Development of an emergency stop system for the software complex for the production of modifying additives

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Abstract. The article presents the results of the development of an emergency stop system for the software complex for the automated production of modifying additives for bridge structures in the Arctic zone. Modifiers obtained by the production process, containing silicon dioxide and carbon, are often used as additives for various special concretes. The developed system ensures high purity, reliability of production and reduces its cost. The purpose, input and output data are described, a block diagram of the emergency stop algorithm of the automation system of the process control of the production of modifying additives for bridge structures based on nanostructures of carbon and silicon dioxide is developed. The test case data provide control over the completeness and correctness of the calculations and generated databases. It is also worth noting that the associated production of construction modifiers has a positive effect on their cost and the availability of development of construction technologies in the Arctic zone.

1. Introduction

Expansion of the field of application of concrete in the Arctic is possible with the improvement of its operational and physical and mechanical properties. This is achieved by using modern construction chemicals, for example, antifreeze additives, as well as plasticizers in concrete. Improving the performance properties of concrete for use in the Arctic is also possible with the use of such production waste [1-4] as microsilica, which also solves the problem of its disposal.

Carbonaceous reducing agents affect the quality of the melt and the composition of the gas cleaning dust. They are divided into two groups: the first includes reducing agents, the quality of which unambiguously affects the technical and economic indicators of silicon production. Their qualitative characteristics include: carbon content, reactivity, electrical resistivity, mechanical and thermal strength, tendency to graphitization, porosity, specific surface area, etc. The second group of reducing agents includes those that primarily affect the quality of the silicon produced due to the content of harmful (limiting) impurities in them, mainly oxides of iron, aluminum, calcium, titanium and boron.

- charcoal, the most active and sufficiently pure reducing agent in terms of impurities, the cost of its carbon is the highest. It is mechanically weak, easily crushed in preparation for melting and in the furnace itself, disrupting the gas permeability of the charge. The quality of charcoal is constantly deteriorating. High-quality charcoal is absent on the free market, which leads to the need for partial and sometimes complete replacement of it with other better quality reducing agents.
- petroleum coke, the purest reducing agent in terms of impurities, but has the lowest chemical activity, and besides, it is prone to graphitization at high temperatures and becomes electrically conductive. Numerous methods of its activation in the production process have not been brought to commercial implementation due to the lack of interest from the producers of petroleum coke.
- coals of a low stage of metamorphism, used without heat treatment, including as an alternative replacement for charcoal, due to their wide variety in quality and chemical composition of ash, require a comprehensive study of their physicochemical properties and influence on the conditions and indicators of smelting reduction;
- the products of thermal treatment of bituminous coals (semi-coke and coke), which have recently appeared on the reducing agent market, also require study, both of methods for their production in order to minimize the deterioration of the quality of materials, and behavior in the process of obtaining silicon. In the future, these can be multifunctional reducing agents with both high chemical activity and sufficient purity for impurities.

However, the properties of concrete modified with microsilica differ depending on the used microsilica [5], which poses the task of increasing its purity [6-10]. But the use of even untreated microsilica leads to a significant increase in the characteristics of concrete, such as compressive and flexural strength, gas and water resistance, frost resistance, and resistance to aggressive influences. In addition, microsilica can be used in lightweight concrete to prevent delamination of the cement matrix and lightweight aggregate, which is especially important in northern regions, since lightweight concrete has significantly lower thermal conductivity, as well as in alternative binders for concrete and composite materials [11-16].

2. Emergency control
This algorithm is designed to control the process line in emergency mode.

The line consists of the same type of technological blocks connected in series. An accident at the technological unit causes the unit equipment to stop, signaling to the workstation, stopping the loading of raw materials from the previous unit and unloading to the next unit. It is possible to control loading and unloading signals at the level of the PI regulator of the regulating body, transferred to manual mode. Other technological units are operating normally. When the alarm is eliminated, the technological unit is put into normal mode by the operator.

Information and technological data used.

Table 1. Input information

| P/p No | Input information array name | Description | Data type |
|--------|-----------------------------|-------------|----------|
| 1      | M_ON_IN                     | Main drive control signal input | BOOL     |
| 2      | M_ON_DEL                    | Time before reaching the operating mode after turning on the drive | TIME     |
| 3      | M_FAULT                     | Drive alarm | BOOL     |
| 4      | LH                          | Lower level | BOOL     |
| 5      | LL                          | Upper level | BOOL     |
| 6      | PV_CUR                      | The current value of the parameter in the control loop | REAL     |
| 7      | PV_TGT                      | Target value of the parameter in the control loop | REAL     |
| 8      | PV_DBF                      | Deadband in controlled units | REAL     |
| 9      | NEXT_FAULT                  | Failure of the next technological block | BOOL     |
| 10     | PREV_FAULT                  | Alarm of the previous technological block | BOOL     |
| 11     | FAULT_RESET                 | Process unit alarm reset | BOOL     |
Solution results

Table 2. Input technological information

| P/p No | Input information array name | Description | Data type |
|--------|-------------------------------|-------------|-----------|
| 1      | FAULT                         | Technological block alarm signal | BOOL      |
| 2      | M_ON_OUT                      | Main drive control signal output | BOOL      |
| 3      | PV_OF                         | The current value | BOOL      |
| 4      | PV_UF                         | The current value of the parameter in the control loop is understated | BOOL      |
| 5      | LD_EN                         | Process block loading permission | BOOL      |
| 6      | UL_EN                         | Process unit unloading permission | BOOL      |

The developed solution algorithm

Figure 1. Solution algorithm stopping a technological line in emergency mode.

Test task requirements

Input task is selected from valid ranges.

Table 3. Input name and data for testing.

| P/p No | Input information array name | Testing |
|--------|-------------------------------|---------|
| 1      | M_ON_IN                       | In the range of values |
| 2      | M_ON_DEL                      | In the range of values |
| 3      | M_FAULT                       | True - Drive alarm, causes block failure |
| 4      | LH                            | True - Top level |
| 5      | LL                            | True - Lower level |
| 6      | PV_CUR                        | Values |
| 7      | PV_TGT                        | Values |
| 8      | PV_DBF                        | Values |
| 9      | NEXT_FAULT                    | True - Alarm of the next technological block |
| 10     | PREV_FAULT                    | True - Alarm of the previous technological block |
| 11     | FAULT_RESET                   | True - Reset the alarm of the technological block |
Table 4. Output data.

| P/p No | Input information array name | Test results                                                                 |
|--------|-----------------------------|------------------------------------------------------------------------------|
| 1      | FAULT                       | True - Technological block alarm signal at (M_FAULT = True) or               |
|        |                              | (PV_CUR out of range at M_ON_IN = True and time M_ON_DEL) or                |
|        |                              | (LL = True and M_ON_IN = True)                                              |
| 2      | M_ON_OUT                    | Main drive control signal output: if FAULT = True within the range of M     |
|        |                              | ON IN, otherwise False                                                      |
| 3      | PV_OF                       | True - The signal the current value of the parameter in the control loop is |
|        |                              | exceeded when PV_CUR goes out of range with M_ON_IN = True                  |
| 4      | PV_UF                       | True - Signal the current value of the parameter in the control loop is     |
|        |                              | underestimated when PV_CUR goes beyond the range at M_ON_IN = True          |
| 5      | LD_EN                       | True - Signal Enable loading of the technological block with FAULT =       |
|        |                              | False and LH = False and PREV FAULT = False                                |
| 6      | UL_EN                       | True - Signal Enable unloading of the technological block with FAULT =     |
|        |                              | False and LL = False and NEXT FAULT = False                                |

Structure

The list of documents and other informational messages, the use of which is provided in the system, is shown in Table 5.

Table 5. List of input discrete signals.

| Name                                     | Bit depth | Periodicity     | Signal type |
|------------------------------------------|-----------|-----------------|-------------|
| Mixer shaft rotation speed               | 16 Bit    | no more than 4 Hz | Pulse (P)   |
| Rotation speed of the auger metering shaft | 16 Bit    | no more than 4 Hz | P           |
| Mixer water consumption                  | 16 Bit    | no more than 50 Hz | P           |
| Water consumption in tank 1              | 16 Bit    | no more than 50 Hz | P           |
| Capacity 1. Rotational speed of the paddle stirrer shaft | 16 Bit | no more than 4 Hz | P           |
| Capacity 2 = Capacity 1.                 | 16 Bit    | no more than 4 Hz | P           |
| Capacity 3 = Capacity 1.                 | 16 Bit    | no more than 4 Hz | P           |
| Capacity 4 = Capacity 1.                 | 16 Bit    | no more than 4 Hz | P           |
| Capacity 5 = Capacity 1.                 | 16 Bit    | no more than 4 Hz | P           |
| Capacity 6 = Capacity 1.                 | 16 Bit    | no more than 4 Hz | P           |

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3. Conclusion

In order to develop the Arctic zone and use innovative building compositions, a technology has been developed for the production of modifying additives for bridge structures based on nanostructures of silicon dioxide and carbon. To improve the quality of production and reduce the cost of modifiers, a process control automation system has been developed, emergency shut down situations have been taken into account, the structure and algorithms of its operation have been designed.
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References
[1] Sivtsov A V, Yolkin K S, Kashlev I M and Karlina A I 2020 Processes in the Charge and Hearth Zones of Furnace Working Spaces and Problems in Controlling the Batch Dosing Mode during the Smelting of Industrial Silicon and High-Silicon Ferroalloys Metallurgist 64(5-6) 396-403
[2] Nekrasov I V, Sheshukov O Y, Metelkin A A, Sivtsov A V and Tsymbalist M M 2016 Slag conditions in electrosmelting: A review Steel in Translation 46(6) 435-442
[3] Sivtsov A V, Elkin K S, Pan’kov V A, Karlina A I 2021 Specific Features of the Electric Mode of the Technological Process of Smelting of Commercial Silicon Metallurgist 64 923-930
[4] Yolkin K S, Yolkin D K, Nemarov A A, Sysyev I A, Karlina A I 2018 Conduct of reduction smelting of metallic silicon: Theory and practice IOP Conference Series: Materials Science and Engineering 411 012029
[5] Ponomarev A, Steshenko D and Rassokhin A 2018 Development of technology for production of fire-resistant nanocomposite constructional rebar and structural elements based on it MATEC Web of Conferences 245 04001
[6] Kondratiev V V, Nebogin S A, Sysyev I A, Gorovoy V O and Karlina A I 2017 Description of the test stand for developing of technological operation of nano-dispersed dust preliminary coagulation Int. J. of Applied Engineering Research 12(22) 12809-12813
[7] Kondratiev V V, Govorkov A S, Kolosov A D, Gorovoy V O and Karlina A I 2017 The development of a test stand for developing technological operation “flotation and separation of MD2. The deposition of nanostructures MD1” produce nanostructures with desired properties International Journal of Applied Engineering Research 12(22) 12373-12377
[8] Konyuhov V Yu, Konstantinova M V and Gladkih A M 2019 Determination of restored units spectrum of equipment and development of the assembly unit repair method at industrial enterprises J. of Phys.: Conf. Ser. 1353 012047
[9] Ershov V A, Kondratiev V V, Karlina A I, Kolosov A D and Sysyev I A 2018 Selection of control system parameters for production of nanostructures concentrates J. of Phys.: Conf. Ser. 1118(1) 012014
[10] Svinitsov A P, Galishnikova V V and Stashevskaya N A 2020 Dataset on the effect of nano-modified additives of concrete mixes technological properties for winter concreting Data in Brief 31 105756
[11] Gladkih A M, V Yu Konyuhov, Galyautdinov I I and Shchadova E I 2019 Green building as a tool of energy saving IOP Conference Series: Earth and Environmental Science 350 012032
[12] Galishnikova V V, Abd Sh and Fawzy A M 2020 Influence of silica fume on the pervious concrete with different levels of recycled aggregates Magazine of Civil Engineering 93 71-82
[13] Petrushenko I K 2018 DFT Calculations of Hydrogen Adsorption inside Single-Walled Carbon Nanotubes Advances in Materials Science and Engineering 2018 9876015
[14] Zykova A P, Chumaevskii A V, Martyushev N V 2019 Effect of Nanosize Tungsten Powder on the Microstructure and Mechanical Properties of Silumin Metal Science and Heat Treatment 61(3-4) pp 222–227
[15] Martyushev N V, Mamadaliev R A, Skeeba V Y 2018 Influence of modification by superdispersed powder of aluminum oxide on lead-tin bronze structure Journal of Physics: Conference Series 1118(1) 012062
[16] Petrushenko I K and Petrushenko K B 2019 Physical adsorption of hydrogen molecules on single-walled carbon nanotubes and carbon-boron-nitrogen heteronanotubes: A comparative DFT study Vacuum 167 280-286