Slide 1

Warm greetings to you, dear colleagues! I am very excited to present your our work, which name you can see on the slide. And of cause, the main idea of it – is the full automated granulometric control system or AGS.

Slide 2

This slide shows the content of our work and some information about the speaker.

As you may know, the modern mineral fertilizer industry are large-scale facilities, which produce dozens of tons of product hourly. At the same time, there are practically no robotic systems of quality control of the ongoing technological processes. In present work main stages of mineral fertilizer production are described and the solution to the problem of robotic online particle size control is proposed. Different solutions of the sampling system are given for two different forms of a fertilizer flow (on a conveyor belt and in a closed pipe) and they statistical characteristics (mean and standard deviation) are calculated. The obtained results are compared with similar laboratory particles size control device (the Camsizer P4).

If you will interesting in this work or me personally – please do not hesitate to visit my site, where this and several other project are describe.

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Well, let consider the mineral fertilizers industry and the role of particle size in it.

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The mineral fertilizer production is a fast-growing industry with a migration to industry 4, which characteristics are decentralization of manufacture and flexible quality control of products.

In the modern industrial production, there is a clear tendency to simplify methods of control to their full automation. The area of mineral fertilizers production is not an exception. Various systems of supervisory control and data acquisition (or SCADA) are being actively integrated into technological processes. However, the major part of the information in these systems concern devices of 0 automation level and displays only a single unit of the concrete information per time.

As you may know, the manufacturing of phosphorus-containing mineral fertilizers is a complex process that combines several production facilities with they own SCADA systems. Firstly, phosphate ore are mining, processed into phosphoric acid and then - into fertilizers. However, all errors and failures in all of these complexes affect the quality of the final product – the granular mineral fertilizer.

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The last and the most important stage of mineral fertilizer production is shown on the slide. In most cases, the finished product of industrially produced mineral fertilizers is a granule with size from 1 to 4 mm. Sometimes, size can vary from 1 to 5, or 2 to 6 mm, which is depends on the customer requires. And yes, most of its time, the mineral fertilizer lives in granular form.

That is why the granulometric composition is one of the most important indicator of the quality of the manufactured product. It is often noted, that parameters of shape (or sphericity) and color of granules are also important, which are associated with some consumer properties of mineral fertilizers (such as dustiness, hardness, solubility and etc.).

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Moreover, despite of all the importance, control of these parameters is carried out in laboratories by methods of sieve analysis at long time intervals. The laboratory control is related to the fact, that continuous automated control requires the installation of complex equipment in aggressive production conditions with vibrations, dust, aggressive acids and gases.

According to the literature, existing methods of laboratory analysis have numbers of drawbacks and the biggest - is time. Also, the most of such systems relate to the 0 level of automation and does not have the possibility of self-diagnostics and self-regulation.

In the present work the robotic control system of the particle size distribution (or AGS) was created for industrial condition. This system include all 3 level of automation (from 0 to 2nd). The ways of modernization this system for sampling from the conveyor belt and closed pipe, as well as results of industrial tests and main statistical characteristics are described.

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Our next step - is describe of the proposed robotic system.

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The developed robotic system used to control products, which are delivered to the storage. One robotic system takes a sample from a conveyor belt in workshop 1 and the other - from a closed pipe with the product from workshop 2. Such scheme provides control of the overall production process and the quality of finished products.

The developed system of robotic control consists of 6 main components.

1) Sampler, which is based on a Single-turn Electrical Actuator (SEA). It's designed for gathering the fertilizer samples from production line and to deliver them at the vibrating table.
2) Vibrating table, which is based on a special vibro-magnets. It's used for even separation and distribution of fertilizer sample granules under the camera, and their removal after the analysis is done.
3) LED lighting assembly is used for even lightening of granules, which is one of the crucial parameters affecting the analysis quality.
4) High-speed digital camera is used for gathering digital pictures of granules for the analysis.
5) Controllino - is an Arduino-compatible PLC, used to control SEA actuator, LED lighting and vibrating table by signals from computer. It also sends ready signal from SEA to computer, to tell the system when the analysis process can be started.
6) PC runs a Linux operating system with an analysis software. It processes digital pictures from camera to calculate particle size, then creates a data file and sends it to the factory SCADA system.

So, AGS covers three lower automation levels and sends granulometric composition (as vector with numbers) to industrial SCADA system (named PI System in JSC "Apatite")

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To represent the flow of data and signals in AGS you can use this structural diagram, which represents the functional algorithm of a system and may be described as follows.

SEA of a sampler cyclically rotates a bucket, which crosses the fertilizer stream, thereby capturing a sample. When it reaches the highest rotation point, SEO hits the endstop, signalizing the PLC that the probe distribution can be started, and turns the bucket to the starting position. PLC turns on the vibrating table relay for a set time period, after that, it shuts table off, turns on the lighting module relay and sends ready signal to computer. After the set time delay, PLC shuts down the lighting module and turns on the vibrating table to remove the probe. Removal duration is also configured by a time delay, after which PLC shuts down the table and goes to standby mode for the next cycle.

A sample is approximately 80 grams of mineral fertilizer. The use of linear vibrations provides an even distribution of the granules in the analysis area as a single layer. When the software receives ready signal from PLC and sends a command to the camera, it makes a set of digital pictures and sends them back to program. The software processes this data and calculates the fertilizer particle size. After that, data file is generated and sent to the Pi System, where it will be processed and represented in graphs.

But the AGS system can work as 2nd level system, and display measured data in operator's desks.

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Our next part is the practical implementation of the developed system

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In this slide you can see two implementation of AGS system: for conveyor belt and for closed pipe. You can say, that the point sampling system is not representative enough. However, granules are delivered to the sampling point after several transfer units. This is how the homogeneous granulometric composition of the entire product flow is achieved. In addition, the analysis every 7 minutes provides the necessary set of statistics.

The next feature is the self-diagnostics and response mechanism of the AGS. If an error occurs, the information is output to the SCADA, and the computer tries to fix the problem or goes into standby mode. In this way, it can be concluded that the designed system is a complete robotic control system.

Industrial testing of the described system was carried out from 12.2018 to 03.2020, as a result of which both systems were accepted by JSC "Apatit" for further operation.

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Furthermore, at stable running of the technological process the evaluation of statistical parameters of AGS, based on 1200 measurements, was made. The difference in granulometric composition between workshop 1 and 2 is caused by production methods and brands properties. In case of workshop No. 1, Diammonium Phosphate is produced according to the BGS scheme. It has a more well-established production mode and the fertilizer is obtained with a lower proportion of small fraction. In case of workshop No. 2 complex triple fertilizers (NPK 15-15-15) are produced according to AG-SB scheme. These fertilizers are characterized by a greater presence of small fraction and large variations of granules size in the production process.

In addition, 30 samples were taken after the AGS analysis and the data were compared with the Camsizer P4 optical device. The increased difference for the small fraction between 2nd and 1st workshops is due to the large amount of dust and the -1 mm fraction in granules. This fraction is determined by the robotic system poorer than the Camsizer because the resolution of the installed camera is not sufficient under production conditions (strong vibrations and large amounts of dust in the air).

In our opinion, the deviation with the Camsizer P4 can be reduced by further optimizing the mass of the injected sample and by damping vibrations in the analysis area. Although the obtained absolute deviations are quite large, the proposed analysis system provides visual control of the trend in mineral fertilizer production, which allows to rapidly monitor the quality of products. Thus, the system can be used as an indicator of the technological process, allowing employees to respond rapidly to changes in technology.

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The conclusion.

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Results of the work you can see in this slide. Features of the developed system include online analysis of granule size distribution, possibility of granule shape and color analysis, operation in production conditions and data transfer to the factory SCADA system every 7 minutes. The system has algorithms for self-diagnosis and response to external conditions. The statistical characteristics of the proposed robotic system (mean and standard deviation) for two types of production were studied as well.

The received results show the possibility of using the proposed system for determining the trend of industrial production and control of technological processes. The provided information on granulometric composition allows staff to quick response, which reduces the output of defective products.

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Thank you for the attention. I will gladly answer to any question.