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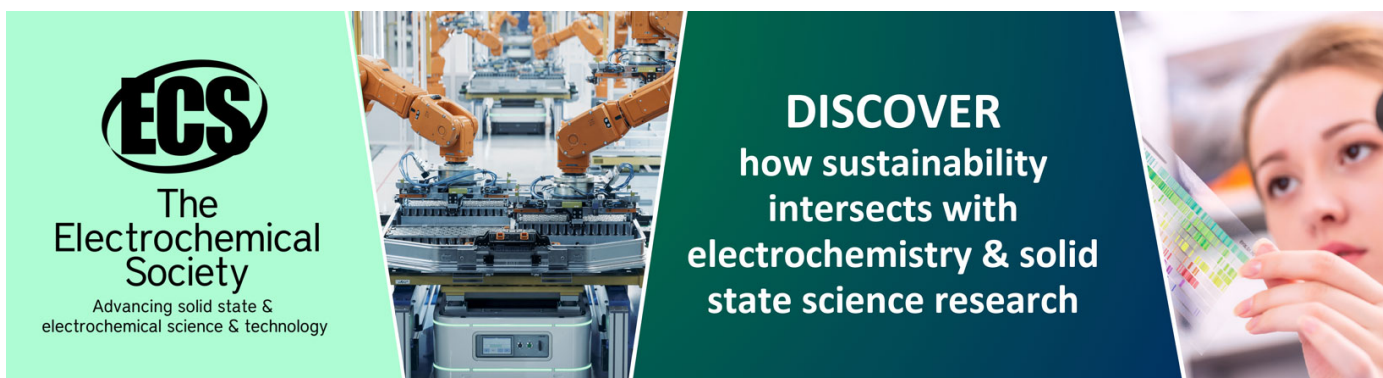
Improving the control efficiency of metallurgical silicon production technology

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Improving the control efficiency of metallurgical silicon production technology

S A Martynov and V Yu Bazhin

Saint Petersburg Mining University, 2, the 21st Line of Vasilyevsky Island,
199106 St. Petersburg, Russia

E-mail: direktor062@mail.ru

Abstract. The production of metallurgical silicon is characterized by the use of stationary units as ore-thermal furnaces. Such furnaces' operational difficulties are associated primarily with a low level of automated control and management. The present article is concerned with the features of the modern technological process for metallurgical silicon production. The following issue of concern in the production chain as the lack of moisture control of the reducing agent was identified. A method that implies a comprehensive approach to control both technological and energy parameters, in particular humidity, ash content and particle size distribution of the reducing agent is proposed as a recommendation. An algorithm for the operation of an automatic control system with the introduction of additional functions that improves the efficiency of the furnace unit has been developed and justified.

1. Introduction

The production efficiency of metallurgical silicon is determined by the degree and level of automation. The lack of operational information on the technological state of equipment, control means and a measurement suite for the production technological parameters makes it impossible to increase the efficiency of ore-thermal furnaces. Possible impacts on the operating procedures or individual operations depend on the instrumentation used, the level of existing control system and process equipment.

While ore-thermal furnaces (OTF) are in service, there are a number of operations that are currently performed manually and they need to be automated.

Today, there is an objective need to create and implement an automatic control and regulation system [1], which is extremely important for the production of metallurgical silicon. When introducing an automatic control system, the basic technological operations will become automatic and the influence of human factor, as the main source of erroneous actions resulting in failure events, will be minimized.

2. Features of technological process

Metallurgical silicon is obtained by the carbothermic method; a complex of reducing agents as charcoal, brown and hard coal, petroleum coke and industrial wood (wood chips) is used as a reducer [2,3].

Charcoal, which is obtained in the furnaces by Kozlov system, is used as the main quartzite reducing agent [4]. Charcoal has a high porosity of 72-80%, which determines its high sorption ability. Coal humidity during unloading from retorts is practically uncontrolled. According to the technological instructions for OTF, charcoal moisture content should be approximately 4-6%, but since it is stored in



a warehouse without proper insulation, the humidity rises to 7-15% due to the fact that charcoal adsorbs water from the air [5]. This is one of the main issues in production, since there is no latest information on charcoal moisture content, which can lead to incorrect calculation of the charge materials proportion. However, operation with charcoal of high moisture content often leads to furnace silicification. The high humidity of the reducing agent leads to a sharp increase in the resistance of the charge materials layer and, as a result, to a furnace power decrease.

3. Recommendations

A change in the charge mixture with an excess or deficiency of a reducing agent in compliance with charcoal incorrect dosing due to the lack of the latest information on its moisture and ash content leads to a further deterioration in the process management quality and reduction of product yield. The solution to this issue is the proposed adaptive control system which will take into account the carbon balance in OTF with an allowance for charcoal current moisture content [6, 7].

If there is a deviation of the furnace operating mode from the one specified in the technological instruction, the proposed algorithm (figure 1) suggests performing the following actions: in the first instance, the granulometric composition, humidity and ash content of the reducing agents are checked by the analyzer; if the deviation is confirmed, a charge with the corrected ratio of reducing agent and quartz is fed [8]. If the carbon balance and the particle size distribution of the charge are normal, then the position of the electrode working end is checked by the electrode position sensor and the upper and lower position indicator.

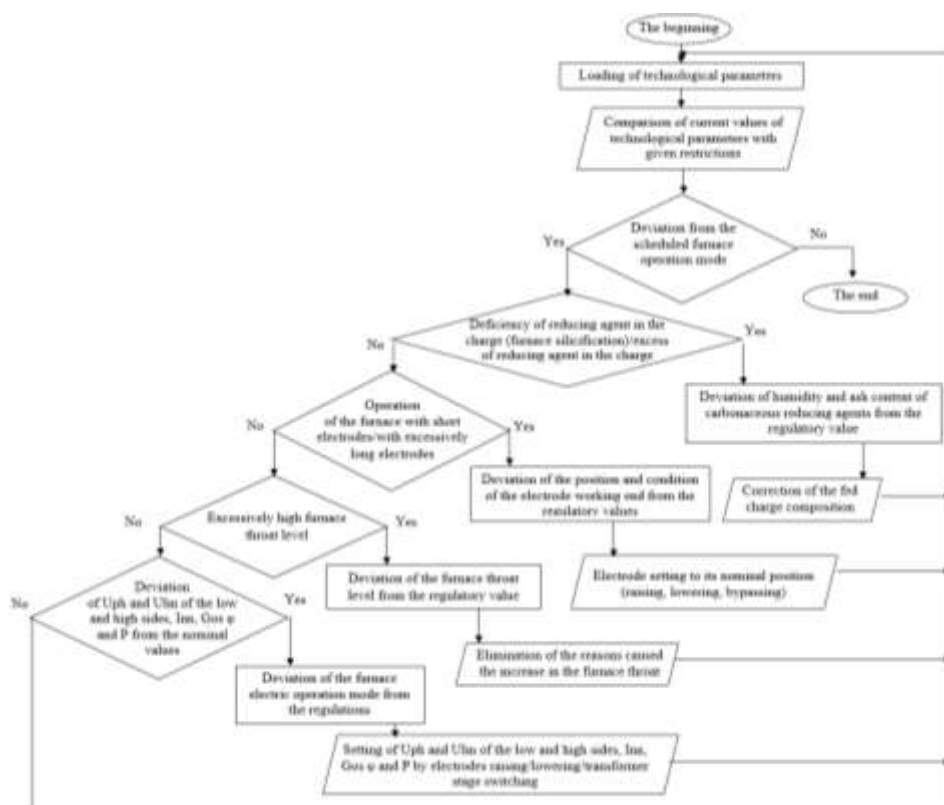


Figure 1. The algorithm of OTF automatic control system.

When working on short or excessively long electrodes, they are set to the optimum position by bypassing or raising (lowering) the electrode. If the electrode position corresponds to its setting, then it is necessary to check the furnace throat level. At a high or low furnace throat level, it's imperative to eliminate the causes of its occurrence and bring it to normal condition by filling with an additional

portion of the charge or vice versa, i.e. stop feeding it. If the furnace throat level corresponds to the set point, then the furnace electric operation mode is checked by comparing the settings with the current readings of linear and phase voltage sensors on the high and low sides of the furnace transformer, as well as the current strength with the values of the measuring current transformers, power factor with the value of the power factor meter and quantity consumed electricity with the readings of a commercial electricity metering, transformer stage number, and calculated value of electrode electric current. If a deviation from the scheduled mode is detected, the following procedure is performed: at the high current (current value exceeds 31 kA at the 6th stage) on the electrode, raise it; at the low current (loss of current load), lower it; if there is a strong deviation, bypass the electrode or switch the transformer stage; if there is voltage on the electrodes, their position should be adjusted.

In addition to controlling the energy parameters, the proposed method also control the technological ones: the carbon balance in the furnace, the ratio of carbon reducing agents, and the moisture and ash content of carbon reducing agents. Due to this, there is an auxiliary control action such as an additional input of charge materials when the carbon balance changes. In the process of producing silicon, the properties of carbonaceous reducing agents, in particular humidity, can change. When calculating the carbon balance in the furnace, the process staff does not take into account the current humidity value, but takes the value as the normative one, which is indicated in the accompanying documentation; this leads to an imbalance of the reducing agent in the furnace. If we use the above methods of controlling ore-thermal furnace, we will save energy, reduce electrode fumes, and eliminate the possibility of furnace silicification, charge sintering, appearance of powerful holes, decrease or fluctuation of the current load, increase of slag viscosity and difficulty of its exit from the furnace.

According to preliminary estimates, the implementation of this algorithm in the control system will increase silicon yield by 5-10% and reduce specific energy consumption by 3-5% [9] while reducing the raw materials consumption by 1-2%.

Conclusions

When considering management systems at existing facilities, the following shortcomings and imperfections of the management system were identified:

- lack of the latest information on the ash and moisture contents of reducing agents;
- lack of a modern process control system.

When introducing an adaptive automatic control system with the proposed algorithm, it becomes possible to achieve the following results:

- increase the degree of silicon extraction;
- reduction of silicon monoxide emissions;
- reduction of specific electricity consumption;
- improving the accuracy of melting mode regulation;
- stabilization of technological parameters.

The proposed adaptive automatic control system by means of an analyzer determines the current values of ash content, moisture content of carbon reducing agents, and charge feeding with the adjusted ratio of carbon reducing agent and quartz in case of deviation from the regulatory value, which allows maintaining OTF carbon balance.

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