Production of modifying additives for highways

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Abstract. The article presents a description and operating parameters of the technological process for the production of modifying additives for concrete and asphalt concrete based on exhaust gas dust in the production of silicon by operations. Described is a foam product, which is a raw material for obtaining fullerene-like carbon, a modifying additive MD2, and a chamber product for spherical silicon dioxide, a modifying additive MD1. The regulated parameters have been worked out, the regulation limits and the norms of expenses are given. The development of a functional diagram is based on the analysis of the technological process, as an object of automation, in which the main control and controlled influences are distinguished, which must be regulated and maintained within specified limits, in order to obtain the final product with the required quality characteristics. The implementation of this scheme is presented in this work. It combines a flow diagram and technical means measuring, controlling and regulating these flows, in order to ultimately obtain products of the desired quality.

1. Introduction

At present, the involvement of waste in various industries [1-3] and concern for the ecology and health of the population [4-5] are gaining in popularity.

Dust from the gas cleaning system of silicon production [6-9], containing nanoparticles of silica and carbon, with the help of a hydraulic removal system through pipelines, goes to the sludge field of CJSC KREMNIY.

It seems rational to consider in parallel two options for taking material for processing for modifying additives for concrete and asphalt concrete.

According to the first, the material is taken directly from the line of the wet removal system through the receiving hopper (RH) and is sent directly to the flotation process.

The second option is associated with the release of the sludge field. The content of the sludge field is a dark gray suspension with a hygroscopic moisture content of more than 85%. At the site in front of the sludge field, work was organized to take a moistened product using chamber pumps and pump it into truck tanks.

Further, the moistened nanodispersed dust enters the technological operation for the preparation of sludge. The final product is nanodispersed dust, which enters the receiving hopper (RH) - at the initial stage of the scheme for the production of modifying additives for concrete and asphalt concrete.

As a result of processing nanodispersed dust, 2 modifiers are obtained. One contains carbon nanotubes, fundamental research and application in various fields of which are described in [10], the second - silicon dioxide, the use of which in concrete has been widely studied [11-15]. The use of
these additives in asphalt concrete and road concretes contributes to an increase in their reliability, resistance to growing loads, climatic extremes, and humidity.

2. Description and operating parameters of the technological process for the production of modifying additives for concrete and asphalt concrete based on exhaust gas dust in the production of silicon by operations

General description of the technological process.

From the RH through the feeder auger (FA1), the rotation speed of which is set by the operator remotely, the initial product goes for mixing with water into the repulpator (RP). The water supply to the RP is carried out from the water tank WT1, which is a closed-type tank.

The obtained homogeneous pulp from the RP enters the flotation machine (FM). At the same time, flotation reagents (a mixture of kerosene and pine oil) and compressed air are supplied to the FM from the capacity of flotation reagents (CF) to carry out the flotation process. Here the pulp is divided into two products - foam and chamber.

The foam product is a raw material for obtaining fullerene-like carbon - modifying additive MD2.

The chamber product for spherical silicon dioxide - modifying additive MD1.

The chamber product is fed through the conveyor to the drum vacuum filter (F1), as a result of which the hygroscopic moisture content of the pulp at the outlet is 6-8%, the filtrate is returned to the WT1 water tank.

Further, the pre-dried slurry enters the rotary calcining bake (B1), where the temperature is maintained at 600-660 °C. At the exit from the calcining furnace, the hygroscopic moisture content of the product is 2-3%.

This product is spherical silicon dioxide, a modifying additive MD1, which is fed to the filling line (FL1), adapted for filling the marketable product in big bags or in paper bags.

The frothy product of the flotation process enters the reactor (R) for washing with hydrofluoric acid, which comes from the acid capacity (AC1) in order to clean the MD2 concentrate from impurities SiO$_2$.

The enriched foam product enters the drum vacuum filter for drying. As a result of the operation, we obtain a paste-like concentrate, which is sent to the foam product washing tank (WT) for conditioning. From the water capacity (WC2), the flushing liquid through the dosing device enters the WT washing tank. Further, the conditioned pulp is sent by a screw feeder to the coagulator (C) for thickening the particles of the solid phase. The coagulant is supplied to the coagulation process through a dispenser from the coagulant tank (CT).

The amount of supplied pulp and coagulant, as well as the output of thickened pulp and sediment, is controlled within the limits indicated in Table 1.

The thickened slurry is fed to a vacuum filter by means of a pump, where it is dehydrated, the resulting paste-like concentrate is sent to drying, which results in a commercial product, fullerene-like carbon. The finished product is fed to the packaging complex for filling in big bags or paper bags.

The regulation limits and flow rates are given in Table 1.

2.1. Technological control standards

The development of a functional diagram is based on the analysis of the technological process, as an object of automation, in which the main control and controlled influences are distinguished, which must be regulated and maintained within specified limits, in order to obtain the final product with the required quality characteristics. The implementation of this scheme is presented in Table 1. It combines a flow pattern and technical means for measuring, controlling and regulating these flows, in order to ultimately obtain products of the desired quality.
Table 1. Technological control of parameters.

| No | Parameter name                                      | Position | Measurement limit          | Indications | Registration | Regulation | Control | Signaling |
|----|-----------------------------------------------------|----------|----------------------------|-------------|--------------|------------|---------|-----------|
| 1  | Furnace top temperature 1                          | TT 1a    | 600-650 °C                 |             |              |            |         |           |
| 2  | Furnace bottom temperature 1                       | TT 2a    | 640-660 °C                 |             |              |            |         |           |
| 3  | Furnace top temperature 2                          | TT 3a    | 350-400 °C                 |             |              |            |         |           |
| 4  | Furnace bottom temperature 2                        | TT 4a    | 470-410 °C                 |             |              |            |         |           |
| 5  | Air flow supplied to the cell                       | UIR 5a   | 10-15 Nl/m³ of pulp        | +           | +            |            |         |           |
| 6  | Air line pressure                                   | UIR 5a   | 0.2-0.4 MPa                | +           | +            |            |         |           |
| 7  | Water consumption from the network in WC1           | FIRT 6a  | 0.2-1.3 m³/h               | +           | +            |            |         |           |
| 8  | Water consumption from WC1 to RP                    | FIRT 7a  | 1.2-1.4 m³/h               | +           | +            |            |         |           |
| 9  | Pulp consumption from RP to FM                      | FIRT 8a  | 1.4-1.5 m³/h               | +           | +            |            |         |           |
| 10 | Consumption of flotation reagent from CF to FM      | FIRT 9a  | 0.002-0.003 m³/h           | +           | +            |            |         |           |
| 11 | Consumption of acid-washed foam product from R to F2| FIRT 10a | 0.16-0.21 m³/h             | +           | +            |            |         |           |
| 12 | Hydrofluoric acid consumption from AC to R          | FIRT 11a | 0.12-0.14 m³/h             | +           | +            |            |         |           |
| 13 | Water consumption from WC2 to WT                    | FIRT 12a | 0.9-1.1 m³/h               | +           | +            |            |         |           |
| 14 | Consumption of washed foam product from WT to C     | FIRT 13a | 0.95-1.15 m³/h             | +           | +            |            |         |           |
| 15 | Coalescer consumption from CT to C                  | FIRT 14a | 0.003-0.004 m³/h           | +           | +            |            |         |           |
| 16 | Water consumption from the network in WC2           | FIRT 15a | 0.2-1 m³/h                 | +           | +            |            |         |           |
| 17 | Raw material level in RH                            | LITR 16a | 20-80 %                    | +           | +            |            |         |           |
| 18 | Water level in WC1                                  | LIT 17a  | 70-85 %                    | +           |              |            |         |           |
| 19 | Pulp level in RP                                   | LITR 18a | 60-85 %                    | +           | +            |            |         |           |
| 20 | Flotation reagent level in CF                       | LITR 19a | 25-95 %                    | +           | +            |            |         |           |
| 21 | Pulp level in FM                                   | LITR 20a | 99 %                       | +           | +            |            |         |           |
| No. | Parameter Description                                                                 | Unit   | Min-Max % | +  | ✫  |
|-----|---------------------------------------------------------------------------------------|--------|-----------|----|----|
| 22  | The level of the foam product washed by the acid in the reactor                        | LITR   | 40-70     | +  |    |
| 23  | Level in the foam product rinsing tank                                                 | LITR   | 60-85     | +  |    |
| 24  | Coagulator level in CT                                                                  | LIT    | 25-95     | +  |    |
| 25  | Hydrofluoric acid level in AC                                                           | LIT    | 50-75     | +  |    |
| 26  | Water level in WC2                                                                     | LIT    | 70-85     | +  |    |
| 27  | Pulp level in C                                                                        | LITR   | 70-85     | +  |    |
| 28  | Top level in F1                                                                         | LA     |           | +  |    |
| 29  | Lower level in F1                                                                      | LA     |           | +  |    |
| 30  | Upper level in F2                                                                       | LA     |           | +  |    |
| 31  | Lower level in F2                                                                       | LA     |           | +  |    |
| 32  | Upper level in F3                                                                       | LA     |           | +  |    |
| 33  | Lower level in F3                                                                       | LA     |           | +  |    |
| 34  | pH of hydrofluoric acid to AC                                                           | QIT    | 3-5 pH    | +  |    |
| 35  | Dust concentration SiO$_2$ in the air of the working area                               | QITA   | 0.5 mg/m$^3$ | + |    |
| 36  | Concentration of vapors of hydrofluoric acid in the air of the working area             | QITA   | 0.5 mg/m$^3$ | + |    |
| 37  | Pulp density at the outlet of the repulpator                                           | DIRT   | 1060-1120 kg/m$^3$ | + |    |
| 38  | Density of the foam product at the outlet of the reactor                                | DIRT   | 900-950 kg/m$^3$ | + |    |
| 39  | Density of the slurry at the outlet of the washing tank                                 | DIRT   | 950-980 kg/m$^3$ | + |    |
| 40  | Moisture content of SiO$_2$ after B1                                                    | MIRT   | 2-3 %     | +  |    |
| 41  | Humidity of CNT after B2                                                                | MIRT   | 2-3 %     | +  |    |

2.2. Temperature measurement
To measure the temperature due to high temperatures in the furnaces (up to 750 °C), the technologist must turn on temperature meters, record the readings in the log, make sure that the readings are within the permissible values according to Table 1, if the maximum permissible values are exceeded, turn off the installation and inform the management.

2.3. Measuring pressure and air flow rate into the cell
The Rosemount-3051 SMV is designed to measure the flow rate and pressure of air supply to the cell.
When measuring the flow rate, standard orifice devices in accordance with GOST 8.586-2005 are used as primary transducers. Measurements are carried out in accordance with GOST 8.586-2005.

The technologist must turn on (if necessary) metering devices for pressure and air flow, record the readings in the log, make sure that the readings are within the permissible values according to Table 1, if the maximum permissible values are exceeded, turn off the installation and inform the management.

2.4. Flow measurement of liquids and slurries
To measure the flow rate of liquid and slurry, a Rosemount 8700 device is used. To measure the flow of liquids and slurries, the technologist must turn on (if necessary) metering devices, record the readings in a log, make sure that the readings are within the permissible values according to Table 1, if limit values turn off the unit and inform the management.

2.5. Level measurement
Metran-150 hydrostatic pressure (level) sensors are designed to measure the level in water and fluor tanks. To measure the level in the receiving hopper, a non-contact radar level gauge Rosemount 5600 is intended. To measure the level in a flotation machine, a guided wave level gauge Rosemount 5300 is intended.

To measure the level, the technologist must turn on (if necessary) metering devices, record the readings in the log, make sure that the readings are within the permissible values according to Table 1, if the maximum permissible values are exceeded, turn off the installation and inform the management.

2.6. Level alarm
The Rosemount 2100 Vibrating Level Switches are designed to alarm the level when the drum filter bucket is overfilled.

To signal a level overflow, the technologist must turn on (if necessary) the metering device, in case of an alarm, turn off the installation and inform the management.

2.7. PH measurement
A Yokogawa PH450G device is designed to measure ph.

To measure ph, the technologist must turn on (if necessary) the metering device, record the readings in the log, make sure that the readings are within the permissible values according to Table 1, if the maximum permissible values are exceeded, turn off the installation and inform the management.

2.8. Concentration measurement
To analyze the air in the working area for the concentration of silicon dioxide dust and hydrofluoric acid vapors, and to signal if their permissible values are exceeded, a universal stationary gas analyzer GANK-4C (R) is intended, using the appropriate chemical cassettes.

To measure the density, a device manufactured by LLC "Piezoelectric" Density meter 804 was selected.

The moisture meter M-Sens 2 was chosen to measure the moisture content of bulk media.

To measure concentrations, the technologist must turn on (if necessary) the metering device, record the readings in the log, make sure that the readings are within the permissible values according to Table 1, if the maximum permissible values are exceeded, turn off the installation and inform the management.

3. Conclusion
The paper presents the results of the development of a resource-saving technology for the production of modifiers for asphalt concrete from metallurgical waste. The regulated parameters have been worked out, the regulation limits and the norms of expenses are given. A functional diagram has been developed based on the analysis of the technological process as an automation object, in which the
main control and controlled influences are distinguished, which must be regulated and maintained within the specified limits, in order to obtain the final product with the required quality characteristics.

One of the main directions of further improvement of this technology is to reduce the cost of the resulting products, automate production, as well as expand the scope of application of the obtained modifiers in the construction industry.

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