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To cite this article: J Rogala-Rojek *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **545** 012009

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IOP Conf. Series: Materials Science and Engineering **545** (2019) 012009 doi:10.1088/1757-899X/545/1/012009

SCADA Class Software of the KOGA Control system of Jig Beneficiation Node

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Abstract. The article presents a proprietary visualization software for the coal beneficiation process, which enables monitoring of the jig node operation and full control of trends relating to all signals from sensors installed in the system and connected to the controller, among others a movement of the float, a position of the culvert and a position of the overflow threshold. The results of analyses regarding the selection of PID regulator settings, determined on the basis of industrial research, are also presented.

1. Introduction

Increasing the quality of products obtained in the process of beneficiation, carried out in jigs, in coal mechanical processing plants, requires a implementation of solutions from the broadly understood industrial automation. An indispensable component of these solutions is computer software, the application of which is related to the hardware layer, communication layer, control, analysis, acquisition, archiving and visualization of data. The jig node control system, developed at the KOMAG Institute of Mining Technology, provides: an operational monitoring and control of its correct functioning, an automatic emergency shutdown and remote manual or sequential stopping and starting of the jig and the machines associated with it.

2. Characteristics of the jig control system

An efficient progress of each technological process requires an implementation of a proper control system of each machine being a part of the jig node. In the process of hard coal beneficiation, taking place in pulsatory jigs, a very important factor, determining their proper operation, includes an efficient and precise control of raw material feeding and removal of the beneficiated product. It is connected with a necessity of a complex automation of the node, which can ensure a proper interaction of the jig with the feed system and bucket conveyors collecting products from the jig. An exemplary structure of the jig node control system is presented in figure 1 [1, 2].

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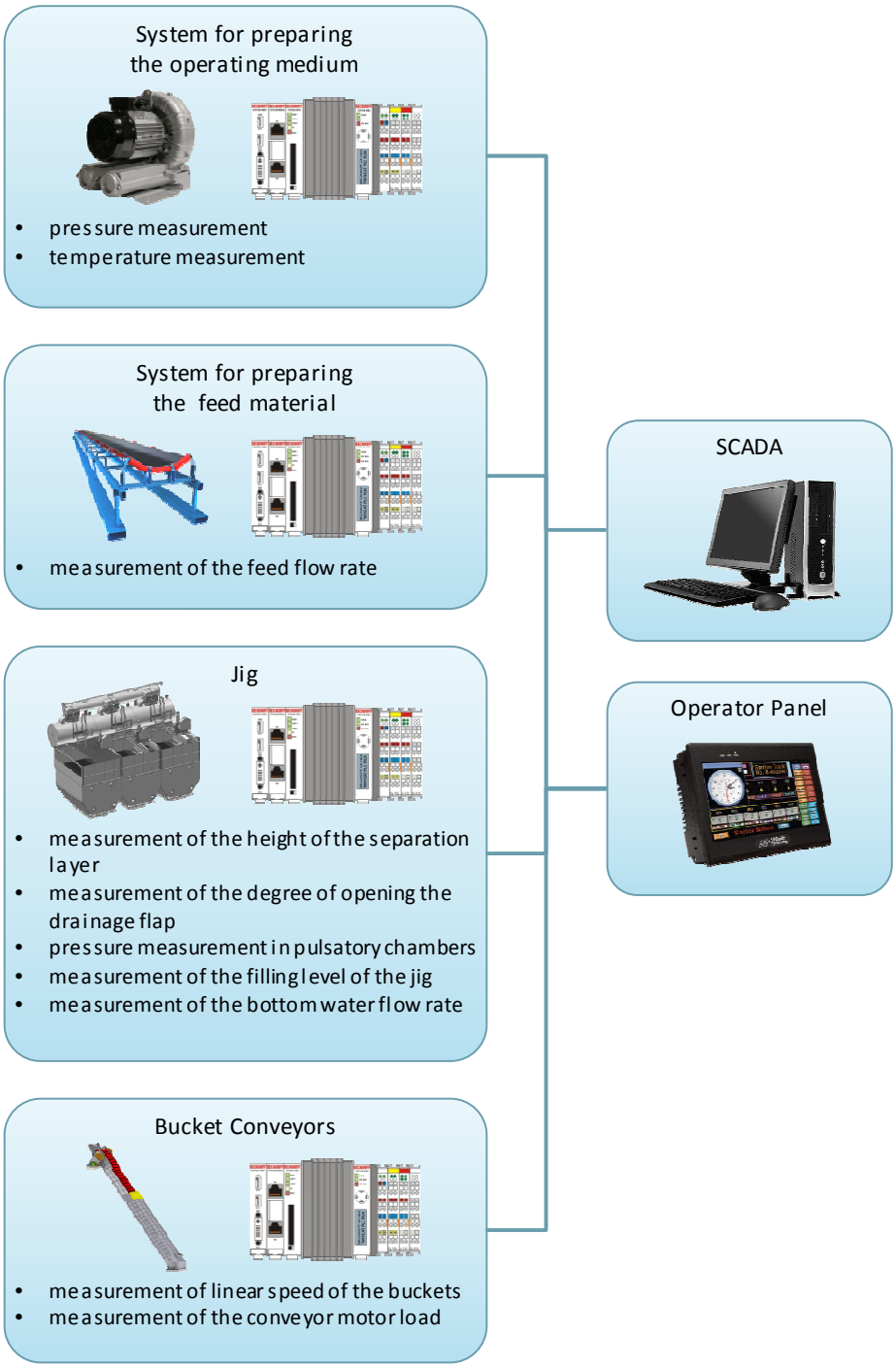

Figure 1. Structure of the distributed control system of jig beneficiation node [3, 4].

The KOMAG Institute of Mining Technology has been conducting research projects on a development of systems for a control of a jig node for several years. In 2010, the first prototype of the system was installed in the processing plant of the Budryk mine. Initially, the system was used to control a pulsatory jig, and then, in the first half of 2011, it was extended by an integration with the bucket conveyor control [1]. The KOGA jig node control system, developed at KOMAG, was also implemented in 2016 in Sośnica mine, branch of KW S.A. (Coal Company) [5].

The control system developed at KOMAG, built on the basis of a PLC programmable controller, provides monitoring and control of the correct operation of the jig node, automatic, emergency shutdown and remote, manual and sequential stopping and start-up of the jig and machines that cooperate with it [1].

The basic functions of the control system include [1]:

- a pulsation control, with a possibility a changing its parameters in relation to the length and number of cycles,
- an automatic adjustment of the heavy products collection,
- a loosening stabilization of the beneficiated material layer,
- a measurement and recording of quantities related to an operation of the machine,
- an automatic control of the jig in the place of its installation as well as a possibility of control through a dispatching system,
- an automatic and manual (from the operator's panel) speed control of bucket conveyors,
- an automatic unloading of the jig.

A very important element of the control system related to a production process is the so-called human-machine interface HMI. The role of such interfaces, in modern systems based on PLCs, is played by operator's panels and SCADA software (Supervisory Control And Data Acquisition) [2].

They provide a textual or graphical representation of phenomena occurring during a realization of a technological process. They also make it possible to track and control a flow of the process via a terminal, such as a computer monitor or an operator's panel screen. Use of these tools increases work comfort, both for the personnel directly operating the process, as well as the management staff, allowing to obtain information about the process in a quick and easy way and at the same time enabling as follows [2]:

- monitoring an operation of the machine:
  - switching the machine on/off,
  - giving orders to the operator concerning e.g.: the correct sequence of switching on and off of a given machine (recipe),
  - displaying process messages and information,
- process diagnostics, including:
  - monitoring process parameters,
  - scaling of values in specific engineering units,
  - displaying text messages, alarm/data history,
  - defining alarm thresholds,
  - signalling faults and alarm confirmations,
- setting values and changes of thresholds of regulation loops,
- conducting manual control of the object,
- keeping of archives of process data with an option of their printing,
- generating of a process visualization.

3. IT system supervising the technological process (SCADA)

An operation of the node is monitored by a visualization application (SCADA), whose main screen is shown in figure 2. The application is installed on a computer, in the control room of the processing plant. Its main functionality includes a visualization of the process and keeping archives of the measurement data, however, the range of its capabilities is much wider. By using an appropriate logging system, it allows trained users to access advanced control functions and settings of regulation loop parameters.

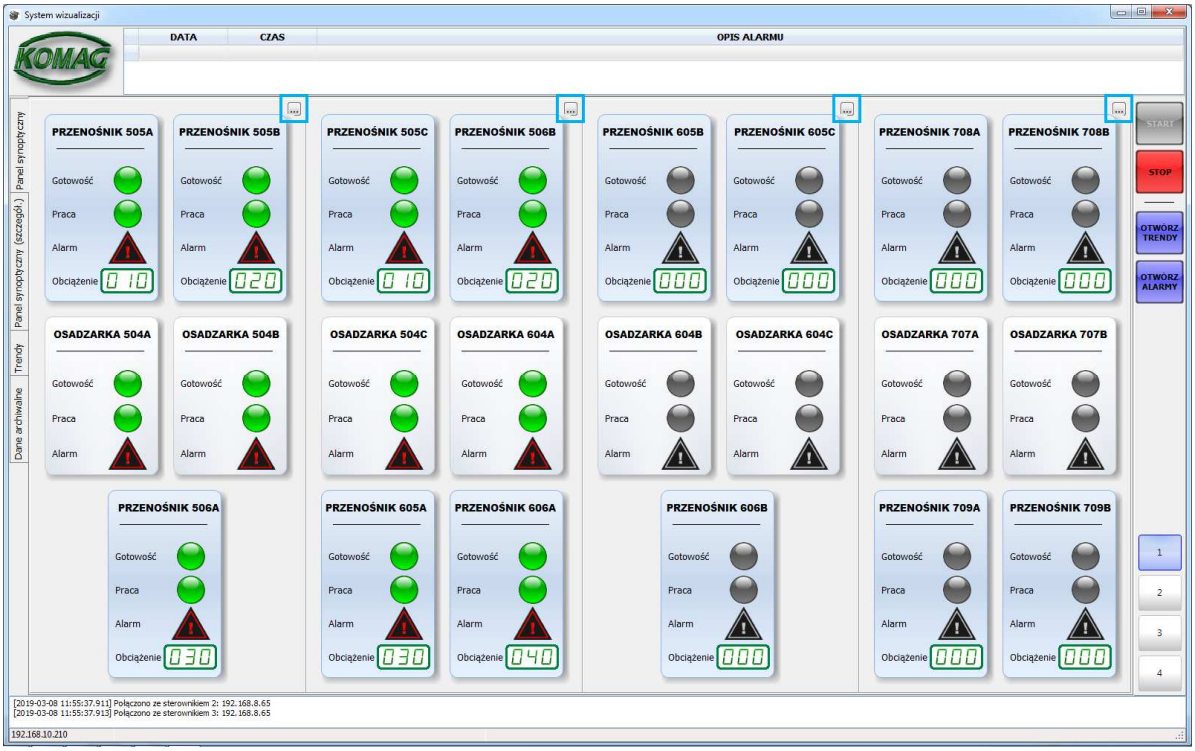

Figure 2. View of the main window of visualization application.

The main screen shows basic information about an operation of all the jigs and bucket conveyors installed in the processing plant. Individual machines are grouped according to their connections to the control cubicles. The software user (after clicking the button marked with a blue frame) is able to view more detailed information on an operation of individual machines (figure 3).

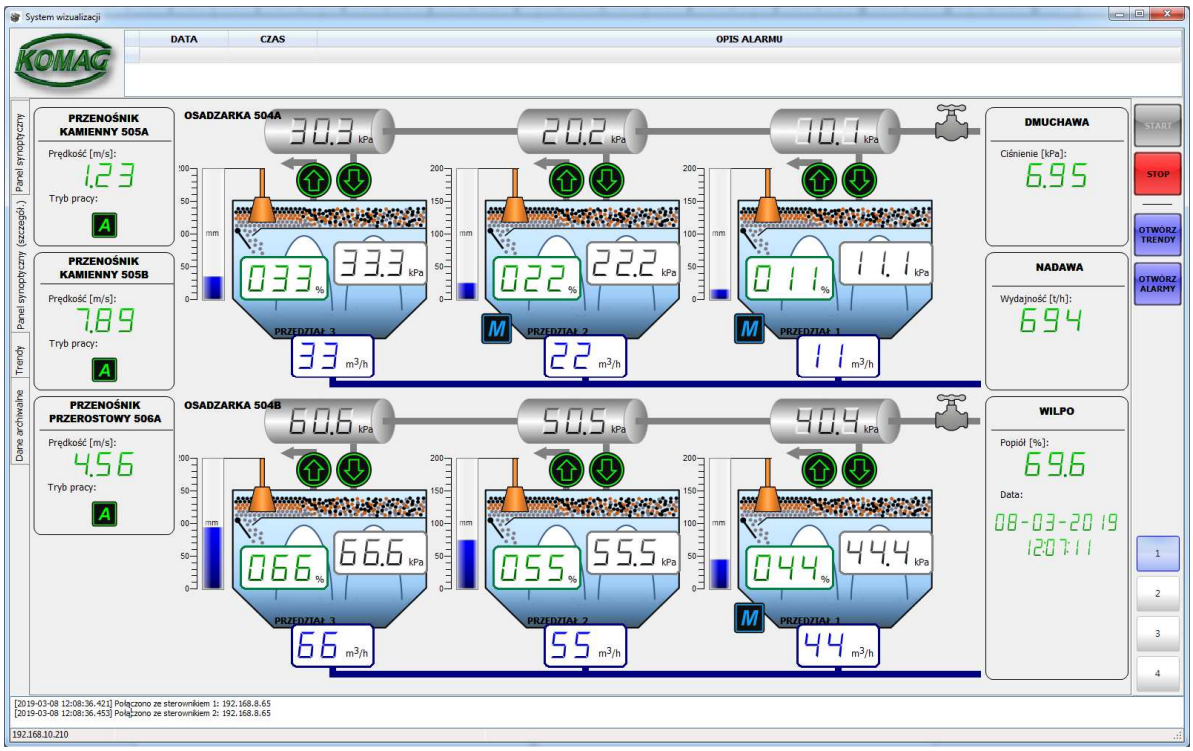

Figure 3. View of the visualization application window with operating parameters of jigs.

The application, beside the current visualization of the jig node operation, enables a presentation of time series of selected parameters and keeping the archives of measured parameters (figure 4). The window is divided into 6 parts, and each of them enables to display time series of parameters measured in the specific jig chambers. Changing of the displayed parameter or selecting the next one is performed by pressing the right mouse button on the selected interval and selecting a given range of parameters (figure 5).

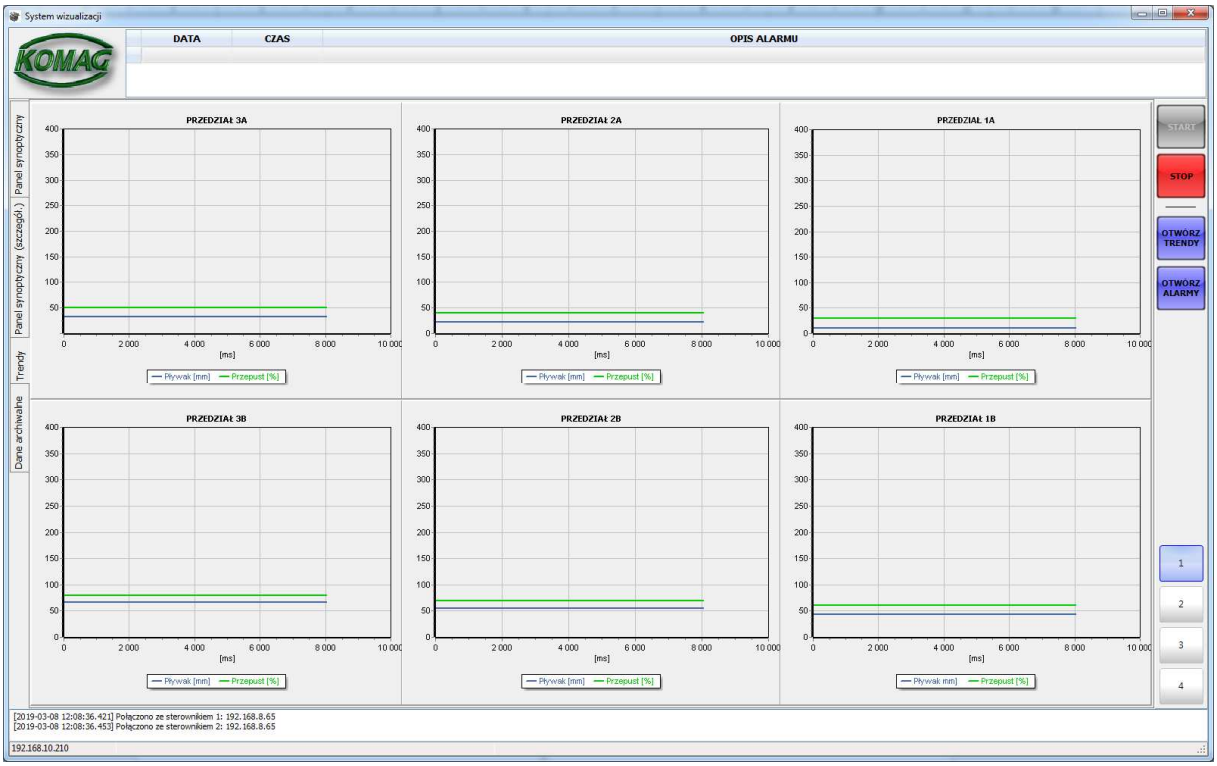

Figure 4. Visualization application window showing time series of selected parameters.

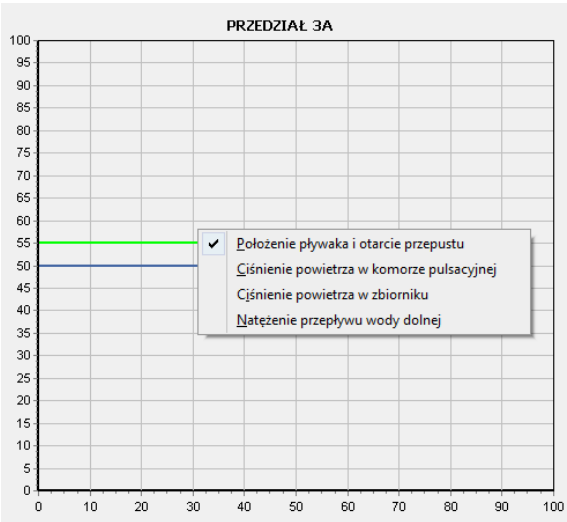

Figure 5. Trend window - range selection of displayed data.

An application also enables viewing alarms or time series of selected parameters from the last 30 days. The "Data" folder with historical data is created on an FTP server supported by the driver. With the start of a new day, further subdirectories are created in the "Data" directory, whose names correspond to the dates of their creation. Data files are saved daily in the subdirectories. A complete directory from the whole day contains 24 files with time series of selected parameters and one alarm file. Selecting a data file causes a display of the recorded waveforms in a tabular form (figure 6), as well as in a form of a graph (figure 7).

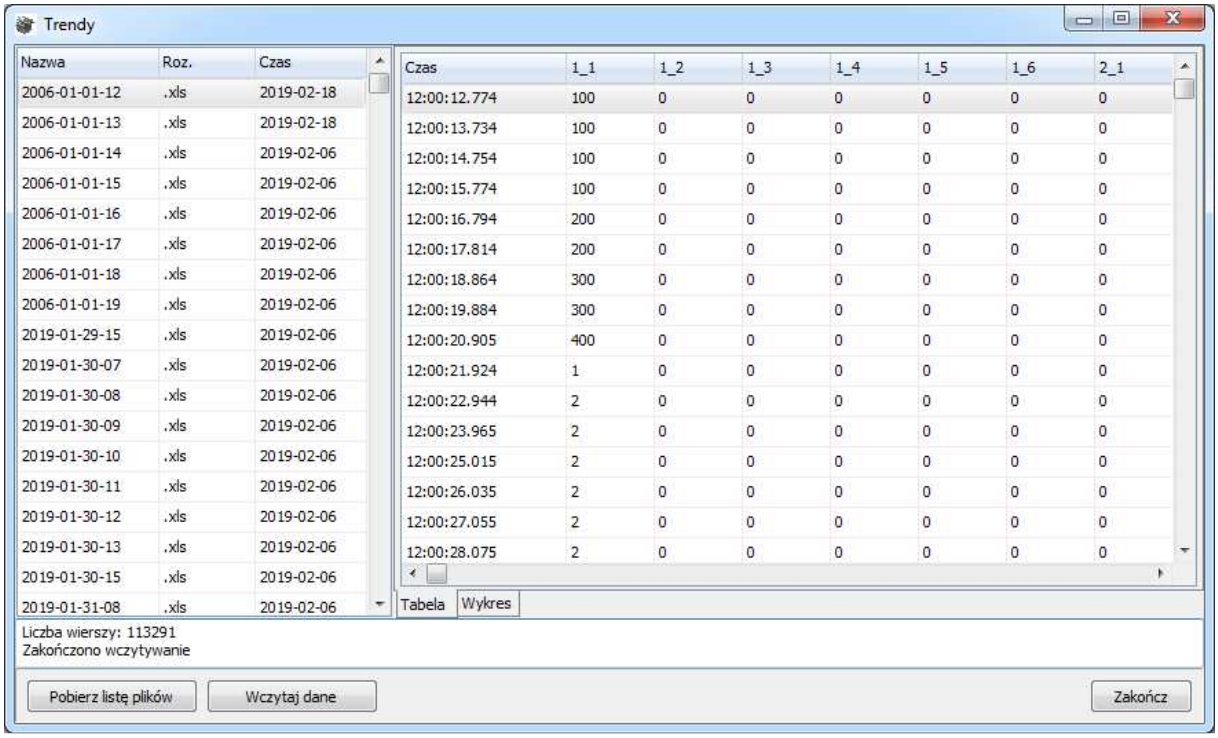

Figure 6. Visualization application window - archival data (in tabular form).

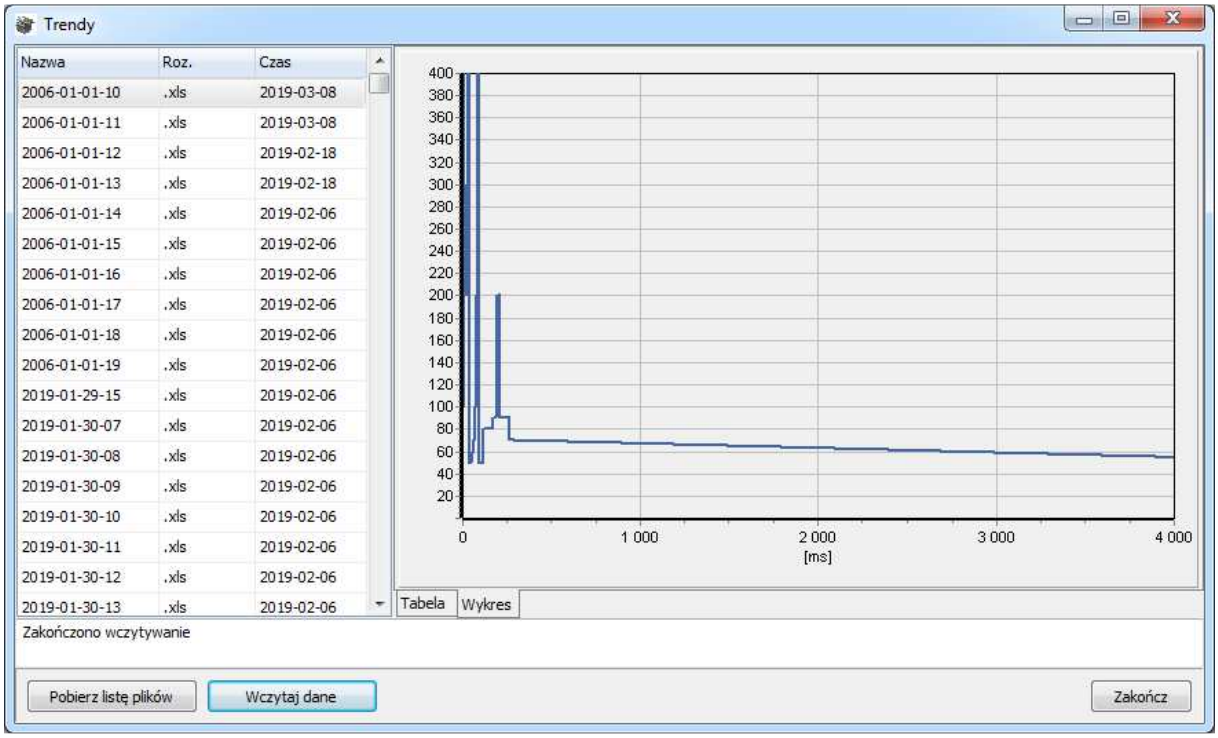

Figure 7. Visualization application window - archival data (in graphical form).

All the parameters are displayed on a single chart, which enables to compare the selected waveforms. It is possible to apply filters and select the data to be displayed on the chart. This is done by pressing the right mouse button and selecting the interesting parameters (figure 8).

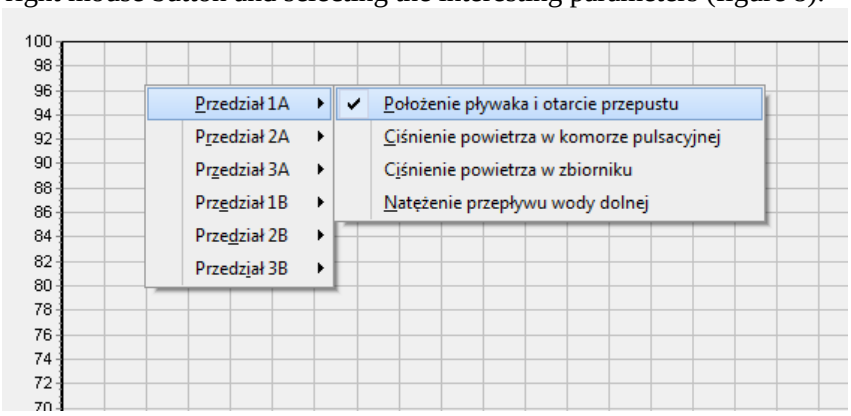

Figure 8. Archival trends window - filtering the range of displayed data.

A selection of the alarm file displays the alarms recorded on a given day (figure 9). It is possible to apply filters and display only the alarms from the selected ranges. This is realized by pressing the right mouse button and selecting an interesting ranges (figure 10).

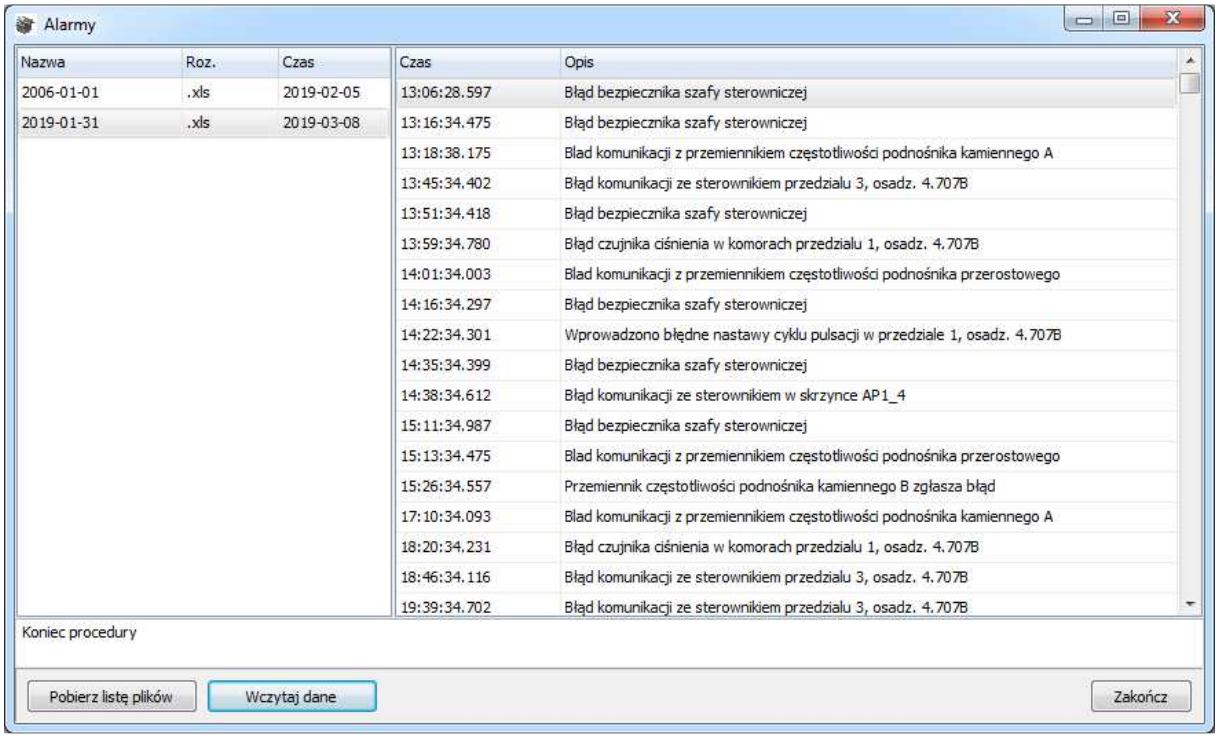

Figure 9. Window for reading recorded alarms.

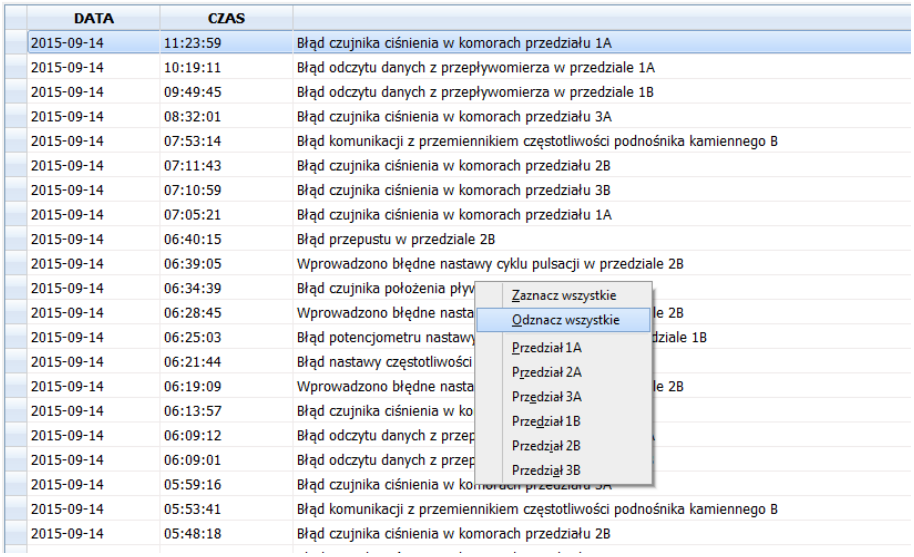

Figure 10. Archival alarm window - filtering the range of displayed alarms.

Since 2010, the correct and failure-free operation of the system installed in the processing plant of the mine, has been noticed.

The collected measurement data allow ITG KOMAG to carry out work related to search for further correlations of process parameters between individual machines included in the jig node [2, 3]. The algorithms implemented in the application enable advanced data analysis and contribute to the development of more perfect and reliable algorithms for effective control.

One of the tasks of the jig node control system is to stabilize the position of the separation layer (density of separation) by keeping the float at a given height. As part of the work carried out, an algorithm was implemented using a PID controller, which controls the opening of discharge slots

through which bottom products are led out. In order to check the effectiveness of regulation, using author's application, the distributions of minimum position of the float in one of compartments of the jig were determined. Results were compared with the initial settings of the PID controller and after the tuning process using, among others, the author's application (figure 11 - 16).

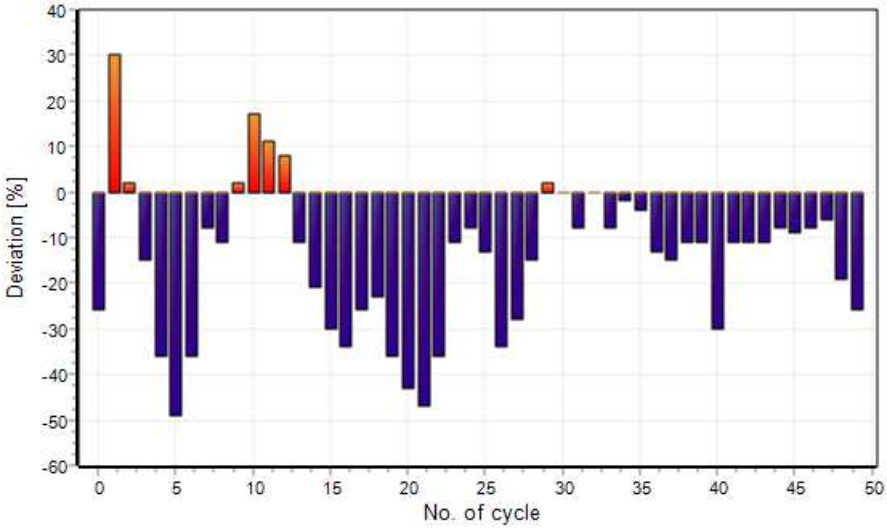

Figure 11. Fragment of the application window (diagram) - degree of deviation of the minimum position of float from the setpoint (PID regulator presetting).

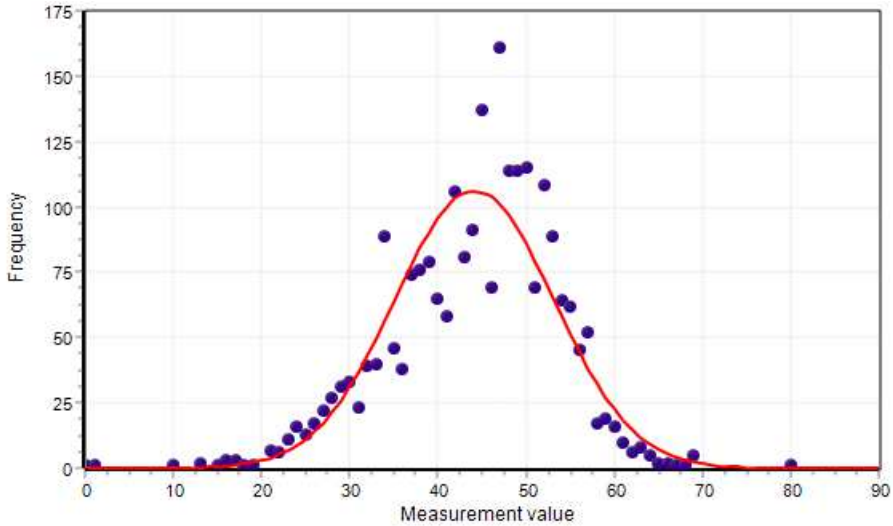

Figure 12. Fragment of application window (diagram) - distribution of change of minimum float position in the range no. 1 (PID regulator default settings).

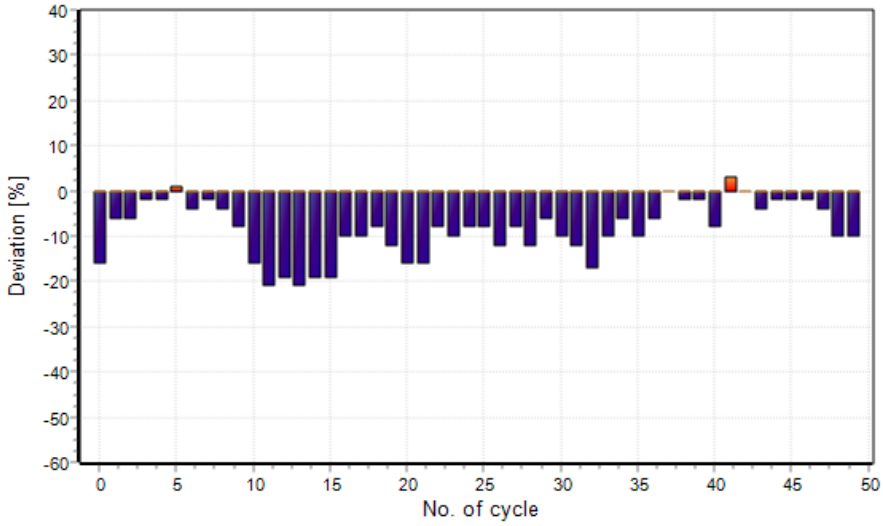

Figure 13. Fragment of the application window (diagram) - degree of deviation of the minimum position of the float from the setpoint (using the PID regulator - after 1st tuning).

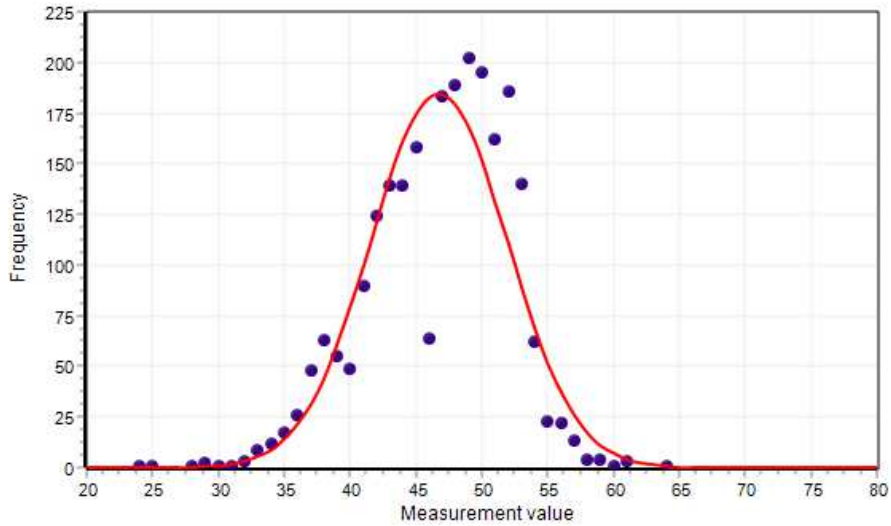

Figure 14. Fragment of application window (diagram) - distribution of minimum float position change in range no. 1 (using PID regulator - after 1st tuning).

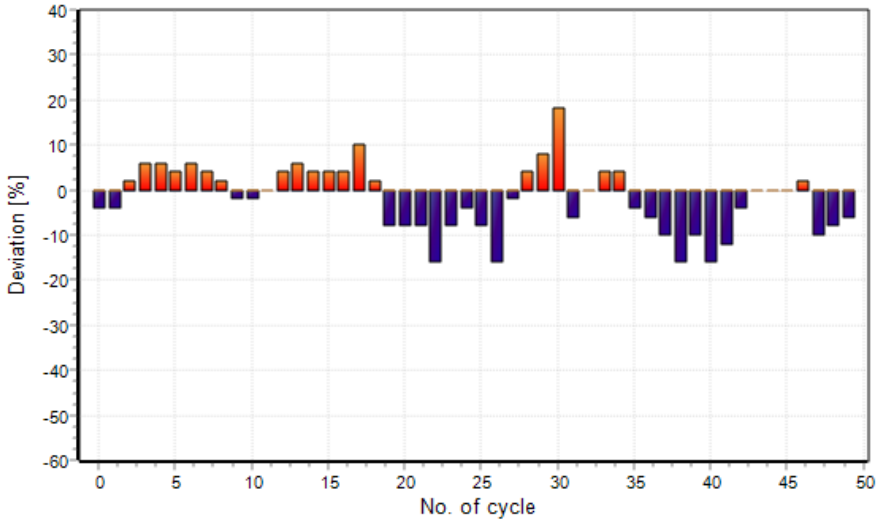

Figure 15. Fragment of the application window (diagram) - degree of deviation of the minimum position of float from the setpoint (with the use of the PID regulator - after 2nd tuning).

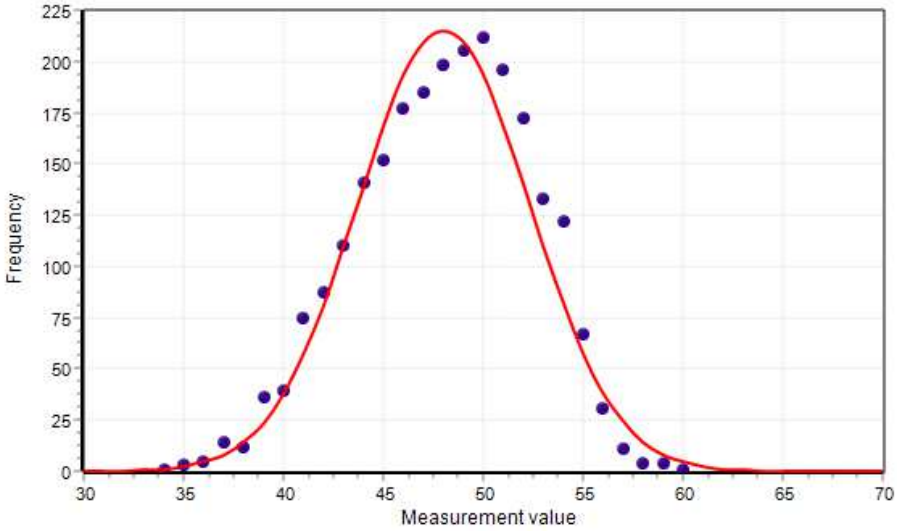

Figure 16. Fragment of application window (diagram) - distribution of change of minimum float position in range no. 1 (using PID regulator - after 2nd tuning).

The presented characteristics were recorded during three measurement sessions, in which the position of the float in one of the compartments was recorded for 60 minutes. The recorded mean values and standard deviations are presented in table 1.

Table 1. Minimum position of float without/with regulation system.

	PID controller presettings	With PID controller (after 1st tuning)	With PID controller (after 2nd tuning)
standard deviations	9,01	5,18	4,30
mean values	44,12	46,75	48,01

During the first batch in 60 minutes, the average value of the separation layer was 44.12 mm and the standard deviation was 9.01 mm. After the process of tuning PID controller, whose task was to maintain the separation layer at the set value of 53 mm, the mean value during the tests was 46.75 mm and the standard deviation was 5.18 mm. After another attempt to adjust the PID regulator settings, the mean value of 48.01 mm and the standard deviation of 4.30 mm were obtained. Comparing the distributions presented in figures 11-16, it can be concluded that the implementation of the control system stabilized the position of the distribution layer (distribution density) at the set value. The tests showed that the mean value was close to the setpoint. The regulator's operation was improved in terms of control efficiency.

As a part of further research and development work, it is planned to extend the application by an advisory module, which, basing on tracking short and long-term trends, will enable to predict hazards and optimize control algorithms. For this purpose, an interface will be implemented, which will enable creating, editing and deleting expert rules, used by the system, as well as procedures of concluding mechanism and of a visualization of its results.

4. Summary

The research and development work undertaken at KOMAG aims at an improvement of the existing solutions as well as a search for new opportunities to apply information technology. The article presents an example of a visualization system, operating together with a control system. The solution, presented above, has been implemented in mines and it is also used in the designing process as well as optimisation of control algorithms at the KOMAG Institute. As a part of further research and development work, it is planned to extend the application by an advisory module.

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