Flotation reagent dosing control system at the coil preparation plant LLC JV “Barsasskoye Tovarischestvo”

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Abstract. The paper considers issues related to the creation of automated process control systems of the fleet-filtering department of the coil preparation plant LLC JV “Barsasskoye Tovarischestvo” (Berezovsky, Russia). The presented automated process control system is intended for controlling the flotation process and auxiliary operations. This system has been integrated into the control system of the entire factory and is intermediate between the main enrichment complex and the drying-furnace department. Integration is carried out at the technological and information levels. Effective management of the reagent dosing process allow to achieve minimal product losses.

1. Introduction

Coil preparation plants involved in the processing of minerals seek to increase production capacity constantly by introducing technological improvements in the structure of production. For example, technological processes that allow capturing small coal fractions, such as flotation [1]. The process of coal preparation by the method of flotation is effective in terms of quality indicators, but costly to use reagents. It is necessary to use the system of the automated control of technological processes that makes possible to use resources optimally - achievement of the best indicators of enrichment at the least expenses for manufacture.

As part of the next modernization at the coil preparation plant OOO JV “Barsasskoye Tovarischestvo” (Berezovskiy, Russia), it was decided to create a fleet-filtering department (FFD). The purpose of modernization was to increase the efficiency of enrichment processes of the technological complex of this department and, consequently, improve the technical and economic performance of the factory [2].

Coal sludge flotation is a process aimed at the enrichment of fine coal fraction. This process is based on selective adhesion of coal particles suspended in water to the surface of adjacent air bubbles. The most frequently used type of foam flotation, the mechanism of action of which consists in the following: pulp (a mixture of coal sludge with water) is mixed, and then it appears in the flotation machine, that implements the process of flotation. In the flotation machine, the pulp gets air consisting of tiny bubbles, the diameter of which does not exceed two millimeters. In addition, the pulp gets a flotation reagent, the presence of which does not allow air bubbles to collapse, getting into the pulp. The coal particles, having undergone preliminary treatment with the reagent, stick to the air bubbles and in such a condition appear on the surface of the pulp, subsequently forming the foam with enriched coal rock particles [3]. The use of flotation reagents in itself makes production more expensive, so it is necessary to dose them with high precision.

There are two approaches to solving this problem: empirical (manual) and automatic. In the first case, the operator independently regulates the supplied amount of floatation reagents filtrate. The
quality of execution of this work directly depends on the operator's experience, which makes this method easy to use, but at the same time, the human factor influences the measurement of indicators. The second method assumes use of systems of automatic control (SAC, or SAR – system of automatic regulation) with application of concrete modes of operation of system that essentially raises accuracy of dispensing. However, this method also has significant drawbacks in the form of multiple input disturbances on the system, due to which the operating modes simply may be unstable at the set values. Consequently, it is necessary to create an automated control system that compensates for input disturbances.

2. Description of the automation object of the fleet-filter section

At the coil preparation plant LLC JV “Barzasskoye Tovarischestvo” a fleet-filtering section object was realized, which is schematically shown in figures 1 and 2.

Figure 1. Flotation scheme.

Coal sludge (S) mixed with water comes from the main building by pumps 946/1 and 945, after that the resulting pulp enters the contact vat (CV) pos. 900, where the pulp is mixed with infeed flotation reagents: a collector (RCF CV1 flow) and a foamer (RFF CV1 flow) - by flotation reagent dosing systems (FRDS) 919/1 and 918/1 relatively. In addition, FRDS supplies flotation agents to chambers 3 and 5 of the flotation machines (FM). In figure 2 the designations, e.g. RCF FM1 C3, correspond to this, which means the flow of the reagent-collector to the third chamber of the flotation machine №1. The flotation concentrate received in CV is also sent to the flotation machines, where the enriched particles are separated from the waste rock, or the flotation tails, which are sent back to the main body to a radial thickener for a repeated cycle of the process. The flotation concentrate, in the form of foam, enters the mixing tank, where it is mixed with filtrate (F) formed by disk vacuum filters.
The concentrate is sent to the filters, by which the enriched product is separated from the filtrate and sent to the drying and furnace section by conveyor. The filtrate itself enters the filtrate tank (filtrate tank in figure 1), from which it is then fed by the 917 pump either back to the mixer or sent through a closed loop to the CV, or sent to the main building to radial thickeners.

Figure 2. Scheme of the system for the preparation of flotation reagents

3. Model development

The task of the control system is to maintain reagent consumption depending on the operator’s settings of the reagent to solid mass ratio in the pulp. For this purpose, flow and density are continuously measured:

1) density of products $P_{CV}^{L}(t)$ entering the contact vat (CV), where $t$ – time;
2) quantity of product $Q_{CV}^{V}(t)$ entering the CV, is calculated on the basis of the set power of the pump pos. 946/1;
3) amount of filtrate $Q_{F}^{V}(t)$ coming from the pump (position 917) is also calculated by the pump power;
4) signal $J_{F}^{E}$ about the infiltration of the filtrate into CV;
5) consumption of product $Q_{F}^{1}(t)$ from CV for the first flotation machine (FM1);
6) consumption of product $Q_{F}^{2}(t)$ from CV for the second flotation machine (FM2);
7) task on the ratio of the reagents supplied to CV, FM1 and FM2.

To the reagent-collector:

Designations:
FRDS – flotation reagents dosing system;
C3 – third chamber flotation machine; C5 – fifth chamber flotation machine
\[ y^*_1 = \frac{Q_{RCCV}^1}{Q_{RC}^1} \]  \hspace{1cm} (1)  
\[ y^*_2 = \frac{Q_{RCCV}^2}{Q_{RC}^2} \]  \hspace{1cm} (2)

To the reagent-foamer:

\[ y^*_1 = \frac{Q_{RFCV}^1}{Q_{RF}^1} \]  \hspace{1cm} (3)  
\[ y^*_2 = \frac{Q_{RFCV}^2}{Q_{RF}^2} \]  \hspace{1cm} (4)

where \( Q_{RC}^1, Q_{RC}^2, Q_{RF}^1, Q_{RF}^2 \) – total amount of collector and foamer reagents on FM1 and FM2; \( Q_{RCCV}^1, Q_{RCCV}^2, Q_{RFCV}^1, Q_{RFCV}^2 \) – the amount of collector and foamer reagents in CV during operation of FM1 and FM2;

8) signals \( J_{FM1} \) and \( J_{FM2} \) about the operation of FM1 and FM2, the physical analogues of which are represented by controlled valves 903-M and 904-M;

9) density of the filtrate \( P_{LF} \).

The structure of the control object is shown in figure 3.

**Figure 3.** Structure of the control object of the dosing system.

**Algorithm for calculating the dosage of the dosing system for the consumption of flotation reagents.**

1. For the first FM:
   a) for the collector reagent:

\[ Q_{RC}^1(t) = k_{RC}^1 \cdot Q_{HF}^1(t) \]  \hspace{1cm} (5)  
\[ Q_{HF}^1(t) = Q_F^1(t) \cdot P_L^{\sum CV} (t) \]  \hspace{1cm} (6)  
\[ P_L^{\sum CV} (t) = a_1 P_L^{\sum CV} (t) + a_2 P_L^{\sum CV} (t-1) \]  \hspace{1cm} (7)
\[ \Delta_+ = T_1; \Delta_+ = T_2; \] (8)

\[ \hat{P}^{\sum CV}_L(t) = \frac{P^{CV}_L(t) * Q^{CV}_L(t)}{Q^{CV}_L(t) + Q^F(t)} + \frac{P^F_L(t) * Q^F(t)}{Q^{CV}_L(t) + Q^F(t)}; \] (9)

b) for the foamer reagent:

\[ Q_{RF}^1(t) = k_{RF}^1 * Q_{HF}^1(t). \] (10)

2. For the second FM:

a) for the collector reagent

\[ Q_{RC}^2(t) = k_{RC}^2 * Q_{HF}^2(t); \] (11)

\[ Q_{HF}^2(t) = \hat{Q}_{HF}^2(t) * \hat{P}^{\sum CV}_L(t); \] (12)

\[ \hat{P}^{\sum CV}_L(t) = a_1 P^{CV}_L(t) + a_2 P^{\sum CV}_L(t-1); \] (13)

\[ a_1 = \frac{T}{T+\Delta}; a_2 = \frac{\Delta}{T+\Delta}; \] (14)

\[ \hat{P}^{\sum CV}_L(t) = \frac{P^{CV}_L(t) * Q^{CV}_L(t)}{Q^{CV}_L(t) + Q^F(t)} + \frac{P^F_L(t) * Q^F(t)}{Q^{CV}_L(t) + Q^F(t)}; \] (15)

b) for the foamer reagent

\[ Q_{RF}^2(t) = k_{RF}^2 * Q_{HF}^2(t). \] (16)

Distribution of reagents between CV and FM.

1. For the first FM

\[ Q_{RCCV}^1(t) = y_{RC}^{1*} * Q_{RC}^1(t); \] (17)

\[ Q_{RCF}^1(t) = (1-y_{RC}^{1*}) * Q_{RC}^1(t); \] (18)

\[ Q_{RFCV}^1(t) = y_{RF}^{1*} * Q_{RF}^1(t); \] (19)

\[ Q_{RFF}^1(t) = (1-y_{RF}^{1*}) * Q_{RF}^1(t). \] (20)

2. For the second FM

\[ Q_{RCCV}^2(t) = y_{RC}^{2*} * Q_{RC}^2(t); \] (21)

\[ Q_{RCF}^2(t) = (1-y_{RC}^{2*}) * Q_{RC}^2(t); \] (22)

\[ Q_{RFCV}^2(t) = y_{RF}^{2*} * Q_{RF}^2(t); \] (23)

\[ Q_{RFF}^2(t) = (1-y_{RF}^{2*}) * Q_{RF}^2(t). \] (24)

Limitation check.

\[ Q_{RC} \text{ and } Q_{RF} \text{ on CV, FM1 and FM2} \]

\[ Q_{RC} < Q_{RC}^{lim}, Q_{RF} < Q_{RF}^{lim}. \] (25)

During the modernization, the algorithm was implemented. Figure 4 shows a pop-up diagnostic video frame that is displayed when you click on the FRDS complex (918/1 and 919/1) on the main
video frame. The window displays the elements of the general control of the FRDS (setting the operating mode, changing the task for supplying reagents), information on the status of the units FM1, FM2 and CV, control elements and data on the current operating modes of the pump group.

Figure 4. Diagnostic pop-up window of FRDS.

When you click on the area of a specific pump, a pop-up diagnostic window of the flotation reagent pump appears (figure 5). It contains information about the status and operating mode of the pump, fields for setting and displaying parameters and unit controls.

Figure 5. Diagnostic pop-up window of flotation machine 1 foamer reagent chamber 3.
4. Conclusion

The presented automated system involves the implementation of not only control functions, but also the functions of automated metering of pulp, solid matter in the pulp and the amount of spent reagents to be able to evaluate the overall performance of the system. The results of the study of the process, synthesis and tuning of the control system can be used as a standard solution [4] for other objects in compliance with their similarity [5].

References

[1] Lyakhovets M V, Venger K G et al 2017 Proceedings of the XI All-Russian Scientific and Practical Conference in Automation Systems in Education, Science and Production (Novokuznetsk: SibSIU) pp 151–156
[2] Myshlyaev L P, Makarov G V et al 2018 Science-intensive Technologies for Development and Use of the Mineral Resources: Sci. J. 4 316–323
[3] Bogdanov O S, Podniek A K et al 1990 Theory and Technology of Ore Flotation (Moscow: Nedra) p 363
[4] Salamatin A S, Makarov G V et al 2018 Science-intensive Technologies for Development and Use of Mineral Resources 4 330–333
[5] Myshlyaev L P, Evtushenko V F 2017 Proc. of the XI All-Russian Sci. and Pract. Conf. in Automation Systems in Educ., Sci. and Prod. (Novokuznetsk: SibSIU) pp 351–355