Project of Control System for Technological Parameters for the Coal Enrichment Using Flotation and Dewatering Methods

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Summary

This publication includes presentation and discussion of scheme designed by the author, that is related to automation of technological flotation node and dewatering of coal slurry, taking into consideration proposal of control and measurement system with loops of control, stabilization, safety and optimization of the most important technical and technological parameters of the process. Designed system will allow to control the technical and technological parameters of process of enrichment of coal using flotation and dewatering methods. Described system and loops allow for stabilization and contribute to control e.g. amount of supplied air, gas, flotation agents, the flow rate of the feed and enrichment products, temperature in the oven, content of volatile matter and fly ash etc.

Keywords: SCADA system, flotation enrichment, dewatering, drying, automation system, control system, safety system

Introduction

In order to ensure proper functioning and development of industrial facilities, decision makers at various levels of management of the technological process, must have continuous access to essential data concerning:

- Individual devices or technological lines status
- Current values of parameters relevant to the process
- Current balance of the material involved in the production
- Historical trends of selected parameters

Supervisory control systems and visualization devices (SCADA) allow for current observation and possibility of interference in the production process from the level of the plant's dispatcher.

As a rule, it is not enough just to have access to the aforementioned information. All data must be organized in such a way that it was possible to rapidly perform all kinds of analyses (e.g. the amount of supplied air in order to comfort proper aeration of flotation pulp), configuration and the relationship between the parameters describing the technological process and their mutual correlation.

The solution of a problems of information management, appropriate data folding and technological parameters control is a compatibility with the SCADA systems. It is a program that allows for automation of production in many industries. It helps in supervising of the technological process and production. It collects current data from sensors, process the data. It is possible to visualize the process and signaling the exceeding of upper or lower values of technological parameters. All this can be done from the dispatcher's desktop.

Project for automation of flotation of coal and dewatering of products

Technological scheme

Automated scheme is based on flotation enrichment of coal slurry that have less than 0.5 mm along with dewatering of the products. The feed is provided to the flotation machine, to which air and flotation agents are supplied. Flotation concentrate is fed to the vacuum filter, and the wastes are directed into Dorr's settling tank. The filter cakes, after initial dewatering, are directed to drying in rotary drier that is fired with natural gas. Dried up to approximately 10 % of moisture, cakes are guided into the container 1, and then loaded onto wagons. The filtrate from vacuum filter is re-routed to the flotation machine as a feed. Flotation wastes in the Dorr's settling tank undergo the process of densification. The clarified water is recycled to technological cycle. Concentrated sludge is fed to the filter press to which pressure is applied. Dehydrated filter cakes are routed to tank 2 from where they are loaded onto wagons and transported to the dumping ground for waste [Mączka, Trybalski, 1981].

Scheme of automation

Flotation is one of the enrichment method of coal slurry, mainly coking coals. This process is multidimensional because of the complexity of the phenomena occurring at the interfaces under the influence of physicochemical and hydrodynamic factors. The high mechanization degree of Mechanical Coal Processing Plant (Zakład Mechanicznej Przeróbki Węgla, ZMPW), continuous work and relatively small disturbances in the course of work foster the implementa-

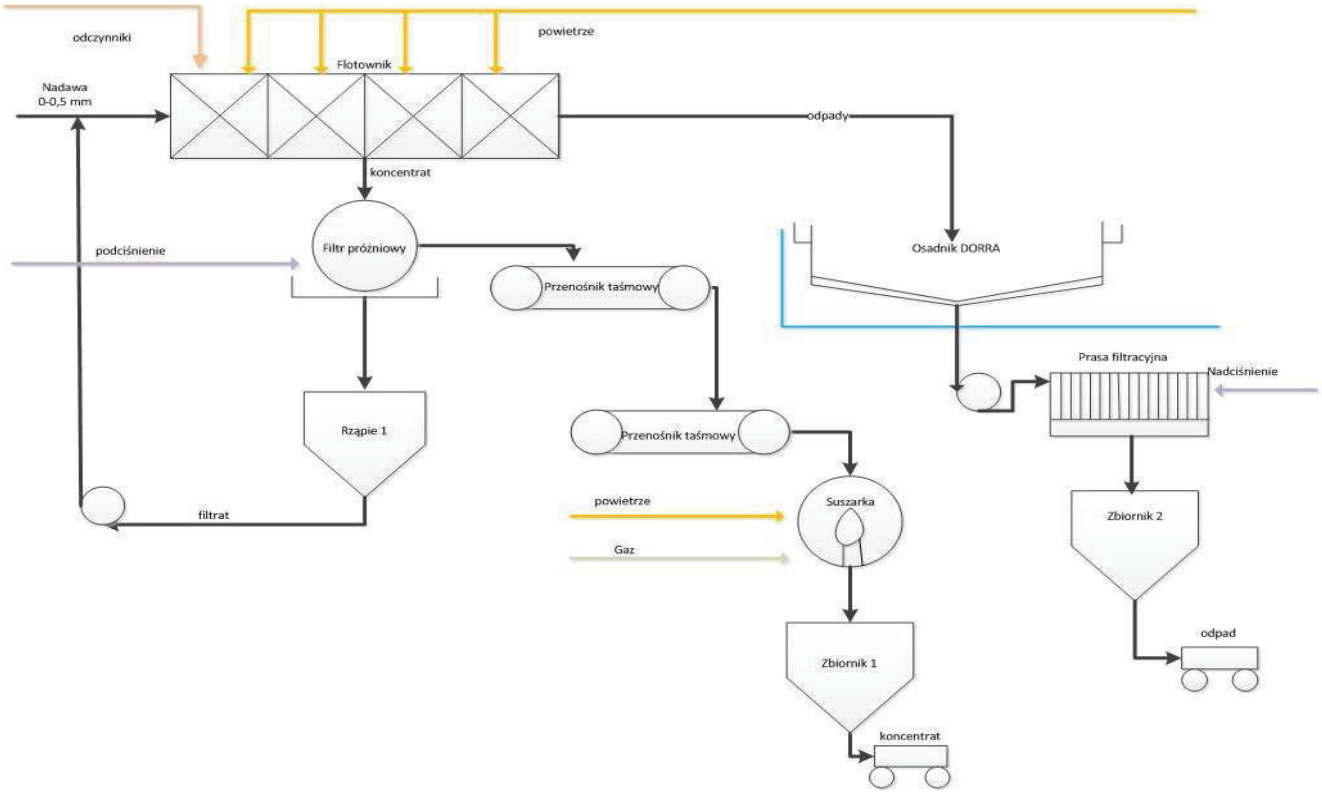

Fig.1. Technological scheme of flotation enrichment of coal slurry and dewatering of products

Rys.1 Schemat technologiczny procesu wzbogacania flotacyjnego mułów węglowych i odwadniania produktów

tion of automatic control system. A variety of models describing flotation process have been developed both in terms of probabilistic [Brożek, Młynarczykowska, Turno 2003], heuristic [Brożek et al. 2003], [Brożek and Młynarczykowska 2007,2007,2010] in relation to the process of cyclic and continuous course [Brożek, Młynarczykowska 2007]. Still, there is a lack of sufficiently accurate, in technological understanding, mathematical models of the process, which is a serious obstacle in this respect.

Treating flotation as a control object, one can distinguish variables sets such as [Mączka, Trybalski, 1981]:

• Input controls:
- Amount of supplied factors
- Amount of air supplied to aeration
- The level of pulp in the flotation machine

• Disturbing input:
- Granulometric composition of the feed
- Density of the feed
- Flow rate of the flotation pulps
- Temperature of the flotation pulps
- pH of flotation pulps
- Water composition
- Technical composition of the machinery and equipment

• Output controlled:
- Strain relief of the concentrate
- Content of the useful component in the concentrate
- Strain relief of the wastes
- Content of the useful component in the wastes
- Yield of the useful component

The success of flotation automatic control is determined by control parameters, both input and output as well as the possibility of automatic adjustment of the most important of them. Selection of control scheme and used control systems depends on the specific technological conditions of enrichment plant and the technical capabilities in the implementation off such systems.

System for pulp stabilization in sump

Maintaining a constant level of a pulp in a sumps is required for several reasons. Firstly, for the correct operation of pressure pumps the level cannot be too low, because in such situation at the stub pipes swirls and vortexes occur that contribute to air suction. Secondly, a too high level of a pulp threatens to overflow by the edges of the sump. Thirdly, maintaining a constant level determines the intentional changes in a control process such as processing change, changing the volumetric flow rate of pulps in sumps is one of the conditions for the proper operation of technological process [Mączka, Trybalski, 1981].

Stability of air flow rate directed to the flotation machines

One of the factors affecting the results of the flotation process is pulp aeration, which is associated with delivering the right amount of air into the machine. Manual adjustment of the valve opening degree requires frequent changes of its position and is also inaccurate, there are significant – even the order of 50 % - fluctuation in the air flow. This is due to factors such as changes in pressure created by the blower, the pressure drop in the supply lines, changes in the amount of air received and changes of the level and density of sumps in flotation machine.

To avoid continuous manual adjustment of valve position and reduce disturbances affecting the process, the automatic regulators for air flow rate are used [Mączka, Trybalski, 1980].

Control system for pulp level in the flotation machine

Maintaining an appropriate level of pulps in the flotation machine (input control) is one of the most important tasks for automating this process. Pulp level directly determines the quality of the enrichment products and also affects the final yield of the process (output). Level of pulp may also be the dimension that controls flotation process, wherein knowledge of other process parameters is required, mostly the content of the useful elements in the products. In practice, there is a number of control systems using mostly electronic and pneumatic automation components [Brożek, Młynarczykowska, 2006]. These systems are facing high requirements such as precision adjustment, time adjustment, independence of pulp density and foam layer thickness, resistance to the operating conditions, the possibility of manual and automatic regulation, local and remote.

Types of automatic control systems (ACS) of filtration process

The filtration process can be equipped with automatic control systems such as:

a) ACS of feed amount stabilization, using excess of minimum and maximum levels in the tank, to which the pulp is discharged from the bath supplying filter or filter press

b) ACS of moisture content in the filter cake by changing the plurality of subatmospheric pressure in the filter

c) ACS of detachment of the filter cake by compressed air by changing the frequency of its delivery in the function of revolutions of the filter disc.

Description of the automation loop

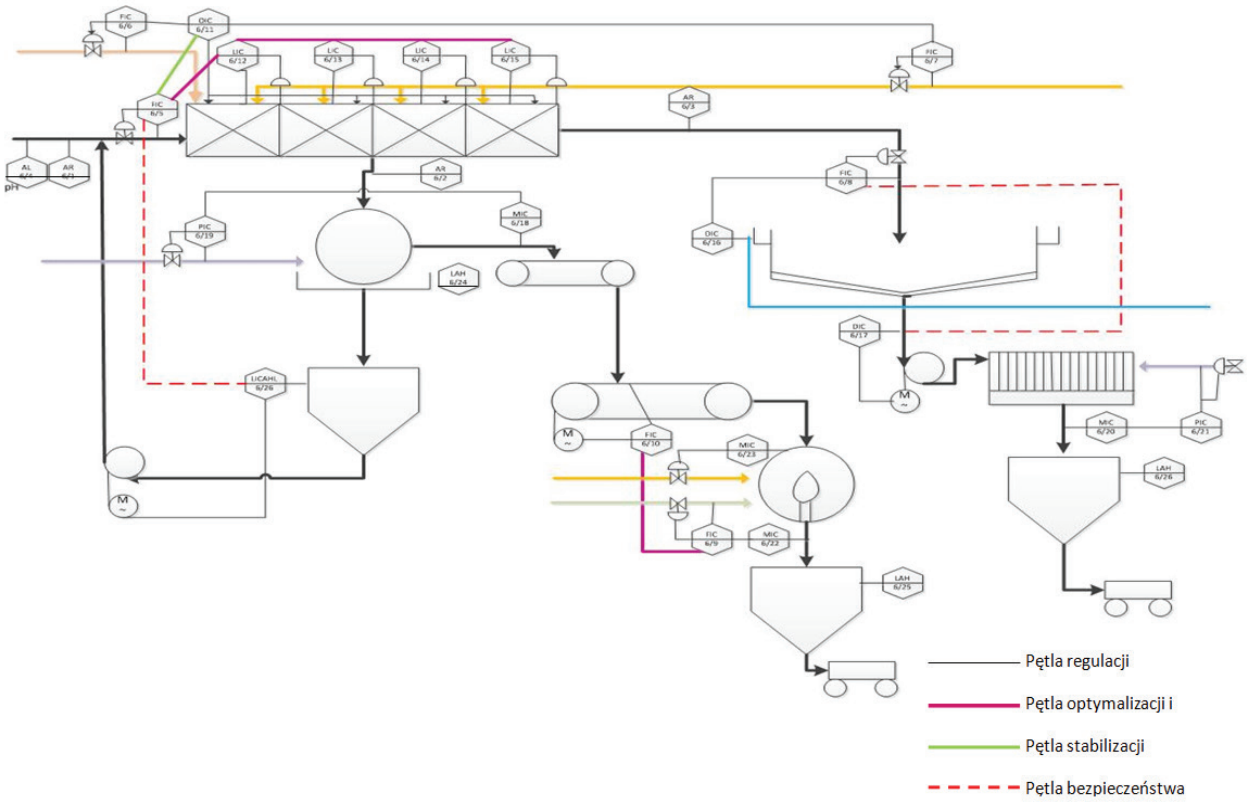

Fig.2. Process automation system with the loops of control, optimization and stabilization and safety

Rys.2 Układ automatyzacji procesu technologicznego z pętlami regulacji, optymalizacji i stabilizacji oraz bezpieczeństwa

Tab.1. Denotations and points of control and measurement
Tab. 1. Oznaczenia i punkty kontrolno pomiarowe

Description of control and measurement points	
AR 6/1	Measurement point for ash content in the feed
AR 6/2	Measurement point for ash content in the concentrate
AR 6/3	Measurement point for ash content in the wastes
$_{pH}$AL. 6/4	Indicating measurement of pH values of feed delivered to the flotation machine
FIC 6/5	Control system for volumetric flow rate of the feed to the flotation machine
FIC 6/6	Control system for volumetric flow rate of the reagent added to the flotation machine
FIC 6/7	Control system for volumetric flow rate of air added to the flotation machine
FIC 6/8 DIC 6/16	Cascade control system for automatic regulation of amount of feed to the condenser by regulation of volumetric flow rate of the feed (8) in a function of strain relief (16), wherein values of both parameters are indicated by scaled instrument
FIC 6/10	Control system for volumetric flow rate of filter cakes to the drier by weighing
OIC 6/11	Automatic control system for regulation of flotation foam parameters by using the image analysis by varying amount of supplied air and flotation reagents
LIC 6/12	Automatic control system for regulation of pulp level in the first flotation chamber with an indication of the height level
LIC 6/13	Automatic control system for regulation of pulp level in the second flotation chamber with an indication of the height level
LIC 6/14	Automatic control system for regulation of pulp level in the third flotation chamber with an indication of the height level
LIC 6/15	Automatic control system for regulation of pulp level in the fourth flotation chamber with an indication of the height level
Automatic system control for purity regulation	
DIC 6/17	Automatic control system for density regulation of concentrated product (with indication) by changing revolutions of the discharging pump
MIC 6/18 PIC 6/19	Automatic humidity control system (with value indication) of the filter cake delivered to the drier by changing the rate of subatmospheric pressure in the vacuum filter
MIC 6/20	Automatic humidity control system (with value indication) of the filter cake by changing the rate of overpressure in the filter press
PIC 6/21	Control system for overpressure delivered to the filter press with indication of measured value of overpressure
MIC 6/22 FIC 6/9	Automatic humidity control system (with value indication) of the filter cake by changing volumetric flow rate of natural gas to the drier
MIC 6/23	Automatic humidity control system (with value indication) of the filter cake by changing volumetric flow rate of cooling air to the drier
LAH 6/25	Signaling for exceeding upper level in the tank 1 by the filter cakes
LICAHL 6/26	Signaling for exceeding upper and lower level in the tank 2 by the filter cakes
LICAHL 6/27	Signaling for exceeding upper and lower level in the sump 1 by the filtrate

Basic control loops

The control loops used in the proposed project are basic in the automation hierarchy. Three flow control systems are designed, among others:

- Feed delivered to the flotation
- Reagent dosed to the flotation machine
- Air supplied to the flotation machine
- Wastes to Dorr's settlement tank

An important parameter of this scheme is computer image analysis of pulps from flotation process. Parameters analyzed are e.g. shade of gray, air bubble size, their shape and stability of the flotation foam. Depending on these parameters, the flow rate is regulated by reagents and air. It is a cascade control system. The level of pulps is automatically regulated with the set value. The humidity of filter cake is regulated by changing the pressure in the filter press.

Cascade control system for volumetric flow rate of the wastes to the Dorr's settlement tank is regulated depending on the density. Depending on the density of settlement tank outflow, the revolutions of pump are regulated. Adjusting the pressure in the filter press is, that if the humidity of the filter cake is higher, the overpressure is increased.

In the drum drier, according to the temperature, the air flow rate, which is a coolant agent, is adjusted. Depending on the moisture content of the filter cake, the flow rate of natural gas is adjusted.

Depending on the condition of exceeding upper or lower level in the sump, the revolutions of the pump are adjusted. The scheme depicts measurement points signaling e.g. amount of ashes in the feed, concentrate and wastes (ash-meters), pH measurement (pH-meter), measurement of the level of filling the sump and tanks.

Stabilization loop

Two stabilization loops have been used. Depending on the level of pulp in the flotation machine, stabilization loops turns on and stabilizes the level of the pulps by changing the flow rate of the feed. The second stabilization loop applies to natural gas consumption. Natural gas consumption is stabilized in the function of concentrate directed to the drier.

Optimization loop

Optimization of the feed flow rate depending on the flotation foam quality parameters using the image analysis. The parameters of the flotation foam are optimized by changing the amount of the feed supplied to the process. Computer image analysis of flotation foam is used for optimization purposes.

Safety loop

Two safety loops have been used:

- Loop limiting/increasing feed flow rate to the flotation machine in the moment of exceeding the levels of sump 1 filling;
- Loop limiting/increasing feed flow rate to Dorr's settlement tank depending on the density of the outflow

Reservoir level gauges, ash-meters, pH-meters and densimeters, shown in the scheme in Fig.2., allow for control of the technological process. The parameters of the process can be easily controlled by use of SCADA software and visualization on the plots and screens. We have the ability of monitoring the amount of winning in the tank, level of the fluid in the flotation machines and level of filling the sump thanks to reservoir level gauges. In the case of too low/high density, opening or closing suitable pumps, valves or bolts, adds or reduces heavy liquid in order to keep the set level. This reduces the losses such as magnetite, natural gas or other media. The appropriate weight of the liquid means better concentrate.

Conclusions

Automation of technological processes, including coal treatment, have a significant impact on the organization of the production process, and simultaneously, its technological and economic efficiency. Modern control systems (SCADA) facilitates the production processes ensuring their full visualization and monitoring and optimization of operating parameters.

The flotation node with products dewatering is difficult to automate from the technological point of view, because of complexity of the various factors. The feed material is diverse in terms of its physicochemical and hydrodynamic parameters, so that automated node have to include loops of regulation, stabilization, optimization and safety.

Designing of schemes of automation production processes must be preceded by the their technological identification, including finding and choosing the input and output variables.

The condition for the automation of technological processes is, as complete as possible, their measurement, that is continuous measurement of main process parameters which is implemented through the control and measurement devices.

Automation of processes of mineral materials treatment is the only effective defense against adverse variability of processes associated with the instability of the feed parameters.

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Streszczenie

Publikacja zawiera przedstawienie i omówienie zaprojektowanego przez autora schematu automatyzacji węzła technologicznego flotacji i odwadniania mułów węglowych z uwzględnieniem propozycji układu kontrolno-pomiarowego wraz z pętlami regulacji, stabilizacji, bezpieczeństwa oraz optymalizacji najważniejszych parametrów techniczno-technologicznych procesu. Zaprojektowany układ pozwoli na kontrolowanie parametrów techniczno – technologicznych procesu wzbogacania węgla kamiennego metodą flotacyjną oraz jego odwadnianie. Opisane układy i pętle pozwalają na stabilizację oraz pozwolą regulować np. ilość doprowadzanego powietrza, gazu, odczynników flotacyjnych, natężenia przepływu nadawy i produktów wzbogacania, temperatury w suszarce, zawartości części palnych i lotnych oraz popiołu itp.

Słowa kluczowe: system SCADA, wzbogacanie flotacyjne, odwadnianie, suszenie, układ automatyzacji, układ sterowania, układ bezpieczeństwa