permission from Client to change the parameters. Figures 3 and 4 show the controlled furnace temperature and fuel consumption during ramp-up of a 3300 tpd calciner [4].

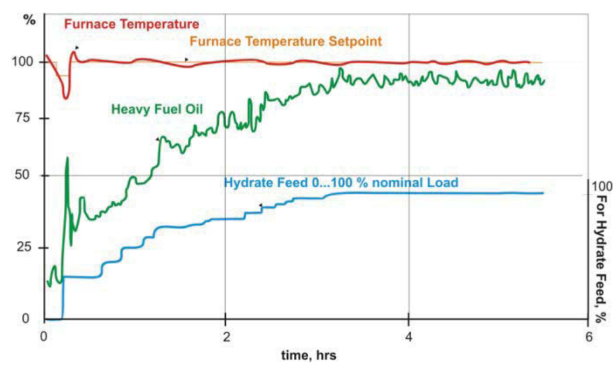

Figure 3. SmartFeed controls fuel consumption and temperature response for fast and smooth Ramp-Up.

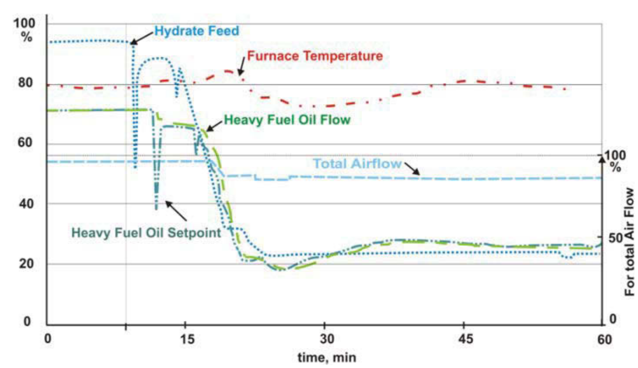

Figure 4: Rapid load change down to the minimum operating level controlled by SmartFeed.

Figures 5 and 6 show data from an industrial plant after the retrofit of the SmartFeed. Figure 5 demonstrates the operation of the O_2 Limiter feature, where the excess oxygen in the off-gas is reduced due to the manual airflow changes, over an automatically controlled feed at nominal capacity. What can be seen is that the excess oxygen always remains above its minimum level (set-point determined by the operator) to ensure complete combustion and continuous operation.

In this case the airflow is adjusted manually, typically by adjusting the additional air. The SmartFeed automatically adjusts fuel and feed to maintain the furnace temperature at the set-point and the oxygen level above the set-point. That results in three major benefits:

- Energy savings (fuel and electricity)
- Operational flexibility down to the minimum operating load
- Reduced requirement for operator intervention.
- Reduction in risk of plant trips.

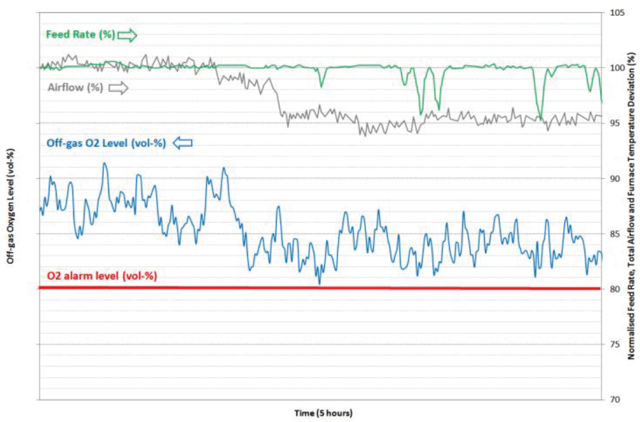

Figure 5: O_2 limiter keeps the excess oxygen above set-point by adjusting fuel, thus ensuring complete combustion and minimum fuel consumption.

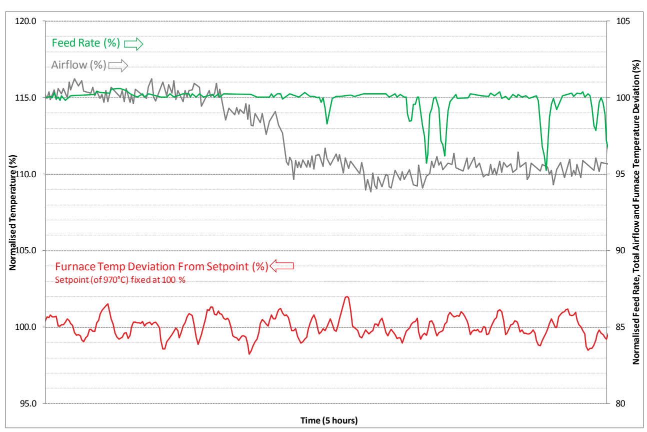

Figure 6. Stable temperature control is achieved through SmartFeed during process changes (reduction of airflow). Feed and fuel automatically controlled.

Figure 6 illustrates the corresponding temperature response in the above example (figure 5), where the airflow is manually reduced. To be noted that the temperature deviates in a range of +/-2% around the set-point of 970°C. The improved temperature stability results in the following benefits:

- Stability of product quality
- Improved plant safety
- Increased expected service-life of refractory lined vessels and reduced maintenance costs

A combined effect of the SmartFeed features is an increased plant availability due to improved process stability upon upset conditions such as feed quality changes, load changes and start-up and shutdown cycles.

The SmartFeed can readily be retrofitted in existing installations. As the energy savings are considerable, the expected return on investment of such retrofit is short (subject to plant's costs).

Outotec Burner Management System and Outotec® DuraBurner

For safe operation the calciner is controlled by the Distributed Control System (DCS) within the limits of safe operation. To ensure the operation of the calciner does not enter into any unsafe state a Safety Instrumented System (SIS) with inbuilt BMS is monitoring the safe operating conditions and transfers the plant into a safe state in the event of any violation of the safe operating parameter limits. In case of calcination it means that fuel flow will be shut and in order to avoid any unnecessary loss of heat also the blowers will be stopped.

These scenarios then usually lead to the requirement to conduct a regulatory purge of any potential unburned gases and thus a cool down of the unit, which then required a reheat before main fuel can be introduced again and production can recommence. The result is extended loss in production plus additional thermal cycling of refractory lining and reduced refractory lifetime.

In order to avoid such scenarios the DCS shall be enabled to maintain safe operation and combustion conditions even during periods of production disturbances, such as limitation of feed or material discharge, etc. This is achieved by implementation of a continuous fully independent operating preheat burner. The burner is then not only used to preheat the furnace to safe combustion temperature for the main fuel system, but also to maintain furnace temperature during production outages. E.g. in case of loss in feed main fuel system can be stopped prior to reaching any unsafe operating limits and air flows reduced and the preheat burner maintain in operation. Once feed is re-established the main fuel can be restarted without the need for a regulatory purge.

For an economical viable solution the preheat burner has to be able to operate on the same fuel as the main fuel system. Below is a description of a system to operate on heavy fuel oil as an example.

Figure 7 shows simplified process flow diagrams of a preheat and pilot burner system operating on heavy fuel oil or natural gas in parallel to the main burners. To improve the availability of the calciners and to make their operation easier, the preheat burner and the fuel injection lances are fully automated through the DCS and are also monitored by a SIS with an implemented BMS.

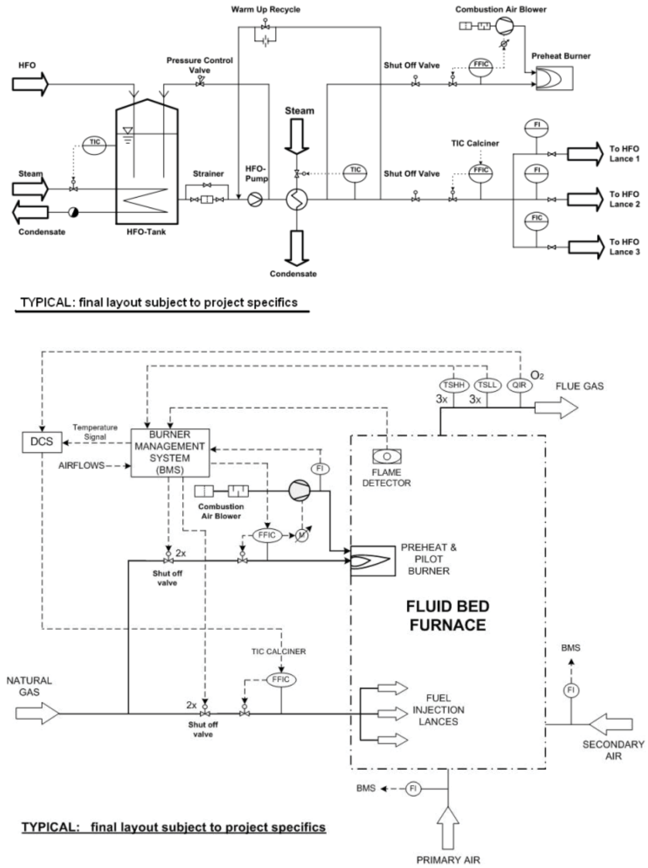

Figure 7. Simplified process flow diagram of a preheat and pilot burner operating on heavy fuel oil (top) and on natural gas (bottom) in parallel with the main burner.

<u>Preheating sequence</u>
Calciners equipped with fully automated preheat burners can be automatically preheated according to a predefined heat up curve (e.g. 70 K/h). Thus no further panel operator action will be required with regards to the burner system during preheat of a calciner, which effectively frees up the operators time for other tasks during the preheating phase. After the automated preheating cycle, the operator can initiate the automated plant start sequence. This increased degree of automation enables a swifter heat-up of the calciner after a trip, thereby reducing production losses.

<u>Start-up</u>
The fuel injection for the main burners is controlled in a similar way as the preheat burner, by the BMS. Once the calciner furnace is above a minimum safe ignition temperature, the operator can start up the fuel injection system in a similar manner to how the preheat burner is started. When the main burner system is in operation and the fuel demand is increasing or decreasing the appropriate number of lances are then started or stopped automatically. Thereby, an operator is no longer needed for the setting of the fuel lances, which consequently speeds up the process of putting sufficient lances in operation when the process demands change.

<u>Operation</u>
During operation the DCS will then operating on a more stringent set of criteria for plant shut-down (temperatures, air/fuel-ratio, oxygen -concentration in off-gas) to transfer the pant into the hot standby with the preheat burner still in operation to maintain furnace temperature before the BMS would initiate a plant wide shut. This improved shut down criteria would trigger the fuel shut down prior to regulation enforced shut downs, thereby allowing for a "controlled" shutdown not requiring a purge prior to a restart.

Conclusions

The challenge in CFB automation and process control is the multivariable nature of the process in combination with the naturally occurring fluctuations. Process stability is critical for product quality and energy consumption reasons. To address these challenges and continuously improve plant availability and operation, Outotec has developed automation expert systems. Outotec® SmartFeed controls feed and fuel automatically, keeping the furnace temperature stable and oxygen content in the off-gas at safe levels. Outotec's BMS is designed to reduce the downtime of the calciner and to allow maintaining the temperature in the CFB furnace during shutdowns by keeping the pre-heat burner (Outotec® DuraBurner) in operation continuously.

Recent experience with small and large industrial calciners has demonstrated some of the benefits with the SmartFeed control, as outlined and discussed in this paper. The SmartFeed can be retrofitted on most CFB plant (with gas or heavy fuel oil) and the expected return on investment is short. To summarize, the benefits of the SmartFeed are:

- Increased plant operational flexibility
- Improved plant safety
- Reliable turn-down to the minimum plant load of 25%
- Increased fuel efficiency, thus lower fuel consumption
- Increased Alumina production due to optimized hydrate feed in conjunction with fuel availability
- Enhanced product quality due to stable furnace temperatures since fluctuations can be corrected before a change in process conditions occurs
- Lower operational risk and increased plant's availability due to reduction of unforeseen downtimes / trips
- Reduced maintenance costs on refractory
- Quick installation during operation

Outotec's revised interlock and operating philosophy with regards to the burner system improves the operability and safety of the calciner and allows for faster restarts after plant trips. This reduces the need to purge and an associated reheating which provides the following advantages:

- Quick restart minimizing downtimes and production of out of spec material
- Increased calciner availability
- Improved plant operability minimizing on site activities and required process monitoring
- Improved refractory service-life due to reduced temperature cycling.

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