Estimation and Optimization Calculations of Alumina Flash Calciner

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Abstract

Gas and dust flows parameters were measured and thermal imaging inspection of alumina flash calciner at RUSAL Kamensk Uralsky was carried out. A closed system of equations for steady-state mode of the flash calciner was developed. It is based on material and thermal balance equations including physicochemical transformations of material, PSD, and kiln hydrodynamics. Mathematical model was calibrated on the basis of the survey and automated control data. Kiln performance, specific fuel consumption, cyclone collection efficiency and other unit characteristics were further specified using this model. A study was conducted to determine the sensitivity of the kiln to changes in thermal regime of drying and calcination processes such as fluctuations in humidity and PSD of aluminum hydroxide, flow rates of air and dust on specific fuel consumption and kiln productivity. Based on the calculations it was established that intensive formation of alpha phase in produced alumina is associated with overheating of material in combustion prechamber of the calciner and in the flame of the burner in the dryer. Implementation of recommended solutions will improve kiln performance by 1 % and reduce the specific fuel consumption by 3 %.

Keywords: alumina hydroxide flash calciner, digital twin, computational fluid dynamics.

1. Introduction

Stationary Calciners are widely used in alumina production since they allow obtaining alumina with low content of α phase at lower specific fuel consumption as compared to rotary kilns. Known in the art are modifications of Stationary Calciners: fluidized bed kilns, kilns with circulating bed, flash calciners. Recently many investigations are devoted to optimization of design and operational conditions of such stationary calciners for calcination of aluminum hydroxide [1-3].

A flash calciner at the Ural aluminum refinery was commissioned in 2004 and so far is the first and the only kiln unit of this type in Russia (Figure 1). It is constructed according to a conventional scheme, and comprises a pneumatic dryer, cyclone preheater, flash calciner, a four-stage cyclone cooler and a system for dust cleaning. Hydraulic resistance of the kiln is overcome by two fans, one of which pumps air in the cooler, and the other evacuates flue gases. The kiln is equipped with a system of sensors including thermocouples, flowmeters for natural gas and air and draught-and-head gauges [4].

From the moment of construction, individual changes were made in the design of the kiln, tuning of a combustion system of fuel that enabled to raise its productivity. A drawback of the system of sensors is the absence in its structure of reliable devices for measurement of hydrate and alumina consumption that led to misunderstanding of its actual productivity and specific data, and required a more accurate specification. Thus, the objective of this work was to assess the performance of the kiln at JSC RUSAL Kamensk-Uralsky and development of measures for its improvement.

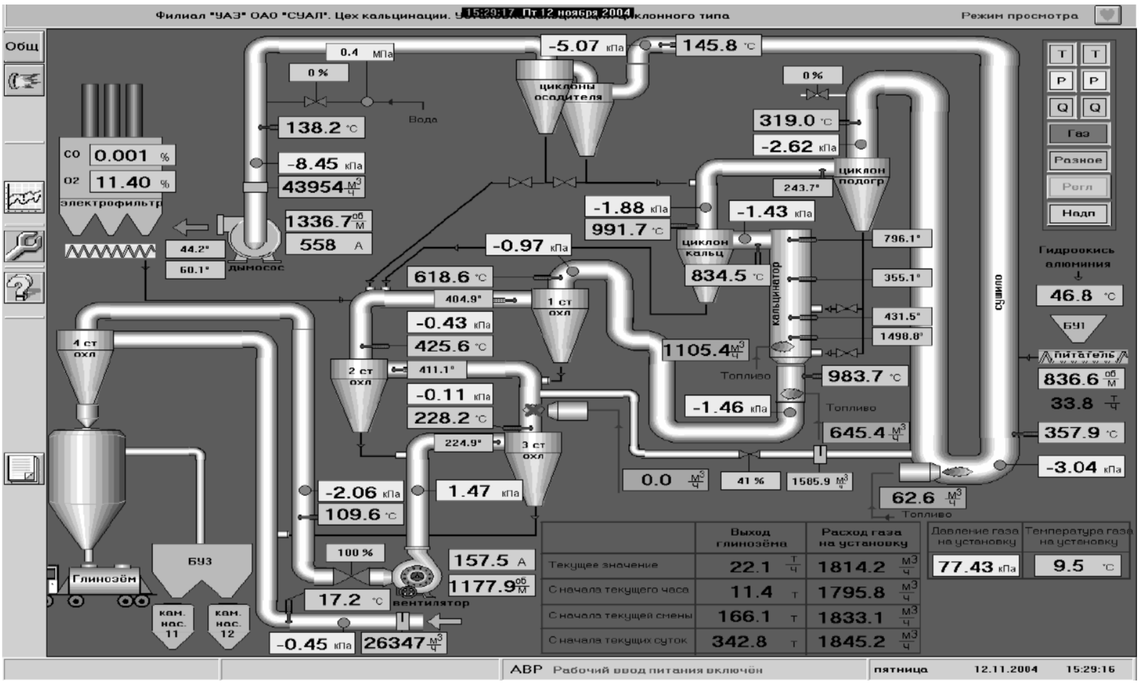

Figure 1. Mnemonic scheme of kiln, 2004. [4].

2. A Closed System of Equations for Steady-State Mode of the Flash Calciner

Development of a detailed mathematical model based on the equations of the mass and thermal balance, population balance of particles and hydrodynamic calculations was considered as the most obvious way to solve the problem of assessing the current state of the flash calciner.

Balance equations of chemical substances and thermal energy are simple algebraic equations:

$$\sum \mathrm{m_{A.out}} = \sum \mathrm{m_{A.in}} + \sum \Delta \mathrm{m_A}, \tag{1}$$

$$\sum \mathrm{Q_{out}} = \sum \mathrm{Q_{in}} + \sum \Delta \mathrm{Q_r} - \mathrm{Q_{loss}}, \tag{2}$$

where $\sum \mathrm{m_{A.in}}$ and $\sum \mathrm{m_{A.out}}$ – total mass flow rate of some substance *A* in flows at input and output from the device respectively, kg/s; Δm_A - a changing in amount of substance *A* as a result of chemical reactions within the considered device, kg/s; $\sum \mathrm{Q_{in}}$ and $\sum \mathrm{Q_{out}}$ - total heat fluxes presented by an enthalpy of the materials supplied and removed from the device, W; $\sum \Delta \mathrm{Q_r}$ - total thermal effect of chemical transformations in the device, W; $\mathrm{Q_{loss}}$ - amount of thermal losses to the environment, W.

For each flash calciner, mass balance equations are registered dividing the material flow into a number of output flows according to the set split factor x_i. In the aerosol state, heat exchange between this material and gas occurs promptly, consequently at the exit of any device of the kiln equality of temperature and material composition for all exit flows is established. Nevertheless, generally, heat exchange between gas flow and solid material can be incomplete, for example, due to uneven distribution of dust in the volume of the gas flow or partial slipping of material into downstream cyclone of a cooler unit. Assumption concerning equality of output temperatures and

7. Conclusion

An integrated mathematical model is developed of flash calciner of RUSAL Kamensk-Uralsky. Based on results of the measurements taken during instrumental inspection and on the basis of data of PCS, adjustment of the mathematical model is performed. The adequacy of the adjusted model to plant data is confirmed.

By numerical modeling on the basis of model of the kiln its current data are estimated, investigation of impact of process conditions and quality of calcined material on productivity, energy efficiency and chemical composition of produced alumina is conducted.

The share of each of kiln devices in achievement of final LOI of alumina is established by calculation, it is demonstrated that only 50 % in this distribution accounts for the calciner.

The most effective measures to increase energy efficiency and productivity of the kiln are determined: decrease in humidity of hydrate, stabilization of alumina LOI at the maximum allowed level due to bypass of material avoiding the calciner, reduction in thermal losses of the calciner. The reasons for high thermal losses of calciner are revealed and the way is proposed to decrease losses by 1.3 times due to change in brickwork pattern.

It is established that in the prechamber of the calciner and in the dryer the process of α-Al_2O_3 formation proceeds most actively, moreover up to 2/3 of this alumina modification is formed in the first device. It is proposed to lower the temperature in the prechamber by 10 °C and to feed the material into the calciner through two feed spouts at different height that allows reducing α-Al_2O_3 content in the products by 1.4 %.

8. References

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