PID regulator of the automated system for the production of nanostructure concentrates

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Abstract. The article presents a description of the cost-effective software package "Control system for the production of nanostructures containing silicon dioxide and carbon". The presented concentrates are a by-product of the production of silicon and high-silicon ferroalloys and are actively used in construction. The proposed system makes it possible to increase the purity and activity of the developed additives, which allows achieving high properties (frost resistance, water resistance, durability) during the construction of roads and bridge structures, which is undoubtedly important. Test methods and procedures are defined during test case development. The purpose of test case development is to establish the structure of specific test suites and to define procedures for conducting appropriate proficiency testing. The use of this set of tests ensures the comparability and recognition of the reports on the performed tests (testing) and thereby minimizes the need for certification testing for the co-production of nanostructures containing silicon dioxide and carbon.

1. Introduction

Modern construction is carried out in all conditions, often even extreme, for example, in the Arctic zone. However, construction in extreme conditions requires a special approach and the use of special building materials, in particular specialized concrete. Concretes intended for use in the Far North must have high frost resistance, water resistance, and durability. Along with various industrial wastes involved in construction [1-3], microsilica is used to improve these characteristics in concrete and carbon nanotubes for asphalt concrete [4-5]. Microsilica has proven itself almost as a universal material for the production of special concretes, as well as binders for inorganic fire-resistant materials [6]. However, the improvement of concrete properties when used is very strongly dependent on the properties of microsilica itself, its purity and fineness of grinding [7-8], as well as the technology of its production [9-11], associated with the metallurgical process [12-15].

One of the main tasks of improving the technological process of obtaining silicon is to organize conditions that provide optimal modes of the processes of gasification of silica. These modes are mainly determined by the possibility of full use of gaseous silicon monoxide in the reactions of formation and destruction of silicon carbide, as well as the maximum rate of destruction of SiC with the formation of elemental silicon in the high-temperature zone of the furnace bath.

The rate of destruction of silicon carbide largely depends on the structural properties of carbon reducing agents used for the synthesis of SiC (t). Distinctive features of carbide phases formed in the process of carbothermal reduction of silicon from SiO2 in the case of using various reducing agents,
this is due to the reactivity of carbon carriers, which is determined by porosity (specific surface area), parameters of the fine structure of the substance (sizes of primary crystallites, degree of three-dimensional ordering of the crystal lattice, etc.) etc.) and the content of impurities.

The scheme is used for the reduction of silicon with carbon, taking into account that the reduction occurs at very high temperatures, and that when reducing with carbon, it is possible to simultaneously obtain three products.

When reducing silicon, it is necessary to take into account the possibility of producing carbide and gaseous monoxide. Their formation not only consumes part of the carbon and silica of the charge, but also changes the conditions for the reduction of silicon. The complexity of the reduction of silicon with carbon is also associated with the fact that the substances formed in the course of the main reactions: silicon, silicon carbide and silicon monoxide can react both with each other and with the initial substances.

Carbonaceous reducing agents must have the following physical and chemical properties:
- low ash content and its favorable chemical composition; it is desirable that the ash contains the highest possible amount of slag-forming elements;
- a weak tendency to form an ordered graphite structure, which affects the conditions for the recovery process in electric furnaces;
- high electrical resistivity, ensuring the operation of the furnace at a higher operating voltage, and hence with stable electrical characteristics. The high specific electrical resistance of the charge ensures a deeper planting of the electrodes, a decrease in the removal of the intermediate product of the carbothermal reduction of silicon from silica (gaseous lower silicon oxide) by the furnace gases outside the working space of the electric furnace and an improvement in the use of thermal energy;
- optimal particle size distribution;
- high reactivity with respect to gaseous silicon oxide;
- good heat resistance, manifested in resistance to crushing and abrasion at high temperatures of the furnace top;
- sufficient mechanical strength, maximally excluding the content of fines;
- low density, providing the best loosening of the top layer of the charge;
- the constancy of the chemical composition;
- good gas permeability, contributing to the uniform release of gases on the top of the furnace.

2. Proportional-integral-differentiating (PID) regulator

This algorithm controls the analog value. It is designed in accordance with the PID regulation law.

Such regulation is necessary to control thyristor converters, positioners, frequency drives and other equipment. The algorithm implies control using a unified analog signal, with the possibility of manual control and automatic regulation of various process parameters.

**Information for controlling.**

| P/p No | Input information array name | Description | Data type | Range of values |
|--------|-----------------------------|-------------|-----------|----------------|
| 1      | COM_RST                     | Resetting the controller settings (restart) | Bool (B) |                |
| 2      | MAN ON                      | Manual control | B       |                |
| 3      | P_SEL                       | P-component | B        |                |
| 4      | I_SEL                       | I-component | B        |                |
| 5      | D_SEL                       | D-component | B        |                |
| 6      | NEG                         | Inverting governor | B        |                |
| 7      | CYCLE                       | Block call time | Time (T) | T#0.1ms .. T#99999s |
| 8      | SP_INT                      | Regulation task | Real (R) |                |
9  PV_IN  Adjustable value  R
10  MAN  Output value in manual mode  R  0 .. 999999
11  GAIN  Gain  R
12  TI  Integration time  T  \geq \text{CYCLE}
13  TD  Differentiation time  T  \geq \text{CYCLE}
14  DEADB_W  Dead zone  R  \geq 0.0
15  LMN_HLM  Upper limit of output quantity  R  \text{LMN\_LLM} ...
16  LMN_LLM  Output value lower limit  R  -100.0 ... \text{LMN\_HLM}

**PID algorithm**

![PID algorithm diagram]

**Figure 1.** PID algorithm.
3. Conclusion

In the course of the study, a permanent technological process control of the equipment operation was developed, including the PID controller, and the parameters of the technological process of the APCS. Organized collection of tests and data allow to ensure high quality of produced concentrates of silicon dioxide and carbon.

**Figure 2.** Solution diagram.

**Task requirements for testing.**

Test methods and procedures are defined during test case development. The purpose of test case development is to establish the structure of specific test suites and to define procedures for conducting appropriate proficiency testing.

The use of this set of tests ensures the comparability and recognition of the reports on the performed tests (testing) and thereby minimizes the need for certification testing of the process control system for the production of nanostructures containing silicon dioxide and carbon.
nanostructures of silicon dioxide and carbon, which is necessary to achieve the required level of frost resistance, water resistance, durability, to ensure the reliability of roads and bridge structures.

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