DOI 10.22314/2073-7599-2018-12-3-4-11

Optimization of Technological Process Management in Plant Growing

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Abstract. At the current development stage of agricultural production, agricultural enterprises are faced with precedent pressure from the market. (*Research of purpose*) Optimize the control parameters of agricultural production by introducing the latest technologies, reducing costs and ensuring more efficient production management. (*Materials and methods*) The elaboration of a centralized unified automated information management system for mobile units and stationary processes incorporates the following components: Automation of the technological process with the possibility of locating every mobile machine, tractor, combiner harvester, any other vehicle, or fixed object in the field; Transferring integrated process parameters to the dispatch center server, transforming these parameters into a convenient form for technologists, agronomists, and managerial staff; Transferring control commands to adjust the process by its performers (operators). (*Results and discussion*) The authors have developed agricultural production systems of a new generation to ensure the productivity level of agrocenoses with high efficiency of invested funds and the use of landscape capacity. The basic prerequisite here is that the productivity of plants depends, first of all, on the soil content of mineral nutrients with their optimum ratio in each elementary field section, as well as a set of crop protection measures. (*Conclusions*) Increased production and cost reduction cannot be achieved without the introduction of the latest information-based automated control systems for production processes based on network technologies for gathering, collecting, analyzing relevant data and developing optimal management decisions. Especially important in agricultural production is the intensity rate of machinery utilization, as well as the line balance and consistency of manufacturing processes.

Keywords: means of automation, robotization and informatization, digital technologies, technological processes in field crop cultivation, agricultural machinery units.

For citation: Izmailov A.Yu., Lobachevsky Ya.P., Khoroshenkov V.K., Smirnov I.G., Goncharov N.T., Luzhnova Ye.S. Optimization of technological process management in plant growing. *Sel'skokhozyaystvennye mashiny i technologii*. 2018. 12(1): 3-9. DOI 10.22314/2073-7599-2018-12-3-4-11. (In Russian)

Agricultural production is characterized by a wide range of technological operations and technological tools to carry out field works [1]. To optimize production management, we should develop algorithms for a microprocessor multidimensional unified system that could be fully used, both on mobile devices and at stationary points for post-harvest processing and storage of agricultural products [2].

In the hardware and software packages, there is no difference in the maintenance of mobile or stationary objects. It all comes down to the processing of analogue, discrete or frequency information from the respective sensors, the transfer of control commands to the executing devices, and the transmission of integrated process indicators to the dispatch center server for further processing and archiving.

Research of purpose. The aim of the present research is to optimize the management of agricultural production by introducing the latest technologies, reducing costs and ensuring more efficient production management.

Materials and methods. The development of a centralized unified automated information system for controlling the work of mobile units and stationary processes includes the following aspects:

- automation of technological processs with linking the location of mobile units in the field, whether it is a machine-tractor unit, a combine harvester, a vehicle or a stationary object;
- transferring integrated technological parameters to the central office of the dispatch center, transforming these parameters into a form convenient for providing information to technologists, agronomists, or enterprise managements;
- passing control commands to adjust the process to actual performers.

Such system of control allows improving the organizational model of an enterprise, the structure of production and management units, the function of information processing, the development of managerial decisions, bringing them to performers, which ultimately

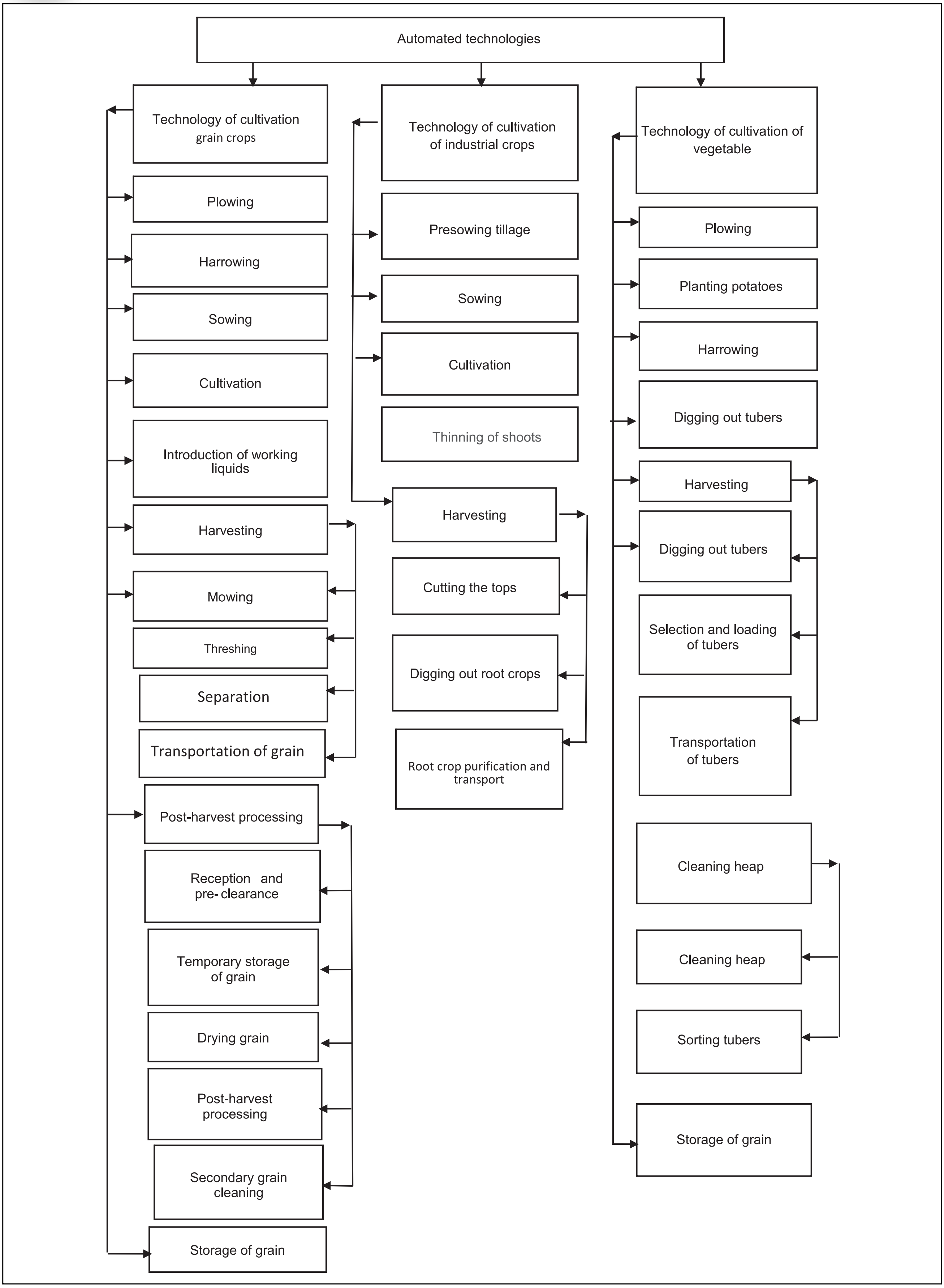

Fig. 1. Block diagram of automated technologies in plant growing

increases the efficiency of technological processes, through the line balance, optimal utilization of production capacity, rapid elimination of emergency situations with units, machines and individual processes that occur during the performance of technological operations.

Figure 1 presents a block diagram of automated technologies for the production of cereals, technical vegetable crops and potato.

At present, the requirements to the flexibility of production and to the promptness of making managerial decisions have sharply increased in the sphere of agricultural production, which in turn calls for the intellectualization and informatization of the management processes [3]. To this end, it is necessary to solve the following tasks:

- monitoring all technological processes of agricultural production;
- providing support for making managerial decisions based on mathematical modeling and the use of information and analytical systems;
- expert evaluation of decisions and their optimization.

Collection and analysis of incoming information about all technological processes of agricultural production in real time, identifying bottlenecks of production, emergency situations, unproductive outages of equipment and mobile facilities should be based on the use of digital technologies, mechatronics, the development of optimal algorithms for high-speed information flows and their mathematical support with taking into account the rapidly developing microprocessor means [4].

The system hardware and software of modern automated systems provide conditions for solving a wide variety of problems - organizational, technical, financial, psychological, including economic ones, and provide prompt and reliable information on the production status necessary for automatic generation of key indicators and adoption of optimal managerial decisions. The hardware and software produced by industry and foreign firms for automation systems include:

- programmable controllers;
- integrated management systems;
- distributed input-output stations;
- modular software;
- devices and systems of the man-machine interface;
- components of different communication;
- web-technologies;
- continuous process control systems;
- drive regulation and control systems;
- systems of so-called machine vision.

In this respect, the development of mathematical models and algorithmic support adequately reflecting such technological processes as soil cultivation, sowing, fertilizing, harvesting, post-harvest processing and storage of agricultural products is extremely important [5].

The application of a mathematical apparatus in solving the problem of optimizing the control system of agricultural production leads to finding the extremum of the target functional according to the given criterion of the entire enterprise efficiency.

The use of artificial intelligence in the control system allows to proceed to the controlling of the object (soil, plant, machine, technology) not by deviating one of the parameters or a group of parameters from the accepted norm, but in accordance with the function of the control object assignment and the constraints imposed by environmental requirements, the seasonal nature of work, and the impact characteristics of external factors [6, 7].

Together with the database (DB) obtained from a variety of sources of various systems, information is accumulated and consolidated in a single data storage, thus making an integrated information environment for solving a wide range of tasks, including the calculation of key indicators that are necessary for the analysis of production and technological situations.

Complex system analysis of production and technological situations in agricultural production includes:

- defining information requirements of users, that is, identifying the form, in which information should be provided to agronomists, livestock specialists, engineers, mechanics, and operators.
- determination of unknown factors influencing the production process;
- development of recommendations for the optimal management of production processors and the elimination of equipment downtime;
- visualization of the analysis results of economic activities of agricultural enterprises, preparation of reports on production and sales of products.

Integrated automated information management system for all technological processes in agricultural production should solve the following tasks:

- input of technological data during field works, in post-harvest processing and storage of agricultural products;
- transfer of technological data to the production and dispatch service, as well as their collection and storage in a centralized database;
- transfer of control commands from the higher levels of the common control system to the lower level;
- archiving data on all indicators in a general access format;
- generating reports and summaries.

Information coordination of technological and technical means ensures the maximum utilization of power and transport vehicles, as well as general purpose vehicles.

To solve such a problem, it is necessary to develop and create a database consisting of the following sections and subsystems:

1. *Regulatory reference and infrastructure subsystem* (an administrative unit implying the maintenance of regulatory information on):

- certification of fields in a digitized form;
- crops, including different varieties, stages of their development (life cycle) and optimal terms;
- crop rotation;
- types of fertilizers and plant protection products;
- types of soils;
- the infrastructure of a farm enterprise: departments, roads, permanent storage facilities, fuel depositaries, machine fleets, repair shops, rational paths connecting pairs of objects;
- types of tractors, vehicles, combine harvesters, forklifts, mounted implements, according to the maintenance regulations;
- field works and operations, as well as certification of fields in a digital form.

2. *Subsystem for collecting primary information about the control object* (system administrator, dispatcher) collecting and processing primary information:

- automatically taken from the sensors of mobile objects;
- taken from the control object manually;
- obtained by analysis of samples and equipment;
- urgent delivery of messages about unforeseen events to decision-makers (automatic delivery to dispatchers and company management).

3) *The subsystem of planning crop production works and the corresponding resource support* (planners-agronomists, mechanics, supply engineers) – planning:

- use of fields for farm produce growing;
- annual implementation of the plan for agricultural work for each field and all stages of the field campaign;
- the use of operations to carry out field works for each field and all stages of the field campaign;
- needs for machine resources for the performance of agricultural works with a breakdown by machine type and the timing of their involvement;
- need for fertilizers, plant protection means, fuels and lubricants, the timing of their purchase and transportation to storage facilities;
- evaluation of the required amounts of the utilization of internal machine resources, seeds, fertilizers, plant protection means, fuel for seeding, cultivation of crops, and harvesting;
- drawing up of the operative executive plan of the performance of works with a specification by fields and taking account of planned operations;
- formation of orders for the use of equipment and invoices for obtaining seeds, fertilizers, plant protection means, fuel and lubricants, and spare parts;
- adjustment of the executive plan for the performance of works (taking into account information on the state of soils, crops, the amounts of work performed) for the field in the conditions of the sowing campaign;
- a set of tasks for planning the transportation of crops.

4. *The subsystem of operational dispatch control of the performance of works and operations of crop production and the corresponding resource support* (dispatchers-agronomists):

- monitoring the quality of agricultural operations and their implementation;
- development of options for solutions (reactions) to unforeseen events (including the adjustment of the executive plan).

5) *Subsystem for assessing the state of control objects:*

- soil;
- crops in the field;
- the scope of work, including the field ones, as well as those on the restoration of resources;
- current resources (fertilizers, seeds, plant protection means, fuel and lubricants, equipment, free space of storage facilities, and personnel);
- losses incurred during the storage of agricultural products;
- technical base of stationary objects.

The principles of control and management of a multidimensional unified automated system include methods for assessing the status of the technological process as an object of control and management, deciding on the compliance of this management practice with the established requirements.

The implementation of these principles requires the elaboration of control and management algorithms. Such algorithms should be based on the dependencies connecting the statistics of the performance indicators of technological processes with tolerances and probabilities of their keeping or exceeding [8].

Agricultural units and their complexes operate under conditions of varying external influences [9].

The main types of them, in addition to climatic factors, include physical and mechanical properties of soil (moisture, density, granulometric composition); relief, road conditions, which determine the energy costs for unit movement and soil cultivation; properties of plants (yield, etc.), affecting the energy costs and quality of the machines; change in the unit mass and its technical state during the performance of a technological process.

The functioning of the unit is usually considered as a reaction to input disturbance and control actions. Figure 2 shows a generalized structural diagram of a tillage implement, which is one of the objects of the field subdivision.

The mathematical model of an object of automatic control of the tractor engine load on the scheme includes the transfer functions on the control channel – $W_{U1}(p)$, $W_{U2}(p)$, $W_{U3}(p)$, $W_{U4}(p)$, along the perturbation channel – $W_{f1}(p)$, along the cross links inside the object – $W_{\Pi 1}(p)$,

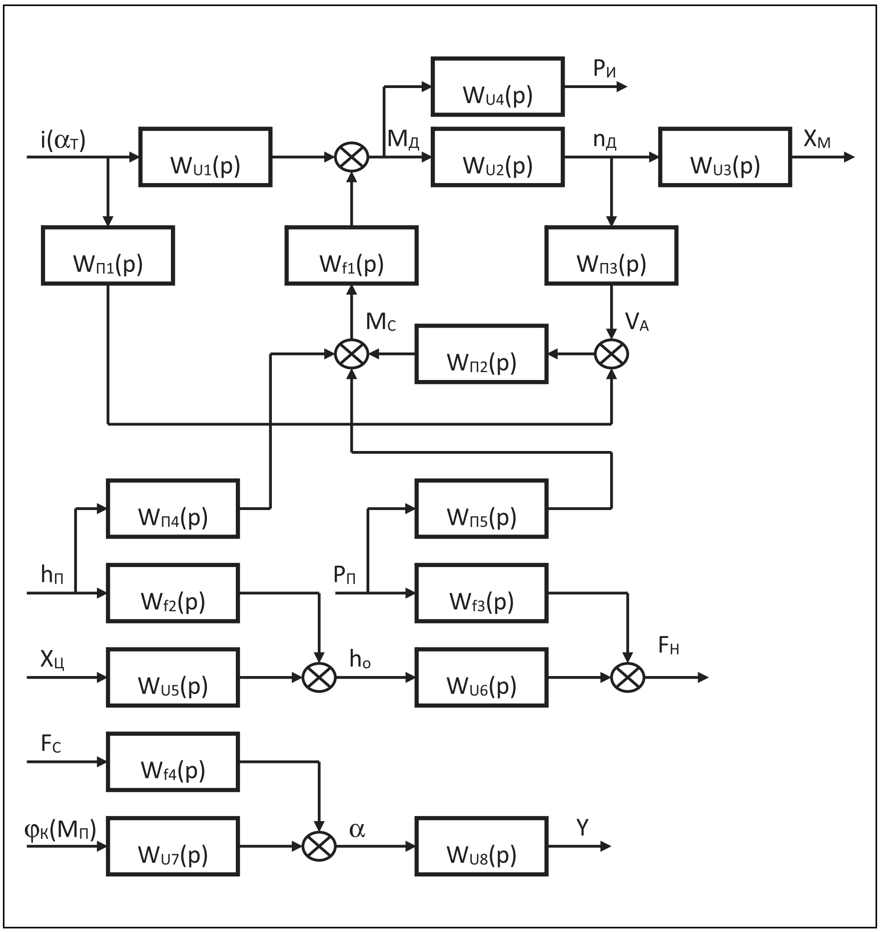

Fig. 2. Generalized structural scheme of ploughing MTA as a multidimensional object of automatic control

$W_{П2}$(p), $W_{П3}$(p), and between objects – $W_{П4}$(p) and $W_{П5}$(p).

The mathematical model of an object of automatic control of the soil tillage depth in the scheme includes the transfer functions along the control channel – W_{U5}(p), W_{U6}(p), along the perturbation channels – W_{f2}(p), W_{f3}(p), and cross links – $W_{П4}$(p), $W_{П5}$(p).

The mathematical model of an object of automatic driving of a machinery-and-tractor unit includes the transfer functions on the control channel – W_{U7}(p), W_{U8}(p) and the transfer function along the perturbation channel – W_{f4}(p), which are presented on the diagram.

The model of the unit functioning (control and automation of work) is represented in the form of a system, where the input is acted upon by the vector functions of the working conditions $X=[x_1(t), ..., x_n(t)]$, controls $U=[u_1(t), ..., u_m(t)]$ and the inner connections $\Phi = [\varphi_1(e), …, \varphi_l(t)]$. This means that there are n perturbing, m control and l internal influences on the unit.

Output variables form a vector k-dimensional function $Y=[y_1(t), ...,y_k(t)]$, which determines the technological, energy, operational and other performance indicators for given vectors X, U and F.

The number of components n, m , l and k vectors depends on the unit type and the consideration degree of working conditions [10].

For the operational control of the efficiency of technological process, determined by the implementation of $y(t)$ at a specific period T, it is necessary to continuously have information about the implementation of $y(t)$, to find the statistics of this implementation and compare it with the tolerances basing on the given values of the tolerance Δy and the probability $P_{\Delta 3}$.

Such an algorithm for monitoring the efficiency of a technological process is hard to implement, because in the process of monitoring, it is necessary to form the average value of the $y(t)$ implementation, with which the current value of the control parameter should be compared.

It is more expedient to use as a deviation base the deviation of the implementation ordinates not the average implementation value $y(t)$, but the adjusting (nominal) value y_n. With a given a tolerance $\Delta_{ун}$ to the deviation of $y(t)$, the indices from the tuning value of y_n, and the generalized estimate of $P_{\Delta н}$ are implemented quite simply, because the ordinate values of the $y(t)$ implementation are directly compared with y_n. For a certain period of monitoring T in the measuring unit, due to the mathematical expected of my, estimates are formed:

$$P^{+}_{\Delta н} = T^{+}_{\Delta н}/T;\ P^{-}_{\Delta н} = T^{-}_{\Delta н}/T;\ P_{\Delta н} = P^{+}_{\Delta н} + P^{-}_{\Delta н}$$

$P_{\Delta n}$ – where the overall estimate of the probability of finding the implementation $y(t)$ in the tolerance field.

An algorithm for outputting information during soil cultivation and other technological operations for sowing, the introduction of liquid complex fertilizers and use of plant protection means, for the operation of a mobile agricultural unit has also been developed.

Figure 3 shows the algorithm for controlling the grain cleaning machine.

Results and discussion. The new generation of farming systems that are currently developed aims at ensuring the level of productivity of agrocenoses with a high coefficient of efficiency of the invested funds and the use of the landscape capacity, while the productivity of plants depends, first of all, on the availability in soil of mineral nutrients in the optimum ratio at each elementary section of the cultivated field, as well as on plant protection measures [10-14].

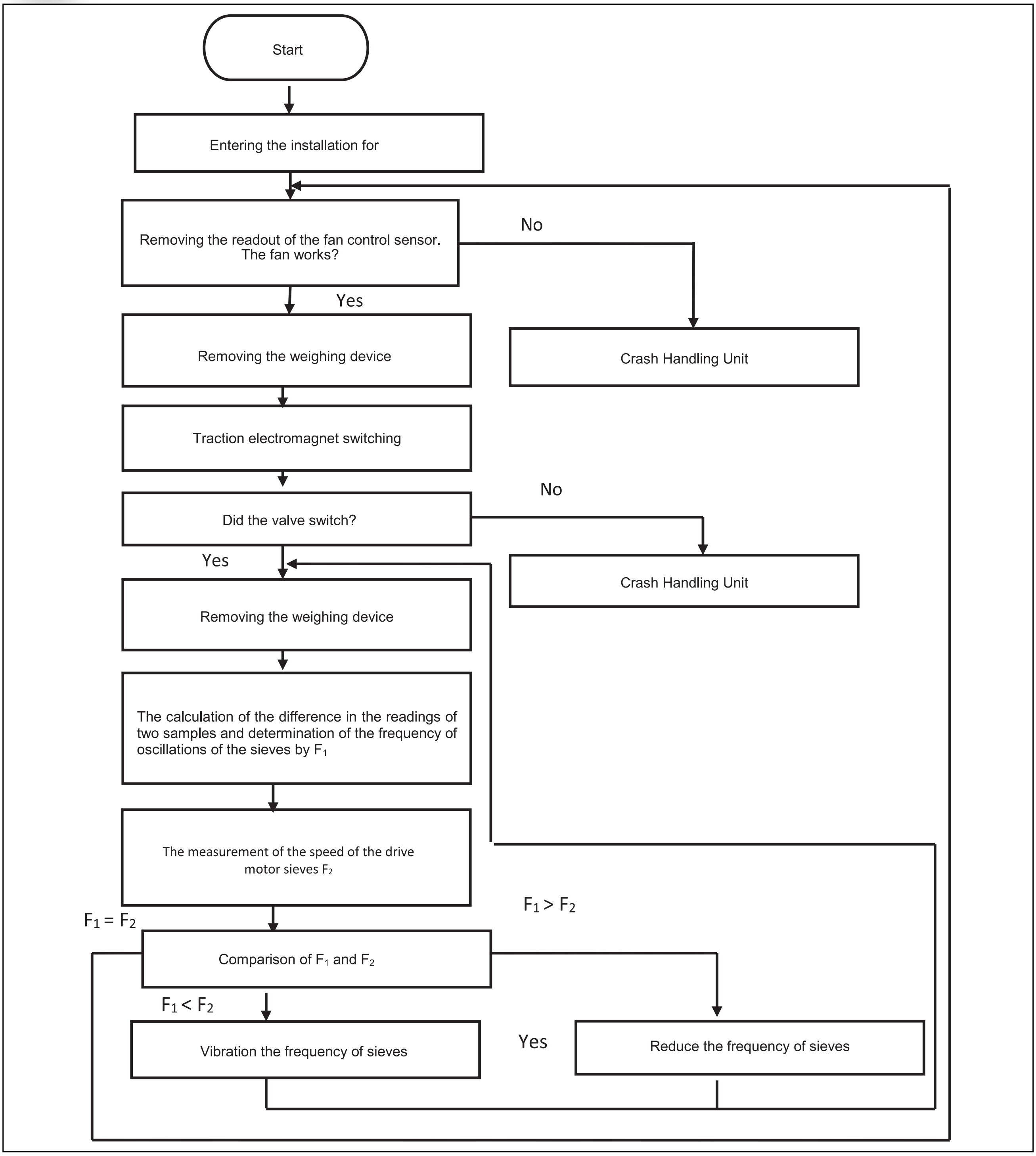

Fig. 3. Program algorithm for automatic control and regulation of a grain cleaning machine

Conclusions. Intensification of production and reduction of the farm produce cost cannot be introduced without the latest automated production information and control systems based on network technologies of data gathering, collecting, analyzing and developing optimal managerial solutions.

The emphasis on the quantitative analysis of the production situation allows to shift from logical-intuitive methods to a deeply formalized computer-assisted base in developing draft solutions.

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The paper was submitted to the Editorial Office on 03.04.2018 The paper was accepted for publication on 27.04.2018

Conflict of interest. The authors declare no conflict of interest.