For the start, let me apologize for my English. I understand it well, but unfortunately, I have very little conversation practice. So today, I will be sometimes using a cheat sheet. I ask you to be kind.

Good afternoon, dear colleagues! Today we will consider an important problem for the fertilizer industry – the online control of granule size or in other words – granulometric composition.

Slide 2

This slide shows the content of our work and some information about the speaker. Moreover, I am sincerely glad that I can report about problems of our production to you. **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.**

Slide 3

So, let us move on to the first point - mineral fertilizers and the role of particle size in this industry.

Slide 4

The mineral fertilizer production is a rapidly growing industry in Russia and the world. At the same time, there is a clear desire to use the basic principles of Industry 4 in it, such as decentralization of production and quality control. It is expressed in active develop of the automated detection and decision-making systems. Including the quality control procedure.

The one of the important parameters of mineral fertilizers is the particle size of granules and powders. In the literature it is often described that the particle size is responsible for the quality of the technological process, the quality of pellets, the agronomic effect and the quality of sample preparation for chemical and physical analyses. (**This parameter will be a key parameter in our work. The possibility of its online-automated control will be considered** – see in room).

Slide 5

(As I mention the purpose of this work is to **develop an online and automated method for the optical-electronic control of particle size)**. This is necessary because existing approaches have a number of drawbacks. (I would like to note that the described disadvantages do not allow implementing these methods in the automated industrial control of granular materials). For example, the sieve analyses can implement in production, but it will change the output distribution

of size and easily can block by big mass of granule. Moreover, out production give about 50 ton in hour for one technological system.

Thus, we think that the most perspective and informative method is the optoelectronic control. That's why we chose it and develop the special approach, which allows us to control granulometric composition and display this data in plant information system (PI System).

Slide 6

Let's consider more details of the proposed algorithm. It will allow us to take sample from the conveyer belt, analyse it and display the data in PI System.

Slide 7

First of all, let's consider the developed device. Mainly it consist from three parts: the rotary sampling system, the vibration surface for transport granule and the optical analysis unit. All this parts is controlled by built in computer.

The automatic rotary system take from conveyer belt about 80 gram of fertilizers in one point of the flow and transport it to the vibration surface were granule form the monolayer and place under the camera. Then, the 3 photo is taken, granule shape is calculated and after that sample is utilized.

The other specification is shown on the slide.

You can think that the point sampling system is not representative enough. However, granules are delivered to the sampling point (finished product conveyor) after several transfer units, which ensure the mixing of it. This is how the homogeneous granulometric composition of the entire product flow is achieved. In addition, the analysis every 5 minutes provides the necessary set of statistics.

Slide 8

In the next slide, we can see the main stages of the developed algorithm. I would like to note, that we use the Gaussian filter for smoothing the image because of its sufficient speed and good noises removal. Furthermore, the image was binarize with adaptive algorithm. Finally, counters was determined by the open cv findCountours function (with topological structural analysis of digitized binary images). This is the main object for calculation; from it, we calculate size, colour and shape.

There are a lot configurable parameters for described algorithms. You can find it in the python documentation for this function. Some of it we have been searching with a grid search in python. The other one, like morphology and

erode parameters we've been searching based on visual effects of counters determination.

Slide 9

With the described approach, we received a lot of information. Let's take a look at it.

Slide 10

In this slide, you can see the comparison between proposed system and other laboratory methods of control. I need to mention that for that comparison our method work in laboratory condition too. We use only the optical block of analyses, calibrated to the mass of fraction.

The quite high absolute deviation between all methods is caused because of two factors: difference in measure principals, and the irregular shape of granules. For example, in sieve analyses is used the control of the mass of fraction, but in optical control is used the calibration, which is based on the real size of granules. Besides, particles have the irregular shape (not smooth and not spherical). This causes various random and systematic errors for different methods. Although the absolute deviation is quite high, the proposed system of analysis provides express visual control of the trend of mineral fertilizers production, which allows us to monitor the quality of products in real time.

In the other plots you can see compare with camsizer. In this case our system work in industrial condition and after analyses 80 g of granule it analyze in camsizer in laboratory condition. In addition, the other plot represent the trend of granulometric composition in plant information system.

Some other information you can see here. I would like to add, that the relative standard deviation in the results of the analysis of the proposed method in production conditions does not exceed 7%.

Slide 11

With the use of PISystem data for 3 months, we analyze correlations of granulometric composition with other parameters of mineral fertilizers production. The map of linear correlations for the fraction of particles size less than 2 mm and 2-5 mm, the average diameter of particles and the number of production parameters you can see here.

As you can mention, all industrial parameters are highly correlated. This is a natural effect, as all the stages within the production process are linked to each

other. Received data allow us to conclude that the proposed method provides relevant information, which is related to the general production technology.

However, the trick is that due to the specifics of production it is extremely difficult to control the target parameter (granulometric composition) according to the other parameters considered (for example, the operation of crushers and raw material consumption). The size of granules is affected by a number of other parameters not controlled by the PISystem (temperature and flow of drying gas, mass and size of granules, which is returned to production, etc.). However, with knowing the granulometric composition the other unknown parameters can be control (this is the inverse control scheme).

Moreover, since it is the granulometric composition that is the target quality indicator in fertilizer industry, the other parameters can be selected based on it requirement. Thus, knowing the size of particles, the better control scheme with saving of raw materials and energy resources of the plant can be achieved.

Slide 12

In this way, we can draw the following conclusions, which listed on the next slide.

Slide 13

(Pause at 1 minute). As I mentioned before, due to the established interrelationships it will be possible to save resources and energy consumption of the plant. In addition, the difference between proposed automated online control and laboratory methods of sieve and optical analysis does not exceed 20%.

The obtained results indicate the possibility of using the proposed system to determine the trend of industrial production. The information provided on the granulometric composition allows quick response of the worker's needs, which can reduces the output of defective products.

I would like to point out that the views expressed in this work are those of the author and do not necessarily represent those of "PhosAgro" corporation.

Slide 14

Thank you for your attention. I will be happy to answer any questions.

Possible question

1. What does your company do?

I am the researcher's group leader in "PhosAgro" corporation and the lecturer in the Cherepovets State University. We are looking for new quality parameters and we are trying to automate the industrial quality control. Recently, I have developed and implemented a device for optical automatic control of granulometric composition.

2. Why not use existing particle size determination methods?

Unfortunately, they are expensive and do not work well in the production environment.

3. What are the reasons for the restrictions in the resolution?

Granule border must be clearly visible in the image, so that we can precise calculate the counters.

4. Why did you choose that or those?

Our research is the applied work. We have used a set of approaches that give good results and allow us to carry out qualitative analyses. Of course, in the future we have carried out a more complete review of the possible methods.

5. Why did you use Pearson's classification?

It allows us to estimate a rough approximation of linked features.

6. Is your approach really new?

Yes, we have not found any literature on the use of these methods to work in this way in mineral fertilizers industry.