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SYSTEM FOR ANALYZING THE QUALITATIVE CHARACTERISTICS OF GRAIN MIXES IN REAL TIME MODE

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Abstract. During the implementation of scientific research on the direction of automation of feed mills there was a significant disadvantage. The losses resulting from this shortcoming are, according to our estimates, about 1.2 billion hryvnias per year only within the framework of Ukraine. The disadvantage is connected with the current system of techno-chemical control. The presence of significant delays in the channel analysis of qualitative characteristics leads to the loss of the possibility of using the information obtained in the work of the automatic control system. The developed system of automatic samplers allows to minimize the time for obtaining actual data on the qualitative characteristics of grain mixtures directly during their processing and accordingly expands the possibilities of automation of these processes. Existing systems of analysis of grain characteristics in real time, i.e. directly during the process of processing, are quite costly, which greatly complicates the possibility of constructing an expanded system for analyzing the quality of raw materials at all stages of production. In addition, the integration of these analyzers requires the production of serial installation work on the production line, and accordingly requires for the installation of a temporary stop of production. The installation of stationary multispectral analyzers requires the presence and, accordingly, further maintenance of a full-fledged laboratory. However, the essential disadvantage in this case is the lack of relevance of the data. Thus, when using stationary multispectral analyzers, the data obtained only records the logs and in no way are used by systems of automatic process control at the enterprise. In a sublunary manner, analyzers have been tightened due to the separation of two different processes in principle, which are to be in the multispectral analysis, namely, the process of removing the multispectral sweep and analyzing the resulting scan with the aim of determining specific quality characteristics of the grain mixtures. Thus, in some devices, the sweep is taking place, and their analysis is already taking place in a single multispectral analyzer, which in turn is connected to cloud technologies.

Key words: automatic control system, samplers, grain mixtures, multispectral analysis.

СИСТЕМА ДЛЯ АНАЛІЗУ ЯКІСНИХ ХАРАКТЕРИСТИК ЗЕРНОВИХ СУМІШЕЙ В РЕЖИМІ РЕАЛЬНОГО ЧАСУ

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Анотація. Під час проведення наукових досліджень в напрямку автоматизації комбікормових заводів було виявлено істотний недолік. Збитки від цього недоліку, за нашими оцінками, становлять близько 1,2 млрд. грн. на рік лише в рамках України. Недолік пов'язаний з існуючою системою технохімічного контролю. Наявність значних затримок в каналі аналізу якісних характеристик призводить до втрати можливості використання інформації, отриманої в роботі системи автоматичного управління. Розроблено систему автоматичних пробовідбірників, яка дозволяє мінімізувати час отримання актуальних даних про якісні характеристики зернових сумішей безпосередньо під час їхньої обробки і, відповідно, розширює можливості автоматизації цих процесів. Існуючі системи аналізу характеристики зерна в режимі реального часу, тобто безпосередньо в процесі обробки, є досить високовартісними, що значно ускладнює можливість побудови розширеної системи для аналізу якості сировини на всіх стадіях виробництва. Крім того, інтеграція цих аналізаторів вимагає проведення серійних монтажних робіт на виробничій лінії та вимагає організації тимчасової зупинки виробництва. Установка стаціонарних багатоспектральних аналізаторів вимагає наявності і, відповідно, подальшого обслуговування повноцінної лабораторії. Суттєвим недоліком у цьому випадку є відсутність релевантності даних. Таким чином, при використанні стаціонарних мультиспектральних аналізаторів, отримані дані тільки реєструють журнали і жодним чином не використовуються системами автоматичного управління процесами на підприємстві. Розроблено систему автоматичних пробовідбірників, що дозволяє звести до мінімуму час на отримання актуальних даних щодо якісних характеристик зерносумішей безпосередньо в ході їхньої переробки і ,відповідно, розширює можливості автоматизації зазначених процесів. Процес аналізу аналізатором було розділено на два принципово різні процеси, які від самого початку були в мультиспектральному аналізаторі, а саме, на процес отримання мультиспектральної розгортки та аналізу результатів сканування з метою подальшого визначення конкретних якісних характеристик зернових сумішей. Таким чином, в одних пристроях визначається розгортка, а їхній аналіз вже виконується в інших мультиспектральних аналізаторах, які, в свою чергу, підключені до хмар.

Ключові слова: система автоматичного управління, пробовідбірники, зерносуміші, мультиспектральний аналіз.

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Introduction. Formulation of the problem

During the implementation of scientific research on the direction of automation of feed mills there was a significant disadvantage. The losses resulting from this shortcoming are, according to our estimates, about 1.2 billion UAH per year only within the framework of Ukraine. The disadvantage is connected with the current system of techno-chemical control. Today, almost all feed mills in the World in general and in Ukraine, directly sampling raw materials in the flow is carried out manually. As noted earlier, the laboratory of each company from each machine, which intends to enter the territory of the enterprise automatic cranes-samplers in different places of the body takes at least 4 samples with a total weight of 3–4 kg. If the car is equipped with a trailer – similar 4 samples are taken in addition to the trailer. Nominally specified tests are taken for the basic determination of two indicators: contamination and moisture. As a result of the determination of moisture, the refusal to enter is unlikely, an order for additional drying may be issued. In case of positive analysis, the car is denied entry to the territory. Further from samples of cars that have already stopped further determine the basic indices for crops: nature, garbage impurity, grain admixture and so on.

Analysis of recent research and publications

As we know, in the processing of seeds of cereals and oilseeds, there is a sufficiently large number of technological operations, such as cleaning, drying, shell destruction, calibration, etc. When performing these operations, the grain mass comes into contact with the working organs of the technological equipment. At the same time, there is a certain effect on the quality of the seeds, in addition to the main, provided by one or another process. One of these processes is the drying of raw materials, the passage of which also has a side effect on products, for example, the burning of the nucleus with the fuzzy regulation of the temperature of the coolant, the destruction of the nucleus due to the impact of seeds on the construction of dryers, the coagulation of proteins when the temperature of the grain mass exceeds 65°C, and others [1-8].

To determine the concentration of any component by the chemical method, it is first isolated from the sample, and then its quantity is measured. The procedure for isolating a component from a sample is usually time consuming. For example, the release of fat from sunflower seeds is performed during the day. Quantitative analysis does not take much time, but usually requires expensive equipment and reagents. The idea of the BIC (Bayesian information criterion) analysis method is to, without separating the components, to determine the composition of the sample according to its spectrum. Different components of organic samples (proteins, fats, moisture, cellulose, etc.) selectively absorb light at different wavelengths, that is, they have unique spectra. The spectrum of a sample is the sum of the spectra of its constituent components and depends on the composition of the sample. If we find such dependence (it is called calibration), it is possible to determine the concentration of components from the spectrum of an unknown sample. Moreover, it is possible to simultaneously determine the concentration of several components and the properties of the sample. The spectrum of the sample is conveniently measured in the near infrared (NIR) region, hence the name of the method. In NIR spectroscopy, both quantitative and qualitative calibrations can be developed [9]. In addition, similar methods are also used for multispectral image analysis of green plants to identify stress conditions [10-17].

During the production of fodder, the laboratory staff every 2 hours independently, or extraordinary time at the request of the head of the shop, take samples to determine such quality indicators as humidity, size, salt content, fat content (for oilseeds), protein content, cellulose content, separate for already granulated feed, content of fine fraction, the fragility of the granules.

At the same time, firstly, the results of all these analyzes are performed locally, which necessitates the presence of specialized laboratories with appropriate specialists and equipped with superficial equipment as a multispectral analyzer at each enterprise, and second, the significance of the above parameters of the quality of feed at different stages of its production simply fixed to a paper journal and, accordingly, can't be further used by the system of automatic control of feed mixed production processes. This entails a significant problem – the irrelevance of certain data. Given that it is about modernization of automatic control systems for large feed mills with a productivity of more than 30 tons/hour, the discreteness of obtaining data on the progress of the technological process in 3 hours significantly increases the risk of poor quality products production, or in general, the risk of an emergency stop of the line. It is important to note that the simplicity as a result of an emergency stop of only one line leads to losses amounting to about 4 million UAH (30 tons/hour*24 hours *5600 UAH per ton). We decided to improve this node by automating and fully reorganizing the sampling process by installing autonomous samplers.

The purpose of work. To develop a system of automatic samplers for the analysis of quality characteristics of grain mixtures was created at all stages of its production – G.MIAN (Grain Mix Analyzer).

Research objectives.

1. Investigate the work of existing streaming;
2. To prove the possibility of separating the process of multispectral analysis into 2 fundamentally different processes: the process of obtaining a multispectral sweep and the process of analyzing the sweep to determine the qualitative characteristics of the biopolymer;
3. To develop a stream analyzer capable of performing multispectral sweep and transmit it to the distance as information.

Research materials and methods

Initially, the samplers of the system were planned as standalone devices capable of transmitting to the cloud data ready for such qualitative characteristics as the fragility of the granules, the content of fine fractions, moisture, the content of fat, protein and fiber. Later the concept of the system was changed: from the original concept of analysis of qualitative characteristics directly "on board" to the analysis of the infrared spectrum of the sample and the transfer of the photo itself to the cloud, where the stationary connected to the cloud, the multispectral analyzer already analyzes the frame by comparing it with its generated database. As a result of this change in the concept of the system managed to avoid over-the-counter and complicated process of calibration of the device. It was decided to implement samplers in the form factor of a standard sampler with a diameter of 50 mm. (Fig. 1 and Fig. 2 show the appearance and the internal structure of the sampler).

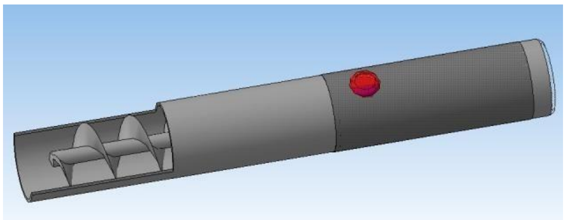

Fig. 1. Appearance of external rendering of G.MIAN sampler device

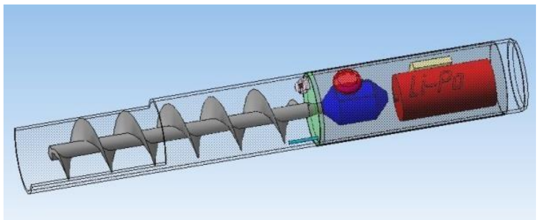

Fig. 2. Appearance of rendering inside the G.MIAN system sampler

Onboard each sampler of the system, the location of such components of the equipment as: IR analyzer (camera capable of taking a shot of a selected portion of raw material in the infrared spectrum); lithium polymer battery; screw for sampling and returning from the flow after analysis; step electric motor, which causes the screw to travel; connection module for the sampler with the Internet.

The analyzers of the developed system are easily integrated into various modern machines and feed production lines due to the full compliance with the form factor of widely used blades for sampling for further analysis in laboratory conditions. Integration of the system eliminates the need for a temporary time lag and, as a rule, significant funds necessary to rebuild the existing production line. To check results of samplers work we used DA7300.

DA7300 – its in-line infrared express analyzer DA 7300 is a modern tool for analyzing products in the milling, grain, feed and other industries. DA 7300 is mounted directly into various closed-type production lines (pipelines, channels, bins, mixers, etc.) and continuously, in real time, analyzes information about the properties of the product. This fully automates the process of quality control and allows you to respond in a timely manner to all changes in the quality of the product directly in the production process. The software of the device allows realizing a large number of possibilities for perceiving information in the form of digital results, reports and graphs. By setting the maximum limits of the required product specification values, you can visually observe on the chart all changes in product parameters, as well as ensure the consistency of the recipe by setting allowable limits for monitored indicators. DA 7300 connects to a personal computer with minimal system requirements, on the monitor of which all information on measurement results is displayed.

Below are some photos (Fig. 3, Fig. 4, Fig. 5 and Fig. 6) of the assembly stages of the MVP (minimum viable product) system. Of the world's counterparts streaming measurement of qualitative characteristics of biopolymers is extremely expensive (more than 80 thousand. Euros) and provide for the integration of significant changes in the equipment because they have a full sense of "embed" in the process. A significant decrease in linear dimensions and cheaper analyzers was achieved by separating the structure multispectral analyzer on its two principal components: a picture in the infrared spectrum using filters and image analysis in terms of the finished matches with the database analyzer.

To confirm the possibility of separating the process of multispectral analysis into two fundamentally different processes, experiments with a DA7300 (Perten) stream analyzer based on no moving parts were carried out, and the multispectral scan obtained on board is analyzed with a full-fledged computer, which is also located on board. To conduct the experiment in the laboratory, a special stand was built. The DA 7300 is an in-line NIR instrument that provides users with results in an industry standard communications interface. The data may be displayed either on a computer with interface software installed or may even be integrated fully into existing quality control and assurance systems. The DA 7300 was specifically designed for measurement to occur within a chamber or vessel. The optical device extends through the wall of the chamber, where the product to be analyzed is presented. This design promotes usage with powders, grains, granules, pellets and similar such products as they are conveyed. Diode array technology is exclusive within the sense that it does not use any moving elements within the prism spectroscope. This greatly improves the soundness of the instrument as there aren't any elements that may be exhausted or misaligned. The result's associate instrument which needs abundant less maintenance than once moving elements square measure used, as an example is that the case with scanning monochromators. A lamp illuminates the sample with white light. a portion of the light is absorbed (depending on the composition of the sample) and also the rest is mirrored. The light that is mirrored hits a stationary grating, that separates the light by wavelength. Rather than white light, we get a "rainbow". Each wavelength is measured by a dedicated detector [18].

Fig. 3. Appearance of the G.MIAN system sampler device

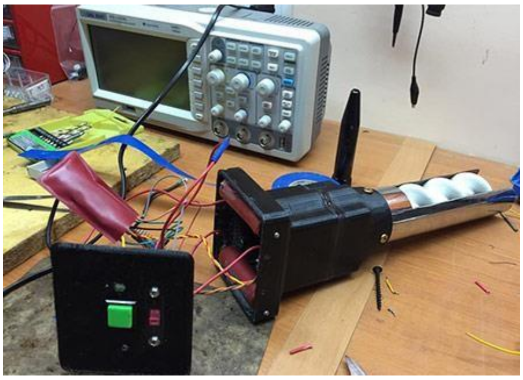

Fig. 4. Assembling the MVP system of G.MIAN

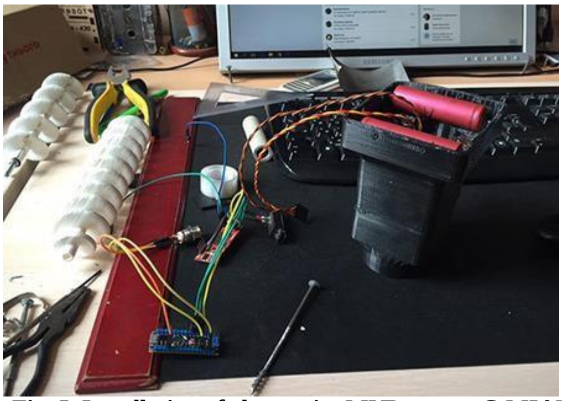

Fig. 5. Installation of electronics MVP system G.MIAN

a) **b)**

Fig. 6. The process of assembling a laboratory stand for the experiment: a) assembly stage; b) finished stand during research

Results of the research and their discussion

In accordance with the plan of experiments, wheat and barley grains were analyzed in real time. The data obtained during the experiments turned out to be relevant in humidity and absolutely irrelevant in terms of the content of gluten and protein in the composition. The irrelevance of the last two indicators was evident due to the lack of calibration files corresponding to the working environments that were used during the experiment. Nevertheless, experiments confirmed the possibility of separating the processes of obtaining a multispectral sweep and the process of its further analysis (Fig. 7-10).

According to the analysis of each of the working environments, the sample was 30 measurements. However, each of the measurements was made by manual start. In automatic mode, the analyzer makes about 100 measurements every second.

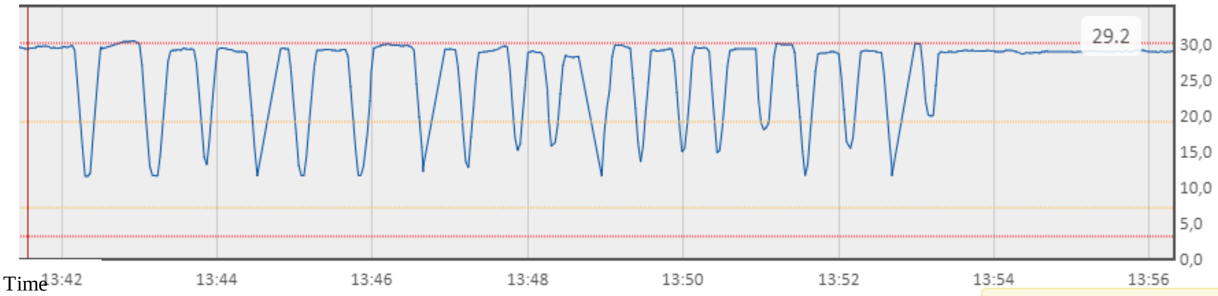

Fig. 7. Wheat grain moisture measurement process

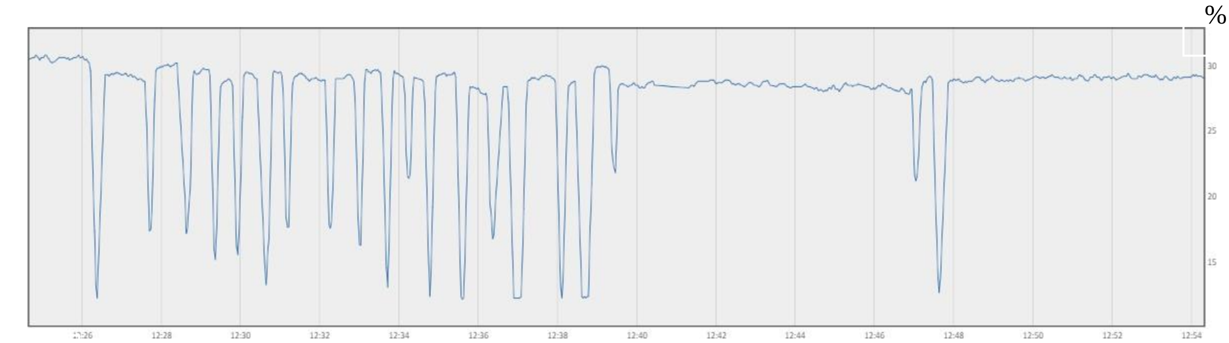

Fig. 8. Barley grain moisture measurement process

14:00:05

Batch Report

Perten INSTRUMENTS a PerkinElmer company

Product	Wheat 2
Started	14.12.2018 13:43:41
Ended	14.12.2018 13:59:50

Parameter	Average	SD	Min	Max	Range	Lab
Protein AsIs	-25,05	13,02	-34,5	12,4	46,9	
Gluten AsIs	-103,96	46,38	-137,3	28	165,3	
Moisture	26,28	5,23	11,4	30	18,6	

Fig. 9. Wheat grain moisture measurement report

13:17:48

Batch Report

Perten INSTRUMENTS a PerkinElmer company

Product	Wheat
Started	14.12.2018 12:56:37
Ended	---

Parameter	Average	SD	Min	Max	Range	Lab
Protein AsIs	-32,23	0,41	-33,2	-31,5	1,7	
Gluten AsIs	-125,24	2,54	-129,6	-119,9	9,7	
Moisture	29,14	0,23	28,6	29,9	1,2	

Fig. 10. Barley grain moisture measurement report

The technology architecture is based on the cyclical integration of the sampler system into the flow of technological processes. Embedded directly into the process through unified holes in the equipment, originally designed for visual inspection of the process by the personnel of the enterprise, a system of samplers with a given discretion over time performs sampling, its further analysis (taking pictures in the infrared spectrum) and transmits a photograph to the cloud computing. In turn, a local multispectral analyzer is connected to the same cloud, which performs the analysis of photographs and already has certain values regarding specific indicators of the quality of feed at different stages of its production (Fig. 11).

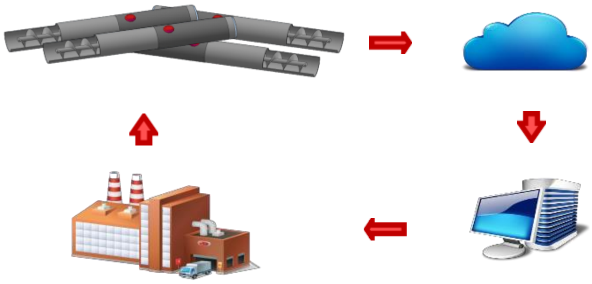

Fig. 11. Architecture G.MIAN technology scheme

The analysis of the multispectral analyzer itself performs quite quickly, and the latest models of known brands do not even require an appropriate preliminary grinding analysis. Considerable time is precisely sampling and transporting them to the appropriate laboratory. In addition, in order to carry out this operation, each plant was previously required to have a laboratory with a multispectral analyzer.

Already available for computing on a cloud the data on key indicators of quality of mixed fodder at different stages of its production are processed by special algorithms for revealing signs of destabilization of technological processes, which is additionally informed through the warning system by the appropriate personnel changes in the enterprise.

Analysis of existing similar solutions on the market indicates the presence of two classes of devices: local separate multispectral analyzers, which are installed directly on the laboratory of the enterprise and current analyzers, which analyze the samples in only a few positions of the criteria and embedded directly in the line of transportation of feed, or its raw materials, which in the last turn, causes significant changes in the equipment lines, and accordingly provide for their integration loss due to the forced stop of the lines. Detailed comparison of technologies is given below (Table 1):

Table 1 – Comparison of the developed system with its analogues

Criterion	G.MIAN	Competitors
Integration	5 min	≥ 7 days
Cost	1500 euro/month for manufacturing line	80000 euro/month for manufacturing line
Startup investments for implementation	1500 euro/month for manufacturing line	100000. euro/month for manufacturing line
Time for the necessary analysis	1 min	≥ 3 hours
The need for additional staff	No	Yes
Data analysis for the resilience of the process	Yes	No
Data analysis for the stability of the process	Yes	No

Conclusions

The above solution is a reflection of simultaneously two technologies of the industry 4.0, namely Internet of Things (IoT - each individual sampler is connected to the Internet and merges with it the necessary information) and Big Data, as the result of the computing cloud is the image of many data that in turn needs to be analyzed.

As we know, the modern Big Data solution consists of several blocks that require the joint work of teams with different competencies and the integration of the set of Open - and software components:

1. A technical solution for collecting, storing and processing large volumes of data marked on the schematic as Big Data Tools. This solution is usually based on the Hadoop stack, because it represents a good balance between cost, reliability and functionality;
2. Advanced analysis of data using data science (Data Science) and algorithms of machine learning;
3. Visualization of large data, as well as creation of interactive reports for management of the company, employees and clients (Business Intelligence). The analytical platform used must be compatible with the Hadoop stack.

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