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ENGINEERING MANAGEMENT OF MAINTENANCE DURING STORAGE OF COMBINE HARVESTERS

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Abstract

When designing combine harvesters primary mind always diverted performance issue and technical and economic indicators (maintainability, life cycle costs, etc.). However, the desire to achieve higher characteristics of samples of combine harvesters has led to the necessity of equipping them with sophisticated avionics system. As a result, the design of combine harvester is much more complicated, and the process of maintenance and repair necessitated additional work and increased cost of maintenance and repair. This was particularly noticeable for combine harvesters of new generation. Analysing the fleet of combine harvesters in Ukraine and the procedure for its exploitation we can state the fact that it is less reliable, and increasing labor costs for maintenance, increased downtime combines harvesters without their functional use, which reduced the indicators of their readiness to perform the assigned tasks. Was recognized the fact that the reliability and maintainability of combine harvesters should be attributed to the main characteristics, which depends on their readiness for safe use. A successful solution to the problem of maximizing the efficient use of all technical and running features of combine harvesters with their high willingness to use depends on how the organizational structure of services of technical inspection and forms of operation correspond to the level of its performance properties and degree of perfection of the means of its operation, that is, from the accepted system of maintenance and repair. All other factors are of subordinate importance, and also depend on the condition and quality operating equipment maintenance and repair. It is known that in the structure of expenses, which reduce profitability and increase the operating costs of combine harvesters, costs related to maintenance and repair 20-30%, ranking second only to fuel costs. And the critical funding situation, an invalid low condition of combine harvesters put forward a number of priority issues of development and improvement of the system of technical maintenance and repair. Efficiency of functioning of system of technical maintenance and repair significantly depends on the effectiveness of the subsystem of the combine harvesters. This puts a number of actual research tasks the task of assessing the impact of subsystem-recovery of complex technical systems on the effectiveness of the process of technical operation.

Key words:
analyse, organization, system, combine harvester, condition.

Introduction

In scientific literature the recovery process of complex technical systems has received little attention (Zagurskiy *et al.* 2018). This explains the relative small number of works devoted to the restoration of combine harvesters (Rogovskii *et al.* 2021a). Existing methods of techno-economic evaluation of the effectiveness of the process of technical operation of combine harvester's rehabilitation works of technical objects and their components are not separated (Novotny, 2016). They are considered part of the overall process of technical maintenance as one of the conditions of evolution of technical systems over time provided that the aggregate repairs and unlimited kit parts and materials (Rogovskii *et al.* 2019). This makes it impossible to assess the impact of the subsystem recovery process maintenance and repair (Palamarchuk *et al.* 2021).

Therefore, there is an actual scientific-technical problem consisting in the development of method of optimization of the recovery process of combine harvesters (Rogovskii *et al.* 2021c), the use of which provides a given level of technical reliability of combine harvesters (Titova, 2021) and minimum system costs of maintenance and repair (Nazarenko *et al.* 2021).

Formulation of problem

To determine the recovery subsystem let us consider the process of technical operation of combine harvesters (Rogovskii *et al.* 2021e), as a set of operations to control the technical condition of its functional elements (Viba *et al.* 2006) and of the work performed under the results of control (Kuzmich *et al.* 2021). In operation let us assume that the ship consists of the following main systems:

– body of the main part of combine harvesters, consisting of the impermeable sheathing (Rogovskii *et al.* 2021f);

– power setup consisting of the main engines (Sergejeva *et al.* 2018), which actuate engine (Rogovskii *et al.* 2021b), diesel generators (Yata *et al.* 2018), switchgear (Pinzi *et al.* 2016), auxiliary mechanisms and systems (Rogovskii *et al.* 2021d);

– propeller, three types devices intended for control of combine harvesters and ensure its operation (Rogovskii, 2020);

– systems to ensure operation of power plant and is designed to create normal conditions of use (Masek *et al.* 2017);

– radio navigation equipment (Dubbini *et al.* 2017);

– means of automation (Rogovskii *et al.* 2021j).

Naturally, the technical condition of the functional elements defines the technical condition of combine harvesters (Drga R *et al.* 2016.). In modern conditions a significant part of the objects of on-Board equipment of combine harvesters is operated to failure or state (Rogovskii *et al.* 2021g). The object that failed or the results of the technical inspection is recognized as faulty (Astashev *et al.* 2017), once replaced with serviceable exchange Fund and sent to repair on the recovery (Luo *et al.* 2013).

Consider the process of technical operation of combine harvesters, as a set of stages (levels) of maintenance and repair of objects of SK (Rogovskii *et al.* 2021h).

Purpose of research

The purpose of research is to increase the efficiency of the process of technical maintenance and repair of combine harvesters to provide required level of technical reliability of combine harvesters in modern conditions.

Research results and discussion

During the transition (first level) continuous monitoring of the state of SC consists of the identification of failures of functional systems (FS) agricultural machines and their most important elements (units, units), depending on the vessel type, using the built-in controls (GCS) or automated on-Board controls (BASC). The fault is at the level of structurally-replaceable units of a particular FS (unit, unit) during operational service.

At the second level (port of registry) during the operational types of preparations and regular maintenance, search failures is carried out using the GCS (BASC), control and test equipment (KPA) and ground-based automated control systems of the vessel (ACK1) the scope of the FS, which was denied. The Assembly refused and removed from the vessel and replaced with a serviceable exchange Fund port of registry.

The third level during the periodic maintenance of repair shops (RTS) operators the search of failures is carried out using the GCS (BASC), KPA and ACK1 within FS that was denied. Search the cracks within the aggregates, recognized as faulty and removed from the vessel according to the testing results of each of the levels is done using a special KPA (SKPA) and automated systems of control and diagnostics of dismantled equipment (ACK2). For this is a subunit, or the fee that refused are on the backup warehouse staff ZIP. Recycled aggregate is checked for serviceability and restores exchange Fund RTS of the operator. The unit cannot be restored under these conditions, is sent to shipyards (SRH).

The fourth level – factory level of service. This can be either the FSA or the enterprises of other ministries and departments. At this level of service turns out to be defective and is replaced by part of the node or Board Assembly is faulty. Recycled aggregate is checked for serviceability and sent to warehouses on supply.

General scheme of functioning of maintenance and repair of agricultural machinery is presented in Fig. 1.

Such a process view of maintenance and repair makes it possible to identify options for the organization of the recovery process on-board equipment of agricultural machinery (building subsystem recovery as part of maintenance and repair), as the possible combinations of phases of the control and recovery of the technical condition of objects of agricultural machinery.

In accordance with the representation of the process of technical operation of agricultural machinery, like combination of stages of maintenance and repair of objects of SK highlight possible directions the process of recovery of airborne equipment of agricultural machinery. In the General case, there exists a finite number of options for the organization of the recovery process, which is determined by:

– main requirements for the system technical maintenance and repair;

– parameters of the system adopted technical maintenance and repair;

– technical characteristics and composition of funds in-service inspection and repair, used to define the technical state and search of a place of failure, and set by the regulations of technical operation for each type of combine harvesters;

– existing repair network;

– accepted system of training engineers;

– adopted by the supply chain management of spare parts and materials to customer.

On this basis, the main directions of improving the system recovery that will ensure the smooth functioning of the repair network facilities for combine harvesters and will resolve the contradiction between the need of ensuring the required level of serviceability of combine harvesters and the existing system of tor are:

1. Reasonable structure of the repair network in Ukraine.

2. Improvement of resource-saving methods and modes of tor combine harvesters of the courts.

3. Improvement in the repair of agricultural machinery due to the expansion of the range of units that are being restored to operating conditions.

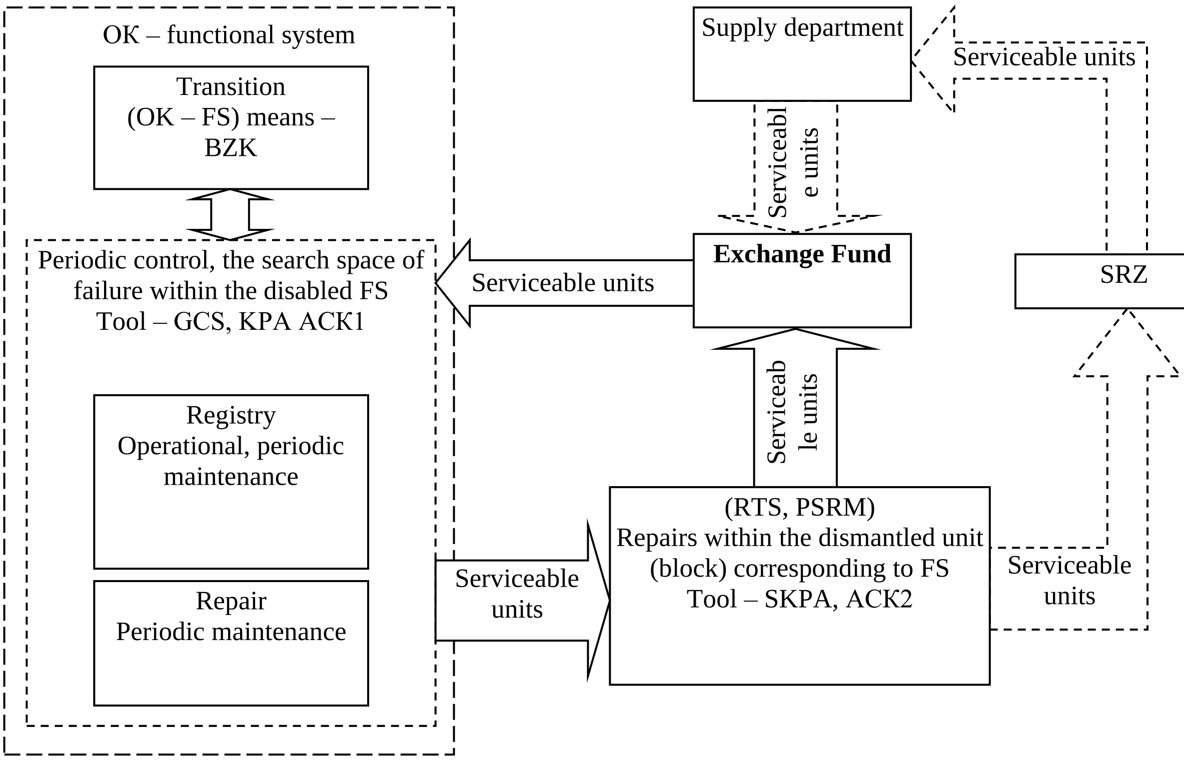

Figure 1. Structural-functional scheme of technical maintenance and repair of combine harvesters.

Table 1. Main variants of organization of system for recovery of complexes of combine harvesters

Embodiments of the recovery system for combine harvesters	Advantages	Disadvantages
1. Recovery of SK by replacing the COA without their further recovery.	Do not need technological equipment to restore the PPC.	Significant economic costs.
	The minimum recovery time, the maximum level of preparedness of the UK.	
	The lower level requirements of knowledge and skills.	
2. The restoration of COA to repair factories and enterprises.	Do not need technological equipment to restore the PPC to centre.	Significant recovery time units.
	Reduction of requirements to level of qualification of experts of RTS.	Simple IC in failed state.
3. The restoration of the COA forces and means of RTS.	Reduced downtime of agricultural machinery in an inoperable condition.	Needs a large number of costly bench and process equipment.
		Increase in number of specialists of high qualification in operator.
4. Repair KUO in the RC (regional databases of repair) using standard means of ground control or autocontrols dismantled equipment (ACK_2) (repair works as the exception).	The decrease in economic costs.	Development and production of systems such as ACK_2.
	Reducing recovery time units.	Need for sustainable building maintenance and repair taking into account requirements for effective functioning of SC and capabilities of system repair.
	Downtime IC in a failed state.	
	Reduction of requirements to professional level of specialists of engineering service (in case of introduction into operation ACK_2).	

Direction 1 provides a solution to a complex dynamic problem of locating repair companies, subject to park and locations of combine harvesters and organs of supply, opportunities strategy tor management of the technical state of agricultural machines, and the like.

Due to the fact that such a complex technical system as an agricultural machine combines a large set of structurally separate detachable units with different characteristics of reliability and maintainability (reliability, seriousness, accountability, technical maintainability), areas 2, 3 require research on:

– effectiveness of strategies tor for each type of the separate detachable units,

– extension to the special conditions of the volume of repair transactions (completeness of recovery),

– effectiveness of the means of the operational control and repair information as part of the process of control of technical state of agricultural machines and their impact on the efficiency of the recovery process of agricultural machines.

The analysis of possible directions of perfection of system restore allows you to define the basic variants of its organization. The main options for system recovery on-board equipment agricultural machinery dismantled in consequence of the refusal and qualitative assessment of the advantages and disadvantages of each of these options is given in Table 1.

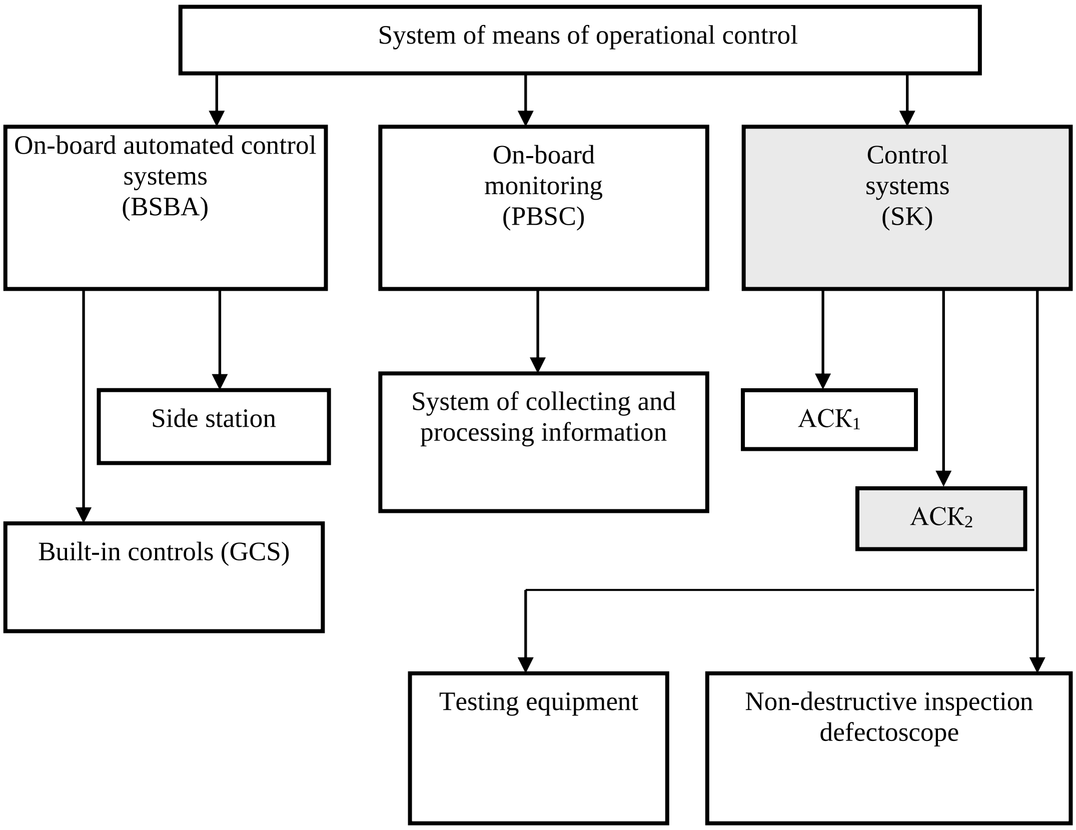

Figure 2. System of means of operational control of technical maintenance and repair of agricultural machinery.

Are given in Table 1 recovery options for the objects of agricultural machinery and their combinations determine the final number of variants of the organization of the recovery system.

As can be seen from Table 1, the most appropriate process is the recovery of the dismantled because of agricultural machinery in a fourth embodiment.

The advantage of which, compared with others, will depend on the share of on-Board equipment that is restored in the conditions of the operator. But it is necessary to solve a number of difficult theoretical and practical tasks such as:

1. During the development of new agricultural machines or upgrading those that are used by the operator:

– introduction to design of IC elements are high reliability, manufactured using new technologies and new materials, reducing the number of components, assemblies and parts in the system design,

– ensure high testability of the system with search capability of failure point with a precision of structurally-replaceable units

– accessibility to the main elements and units,

– the development of improved means of the on-Board control, display and localization of failures,

– reduction in the use of special control and test equipment, wide application of standard controls.

2. In the framework of the system of technical operation:

– reduction of the list and scope of work and repair, introduction to the practice of the method of operation as,

– reduction in the range, number and size of facilities,

– development or procurement of automated systems for monitoring and diagnosing the technical condition of the products SK.

As can be seen from the analysis information system is based on recovery of funds and operational control, which is used to solve the tasks of health checks of onboard equipment of agricultural machinery at the crossings, when performing operational tasks and preventive maintenance, the search space of failure during the repair of SK.

Currently for the control IC used in such tools:

– on-board automated controls (BASC),

– built-in controls (GCS) of the individual systems,

– automated control system of agricultural machines (ACK1),

– automated systems of monitoring of dismantled equipment (ACK2),

– onboard monitoring (PBSC),

– testing equipment (KPA).

In addition, in recent time received the intensive development of artificial intelligence system and as one of their areas of expert systems, which are widely implemented in real time.

The system of operational control means shown in Fig. 2. Onboard automated system of control is designed to control technical condition of onboard equipment at the crossings and at the port in preparation for the trip and also to detect the event of violation of operational constraints and error mechanics on transitions, display and documentation of inspection results.

BASK, depending on the implementation, in turn, are divided into internal and external.

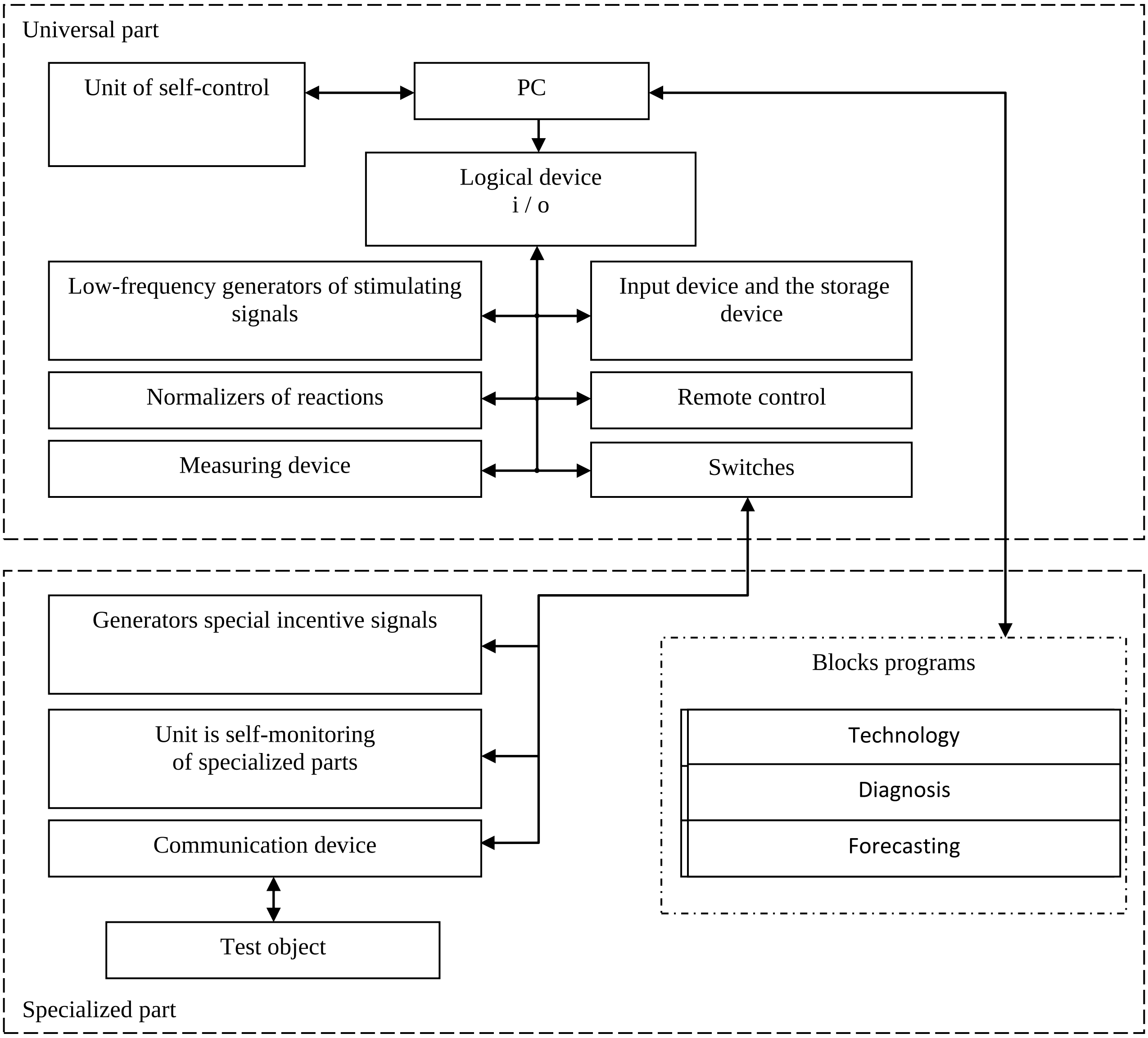

Figure 3. Simplified diagram of unified ACK_2.

GCS enhance the reliability of the fs and to provide the necessary level of security, automatic control of agricultural machinery at all stages of the transition. gcs work during the whole time of functioning and performed in the general construction of a control object. indication of failure, that issued the gcs is used by mechanics at the transitions for a decision about the possibility or impossibility of execution of the task.

Back constructively in a separate device. main tasks basc – implementation of operational control because of agricultural machinery in the transition, localization and liquidation of failure, the output of the vehicle because of the crew or a memory device which are equipped with external back.

PBSC are used to control and check the transitions of the parameters that characterize the technical condition of the main systems of agricultural machines, automatic interpretation and analysis of recorded information.

On the basis of the fixed information to solve problems: evaluation of TC systems that are monitored and forecasting of TS of the uk and recommendations for maintenance, analysis of the causes of events and monitoring of driving technique.

Automated control system used to control the technical state of the ic when performing maintenance and repair, preparation for navigation, troubleshooting, targeted and periodic inspections. depending on the level of interaction with the test object, they are divided into two groups: the ACP is not dismantled equipment (ACK_1) and ask dismantled equipment (ACK_2).

ACK_1 designed to determine the vehicle agricultural vehicles, their power plants because of localization of the ground fault in the coa. information about the vehicle controlled objects is issued at the expense of display and other media. used automated control system of dismantled equipment (ACK_1) for various forms of service because of agricultural machinery and are used in both stationary and mobile execution.

Disadvantages ACK_1 is insufficient depth inspections and detailed inspections of each unit node unit.

Modern controls type ACK2 belong to the class of multi-purpose information-measuring complexes, solving the problems of health monitoring, diagnosis, forecasting in the evaluation of the technical state of complex dynamic systems. designed for: block check, adjustment and adjustment for holding of rejection blocks when sending them for repair and testing after return from repair, the exact localization of the fault, as well as conducting preventive and routine maintenance. Wide possibilities of such systems are provided with application in their structure of computers (PC).

The advantage of ask the dismantled components: high control accuracy, high automation level, the localization of faults to a replaceable module, a relatively high throughput and objectivity of testing results, a full verification of the blocks using a list of monitored parameters, the ability to document testing results for the prediction tasks to reduce requirements for qualification of personnel.

Currently in development of means of control of complex dynamic systems there are such trends.

The desire to reduce cost on the one hand, and expansion of functional capabilities and effectiveness, on the other, leads to the emergence of the unified automated control systems. with high performance, these funds can control several types of control objects, which gives the opportunity to reduce controls.

Unified ACK2 consist of a universal part that includes those devices that are common when testing all types of control objects, and a specialized part, which includes the device, specific for each type of test object. in Fig. 3 shows a simplified scheme of the unified ACK2.

Separate the functions carried out by the specialized part may be transmitted to the universal part. for example, the computer is able to programmatically generate various types of special incentive signals. in this case there is no need to develop specific stimuli generator that is included in a dedicated part of the control system.

High flexibility of control systems, which can be achieved due to more complete use of possibilities of computers and application of the modular principle of construction. ACK2 are built from separate software and hardware functional units, combining which it is possible to get a new device. hardware modules are built on the basis of a unified device that gives you the opportunity to increase individual monitoring devices by connecting them with unified bonds that are subject to the exchange of information between the processor and other devices.

In addition, the emergence in recent years of a compact, yet super powerful computers allow to create a new control system of the type ACK2, which was characterized in comparison with existing:

– much less weight and size,

– reduction of time to prepare for use,

– detection capability 100% failure rate and in 95% of cases to identify the cause of failure of a block or node

– high methodological and instrumental accuracy control.

In the system of General technical requirements engineering specified some parameters of system operation monitoring and, above all, the indicators of the testability of the IC.

So completeness of control in the preparation $\eta_o^* = 0{,}95$ of the vessel for going to be the probability of failure taking into account the real characteristics of the controls (testing reliability) – $P \geq 0{,}85$ percentage error of marriage from all results is not suitable when control of the vessel is less than 20%, the ratio of the depth of search failure (the depth of diagnose) by means of monitoring and diagnosing, >0,9 the COA.

The results of a detailed analysis of the means of control in our country and abroad conducted by the author and the comparative characteristic of modern means of control courts and their foreign counterparts, showed a number of problematic trends that arise during their development and operation:

1. The GCS should be considered as one of the main elements of the onboard systems. Currently, developers can't provide in preparation for the transition given full control (95%):

$$\eta_o = m_{nk} / m_n ,$$

where: m_{nk} is the mathematical expectation of the number of controlled failures,

m_n – the expected total number of failures (damages) within the specified operating time.

Therefore, the level of fault, as a rule, is 50...80%, which leads to the problem of latent failures, which reduce the real level of safety of agricultural machinery.

2. Requirements for mobility and autonomy the use of agricultural machines, reduction of maintenance costs and level of qualification maintenance of the composition cause the necessity of increasing the depth of search failures to the level of the printed circuit Board element in their 100% localization:

$$\Gamma_{пв} = \lambda_{кв} / \lambda ,$$

where: $\lambda_{кв}$ – failure rate, which is controlled by the data means with a depth of structurally-replaceable units,

λ – the General failure rate of the test object.

On the other hand, increasing the fullness and depth of the on-board control leads to an increase in the weight of the equipment and the rising proportion of false rejections of up to 50% and above.

Conclusions

The versatility, integration, resiliency, structural and information redundancy of modern on-Board equipment allow to carry out the task if a fault is detected at the crossings, which increases the requirements for continuous monitoring and timely indication of failure. On the other hand, display transitions may cause the unwarranted termination of the execution of tasks in case of minor or false failures.

Negative experience of use in parts ACK_1 MK, and, on the other hand, high characteristics of the American system AFTA raises a number of questions concerning the choice of directions of improvement of ground controls (to change the strategy of using, modifying software to improve the indicators for test or modify the design).

For this group of contradictions requires the solution of complex theoretical and practical task in the design stages of SK, the directions 1, 2, 3, and validating requirements for airborne and ground control of a vessel, surface of ask of dismantled equipment, direction 4.

References

Astashev V., Krupenin V. 2017. Efficiency of vibration machines. Proceedings of 16th International Scientific Conference “Engineering for rural development”. Jelgava, Latvia, May 24-26, Latvia University of Agriculture. Faculty of Engineering, 16: 108-113.

Drga R., Janacova D., Charvatova H. 2016. Simulation of the PIR detector active function. Proceedings of 20th International conference on Circuits, Systems, Communications and Computers (CSCC 2016), July 14-17, 2016, E D P Sciences, 17 Ave Du Hoggar Parc D Activites Coutaboeuf Bp 112, F-91944 Cedex A, France, 76, UNSP 04036.

Dubbini M., Pezzuolo A., De Giglio M., Gattelli M., Curzio L., Covi D., Yezekyan T., Marinello F. 2017. Last generation instrument for agriculture multispectral data collection. CIGR Journal, 19: 158-163.

Kuzmich I. M., Rogovskii I. L., Titova L. L., Nadtochiy O. V. 2021. Research of passage capacity of combine harvesters depending on agrobiological state of bread mass. *IOP Conference Series: Earth and Environmental Science*. 677. 052002 https://doi.org/ 10.1088/ 1755-1315/677/5/052002.

Luo A.C.J., Guo Y. 2013. Vibro-impact Dynamics. Berlin: Springer-Verlag: 213.

Masek J., Novak P., Jasinskas A. 2017. Evaluation of combine harvester operation costs in different working conditions. Proceedings of 16th International Scientific Conference “Engineering for rural development”. Jelgava, Latvia, May 24-26, Latvia University of Agriculture. Faculty of Engineering, 16: 1180-1185.

Nazarenko I., Mishchuk Y., Mishchuk D., Ruchynskyi M., Rogovskii I., Mikhailova L., Titova L., Berezovyi M., Shatrov R. 2021. Determiantion of energy characteristics of material destruction in the crushing chamber of the vibration crusher. Eastern-European Journal of Enterprise Technologies, 4(7(112): 41–49. https://doi.org/10.15587/1729-4061.2021. 239292.

Novotny J. 2016. Technical and natural sciences teaching at engineering faculty of FPTM UJEP. Proceedings of 15th International Scientific Conference “Engineering for rural development”. Jelgava, Latvia, May 23-25, Latvia University of Agriculture. Faculty of Engineering, 15: 16-20.

Palamarchuk Igor, Rogogvskii Ivan, Titova Liudmyla, Omelyanov Oleg. 2021. Experimental evaluation of energy parameters of volumetric vibroseparation of bulk feed from grain. *Engineering for Rural Development*, 20: 1761-1767. https://doi.org/10.22616/ERDev.2021. 20.TF386.

Pinzi S., Cubero-Atienza A.J., Dorado M.P. 2016. Vibro-acoustic analysis procedures for the evaluation of the sound insulation characteristics of agricultural machinery. *Journal of Sound and Vibration*, 266 (3): 407-441.

Rogovskii I. L., Titova L. L. 2021a. Change of technical condition and productivity of grain harvesters depending on term of operation. *IOP Conference Series: Earth and Environmental Science*. 720. 012110. https://doi.org/10.1088/1755-1315/720/1/012110.

Rogovskii I. L., Titova L. L. 2021b. Design of landing of assembly machine building units with circulating load rolling bearing rings. *Journal of Physics: Conference Series*. 1889. 042004. https://doi.org/10.1088/1742-6596/1889/4/042004.

Rogovskii I. L., Titova L. L. 2021c. Modeling of normativity of criteria of technical level of forage harvesters combines. *IOP Conference Series: Earth and Environmental Science*. 720. 012109. https://doi.org/ 10.1088/1755-1315/720/1/012109.

Rogovskii I. L., Titova L. L. 2021d. Modeling the weight of criteria for determining the technical level of agricultural machines. *IOP Conference Series: Earth and Environmental Science*. 677. 022100. https://doi.org/ 10.1088/1755-1315/677/2/022100.

Rogovskii I. L., Titova L. L., Berezova L. V. 2021e. Conceptual bases of system technology of designing of logistic schemes of harvesting and transportation of grain crops. *IOP Conference Series: Earth and Environmental Science*. 723. 032032. https://doi.org/10.1088/1755-1315/723/3/032032.

Rogovskii I. L., Titova L. L., Gumenyuk Yu. O., Nadtochiy O. V. 2021f. Technological effectiveness of formation of planting furrow by working body of passive type of orchard planting machine. *IOP Conference Series: Earth and Environmental Science*. 839. 052055. https://doi.org/10.1088/1755-1315/839/5/052055.

Rogovskii I. L., Titova L. L., Ohiienko M. M. 2021g. Research of garden sprayer machines of near-stem and inter-stem strips of orchards. *IOP Conference Series: Earth and Environmental Science*. 723. 022035. https://doi.org/10.1088/1755-1315/723/2/022035.

Rogovskii I. L., Titova L. L., Sivak I. M. 2021h. Research of machines for mulching near-trunk strips in perennial fruit plantations. *IOP Conference Series: Earth and Environmental Science*. 723. 042041. https://doi.org/ 10.1088/1755-1315/723/4/042041.

Rogovskii I. L., Titova L. L., Solomka O. V. 2021j. Research of sliding bearings with reverse friction pair and inlaid liners made of thermoplastic composite materials. *Journal of Physics: Conference Series*. 1889. 042010. https://doi.org/10.1088/1742-6596/1889/4/04 2010.

Rogovskii I. L. 2020. Model of stochastic process of restoration of working capacity of agricultural machine in inertial systems with delay. *Machinery & Energetics. Journal of Rural Production Research*. Kyiv. Ukraine, 11(3): 143-150.

Rogovskii I., Titova L., Novitskii A., Rebenko V. 2019. Research of vibroacoustic diagnostics of fuel system of engines of combine harvesters. *Engineering for Rural Development*, 18: 291-298.

Sergejeva N., Aboltins A., Strupule L., Aboltina B. 2018. Mathematical knowledge in elementary school and for future engineers. Proceedings of 17th International Scientific Conference “Engineering for rural development”. Jelgava, Latvia, May 23-25, 2018, Latvia University of Agriculture. Faculty of Engineering, 17: 1166-1172.

Titova L. L. 2021. Simulation of transitional processes of dynamic model of power energy installation of machines for forestry works. *Machinery & Energetics. Journal of Rural Production Research*. Kyiv. Ukraine, 12(1): 147-154.

Viba J., Lavendelis E. 2006. Algorithm of synthesis of strongly non-linear mechanical systems. In Industrial Engineering – Innovation as Competitive Edge for SME, 22 April 2006. Tallinn, Estonia: 95-98.

Yata V. K., Tiwari B. C., Ahmad I. 2018. Nanoscience in food and agriculture: research, industries and patents. *Environmental Chemistry Letters*, 16: 79-84.

Zagurskiy O., Ohiienko M., Rogach S., Pokusa T., Titova L., Rogovskii I. 2018. Global supply chain in context of new model of economic growth. Conceptual bases and trends for development of social-economic processes. Monograph. Opole. Poland: 64-74.