Description of automated functions of high-tech production of nanostructures based on silicon dioxide to improve the properties of building and structural materials

R S Zott¹, A M Gladkih², V Yu Konyuhov²

¹ LLC "Tarasovsky coal", 1, Dzerzhinskogo Str., Irkutsk, 664003, Russia
² Irkutsk National Research Technical University, 83, Lermontova Str., Irkutsk, 664074, Russia

E-mail: gladkikh@ex.istu.edu

Abstract. Within the framework of the project "Development of an integrated resource-saving technology and organization of high-tech production of nanostructures based on carbon and silicon dioxide to improve the properties of building and structural materials", an automated control system for technological thermal vortex enrichment has been created, designed to obtain a modifying additive based on dioxide silicon. The main parameters of the operation of technological lines for thermal vortex enrichment of raw materials, automatic control when threshold values are reached, as well as signaling for the use of control action from automated technological lines are presented. The functions of collecting and primary processing of data, creating control actions, creating and maintaining requests and reporting, providing reporting and data analysis tools are subject to automation. Automation of these functions in the form of a graphical human-machine interface allows for continuous technological control of equipment operation and technological process parameters; ensuring the safety of the technological process in the production of a modifying additive based on silicon dioxide. The collection of data on technological processes and equipment operation, their processing, display and documentation will ensure the optimization of the technological process using advanced visualization tools, modern control algorithms and analysis of the accumulated technological information. Automation of control of the technological process of thermal vortex enrichment will ensure the minimization of the influence of the human factor on the processes of collecting and processing information about the technological process; automatic prevention of the development of emergency situations.

1. Introduction

Known methods for the production of nanostructures in the form of spherical silicon dioxide, characterized by the requirement to use special capacities, increased consumption of raw materials and energy [1-4]. Microsilica is an integral by-product of the production of silicon and ferrosilicon. It is obtained by purifying gaseous emissions from the metallurgical industry, which improves the environmental situation at factories, but creates a significant disposal problem [5-6]. In Norway, after the official adoption of technological solutions in the form of standards and relevant specifications, since 1980, microsilica has been used as a modifying additive in concrete [7]. At present, "nanosilica" is of the greatest interest to researchers as a modifier of building and structural materials [8-11]. The development of technological solutions for the creation of high-tech production for the mass use of
nanomaterials is urgent. In this case, the technology should be based on the selection of nanostructures rather than microparticles. The analysis shows that it is advisable to use the technology of incidental production of nanostructure concentrates in the production of aluminum by trapping dust from ore-thermal electric arc furnaces in the production of silicon [12-15]. In this paper, the automated functions of the control system for the technological process of obtaining a modifying additive based on silicon dioxide (APCS) are considered.

2. The goals of the development of the APCS
The APCS is designed to monitor and control the technological process of thermal vortex enrichment to obtain a modifying additive based on silicon dioxide.

The purpose of creating an automated process control system is:

• collection of data on technological processes and equipment operation, their processing, display and documentation;
• ensuring the safety of the technological process by preventing the development of emergency situations;
• optimization of the technological process through the use of advanced visualization tools, modern control algorithms and analysis of the accumulated technological information;
• minimizing the influence of the human factor on the collection and processing of information about the technological process.

To achieve the goals of creating an automated process control system, the automation of the following processes has been implemented:

• automation of the process of collecting and primary processing of analog and discrete information from sensors, actuators, thyristor converters (analog and discrete signals);
• processing of primary information according to the specified control algorithms and the formation of analog and discrete control actions on the output modules of the USO in order to regulate and maintain technological indicators at a given level;
• backup of data on technological parameters, on equipment operation;
• visualization of pre-configured reporting in tabular and graphical forms.

3. Description of the automation object and parameters to be measured and adjusted
The object is five technological lines for thermal vortex enrichment of raw materials to obtain a modifying additive based on silicon dioxide.

The production line capacity is 200 kg / h. Each line includes the following nodes:

• feedstock bunker;
• dosing device;
• combustion chamber;
• pipe for thermal vortex enrichment of raw materials;
• cooling gas duct;
• bag filter.

The principle of operation of the technological line is as follows. An air flow of a given temperature enters the vortex enrichment tube from the combustion chamber and feedstock is supplied through the metering device. When the dust-gas mixture passes through the vortex enrichment pipe, carbon is reburned from the feedstock. Further, in the cooling gas duct, the temperature of the dust-gas mixture drops below 200 °C and the finished product is captured by a bag filter.

The system provides for the measurement and adjustment of the following technological parameters. Parameters to be measured:

• temperature of the air entering the combustion chamber;
• temperature of the air flow at the exit from the combustion chamber;
• air flow temperature at the beginning of the vortex enrichment tube;
• air flow temperature at the end of the vortex enrichment tube;
• temperature of the air flow in the cooling gas duct;
• temperature of the air entering the cooling gas duct;
• temperature in the bag filter hopper;
• gas pressure entering the burner;
• compressed air pressure;
• pressure at the beginning of the vortex enrichment pipe;
• pressure in the cooling gas duct;
• pressure in the dirty chamber of the bag filter;
• pressure in the clean chamber of the bag filter;
• gas consumption into the combustion chamber;
• rotational speed of the blower;
• rotation frequency of the dosing device for feeding the starting material;
• position of the air supply gate;
• the presence of material in the vortex enrichment pipe;
• the upper level in the feedstock bin;
• the lower level in the feedstock bin;
• upper level in the bag filter hopper;
• the lower level in the baghouse filter.

Parameters to be regulated:
• the temperature of the air flow in the combustion chamber;
• temperature of the dust-gas mixture in the vortex enrichment pipe;
• temperature in the cooling gas duct;
• vacuum in the vortex enrichment pipe;
• consumption of starting material;
• air consumption in the combustion chamber;
• pressure drop across the baghouse filter.

Parameters to be signaled:
• the lower value of the vacuum in the vortex enrichment pipe;
• the lower value of the temperature of the air flow in the combustion chamber;
• the upper value of the pressure drop in the baghouse filter;
• shutdown of the blower;
• turning off the smoke exhauster;
• shutdown of the dosing device for feeding the starting material;
• the lower level in the feedstock bin;
• upper level in the bag filter hopper;
• the temperature in the cooling gas duct is close to the upper limit;
• the temperature in the vortex enrichment pipe is close to the lower value;
• upper temperature level in the cooling gas duct;
• the lower level in the bag filter hopper;
• the upper level in the feed bin.

4. Description of Automated Functions
The automated control system for the technological process of thermal vortex enrichment has a modular structure with a clear division of functions between its subsystems. The performance of the functions of the APCS, as well as access to the data and control structures contained in it, is through specialized components that have mechanisms based on a human-machine interface for interacting with users. In the process of functioning of this system, the procedures for exchanging data between subsystems are carried out using software [10, 16-18].
APCS is a set of automated systems of separate departments, which can function both separately, while ensuring the functioning of individual subsystems at each level in full within a separate automated system, and jointly ensuring the functioning of subsystems within the framework of general information interaction [10, 19-20].

The APCS includes the following subsystems:

- subsystem for collecting primary information, processing, generating control actions and data transmission;
- data storage subsystem;
- subsystem for generating and visualizing reports.

The general diagram of the functional structure of the APCS is shown in Fig. 1.

![General diagram of the functional structure of the APCS.](image)

**Figure 1.** General diagram of the functional structure of the APCS.

The subsystem for collecting primary information, processing, generating control actions and transmitting data is designed to implement the processes of collecting primary information about the course of the technological process, bringing this information to a form convenient for software processing in accordance with algorithms, generating control actions, and data exchange with other automated process control systems via digital communication lines.

The function of collecting and primary processing of information includes the following tasks:

- reception and primary processing of analog and discrete information from sensors, executive mechanisms, thyristor converters (analog and discrete signals);
- reception and primary processing of information and commands (settings, settings) coming from operators through the SCADA system.

The function of forming control actions includes the following tasks:

- processing of primary information in accordance with the specified control algorithms and technological settings;
- formation of analog and discrete control actions on the output modules of the USO.

The subsystem for the formation and visualization of reporting, designed to generate information about the course of the technological process, archived data in a tabular and graphical form.

The function of creating and maintaining a logical presentation of information includes the following tasks:

- creation of a logical representation of information in the form of a description of the stored data;
- modification of the logical presentation of information.

The function of creating and maintaining queries and reporting includes the following tasks:
• creation of data request templates;
• setting up tabular forms and graphs of data analysis.

The reporting function and data analysis tools include the following tasks:
• providing the ability to perform mathematical operations on indicators;
• providing the ability to perform group operations on data in real time;
• visualization of pre-configured reporting in tabular and graphical form.

The table contains a list of subsystems with a description of the process of performing functions.

**Table 1.** List of subsystems with a description of the process of performing functions.

| Subsystem                                                                 | Process description                                                                 |
|---------------------------------------------------------------------------|-------------------------------------------------------------------------------------|
| The subsystem for collecting primary information, processing, generating control actions and data transmission | The processes of collection and primary processing of analog and discrete information from sensors, actuators, thyristor converters (analog and discrete signals). These processes are automatic, processing is by a microprocessor controller. The process of receiving and primary processing of information and commands (settings, settings) coming from operators through the human-machine interface. Data entry is human. |
| The subsystem for generating and visualizing reports                      | The processes of presenting information, conducting mathematical operations on indicators; visualization of pre-configured reporting in tabular and graphical form. All processes are automatic. |

Work on the development of APCS was taking into account the following requirements:
• support for generally accepted technologies for processing and presenting information;
• use of standard sets of tools within the framework of the APCS;
• openness of data structures;
• focus on reliable equipment;
• construction taking into account ease of use for the end user;
• construction of an automated process control system taking into account safety requirements.

The relationship between the upper and lower layers is carried out at the driver level via the TCP/IP protocol. The SCADA system has full access to the read and write memory cells of the programmable logic controller. The interconnection of the APCS parts is via the Ethernet network.

5. **Conclusion**

When organizing the production of nanostructures based on silicon dioxide to improve the properties of building and structural materials, methods of automation of production and management processes were used. Automation of the functions of collecting and primary processing of information allows the processing of primary information in accordance with the specified control algorithms and technological installations. The function of providing reporting and data analysis tools makes it possible to carry out mathematical operations on indicators; providing the ability to perform group operations on data in real time; visualization of pre-configured reporting in tabular and graphical form. The implementation of these functions in the form of a graphical human-machine interface allows achieving the goals of creating an automated process control system.

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