Information and diagnostic tools for monitoring units of agricultural machinery

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Abstract. The issues of assessing the increase in the efficiency of domestic agricultural machinery according to the criteria of suitability for maintenance and diagnostics and the development of measures to improve it are relevant, as they have a significant impact on the reliability and total cost of ownership and resource of saving during operation. It should be noted that not only the costs of maintenance and repair, but also the time spent in an inoperative state, technical readiness, productivity and other indicators of the efficiency of use for its intended purpose, including resource-saving impacts, depend on the level of equipment adaptability. The purpose of the research was to describe the state of the issue and justify the need to develop information and diagnostic tools for assessing the general technical condition of energy-intensive tractors. The analysis and description of the developed tools for diagnosing agricultural machinery have been done in the work. Similar control and diagnostic equipment produced by third-party manufacturers for agricultural machinery was considered. The distinctive features of our own developments were determined and the need to diagnose specific parameters was also reflected. As a result of the work 3D modeling of the device data was carried out. Then they were designed in special software and the first prototypes were assembled. The tests have proven the possibility of developing such digital diagnostic of device. The data obtained on the base of their effectiveness was reflected and justified. A number of improvements to these systems have been proposed. The results of the operation of all information and diagnostic devices were summed up. Further development of this area of work has been proposed for more modern and high-quality maintenance of units and assemblies of agricultural machinery.

1 Introduction

Because of the increased relevance of minimizing technological risk in the operation of agricultural machinery, there is an urgent need to develop multifunctional digital tools for diagnosing tractors that

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will allow service centers and end consumers to minimize risks by preventing failures of individual units and components.

As part of the research work, employees of the Federal Scientific Agro-Engineering Center VIM designed and created two samples intended for monitoring and collecting data from the objects under study and a control panel for an internal combustion engine stand. These installations are intended among other things to develop predictive diagnostic methods and provide:

- indirect measurement of structural parameters;
- in-place diagnostics of components with the ability to assess general and in-depth control;
- assessment of parameters under operating conditions without the influence of the "human" factor;
- timely receipt of condition data to obtain a tangible technical and economic effect.

In order to increase the fuel efficiency of equipment, an information and diagnostic device has been developed that allows optimizing the load modes of using diesel power - a diesel engine econometer. The device allows the operator to determine the diesel load levels, select the required gear to ensure minimum specific fuel consumption due to the diesel output reaching 90% of the rated load during operation, which allows saving about 5-15% of fuel (depending on operations), and is commensurate with the savings fuel when using modern, expensive to maintain fuel systems [1, 2].

The following information parameters were adopted in the research:

- about the level of engine loading: exhaust gas temperature, position of the fuel pump rack, which, other things being equal, also allows us to characterize the need to diagnose lugs and tire pressure, ballast, engine, attachments and trailed equipment;
- when monitoring changes in the temperature of the working fluid, the presence of deteriorating factors on reliability is assessed, while local overheating of the internal combustion engine and gearbox components is not allowed, as this can lead to degradation of rubber goods, bearings and leaks of the working fluid, changes in the geometric dimensions of precision parts [3].

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2 Materials and methods

A prototype of an experimental information and diagnostic digital system has been developed (Figure 1), which includes:

- primary measuring converters (sensors) of physical quantities into electrical signals (exhaust gas temperature sensor, coolant temperature sensor, proximity sensor);
- normalizing converters (analog-to-digital converter or ADCs) that convert various electrical signals into a unified digital signal;
- digital meter with an indicating device that recalculates the digital signal of a controlled physical quantity according to a developed program for subsequent indication of the state, and if it is in an anomalous range, the event registration value;
- test comparator of settings for indicating the qualitative characteristics of diagnostic parameters;
- a device showing the received information in the form of a display, light indicators;
- control device - telemetry terminal.

Fig. 1. General view of the information and diagnostic tool kit.

The experimental information and diagnostic digital system includes a multifunctional device developed by researches of laboratory No. 9.1 of the Federal Scientific Agro-Engineering Center VIM, designed to collect data from digital, pulse and analog sensors built into controlled components and assemblies of machines, calculate machine operating parameters based on these data, display and control of these parameters, transferring them to a PC and to specialized devices for monitoring equipment as telematic terminals via the RS-485 interface and the Modbus LLS protocol (Figure 2).

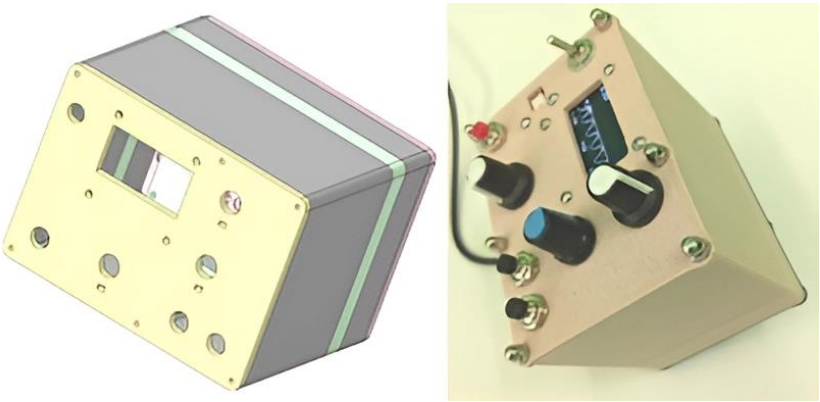

Fig. 2. Appearance of the 3D model of the case and the finished device for recording, analyzing, monitoring and transferring data to a PC.

The advantage of the developed multifunctional device is that, unlike industrial automation equipment such as monitoring measuring instruments or industrial logic controllers (ILC), the developed device independently assesses the technical condition of an individual component and unit and transmits operating parameters and data on current operating hours to the telematics terminal [4].

It also differs in that it has its own display for displaying parameters and setting up operation, selecting an operating mode, etc., and does not require connecting specialized measuring

instruments. The display shows basic information about sensor signals, operating parameters, and calculated diagnostic data. It is also possible to connect any external analog or digital sensors, programmable modules, relay modules and actuators [5, 6].

The device has advanced functionality that allows you to connect simultaneously:

- up to 7 analog sensors;
- up to 3 pulse (frequency meters, rotation speed sensors, counters);
- up to 64 digital sensors with 1-wire, I2C and the like interfaces, as well as other digital devices with their own unique connection interfaces and data transfer protocols.

It also supports the connection of external ADC modules to expand the range, frequency and resolution of read analog signals and increase the number of connection channels [7, 8].

The device's processor is powerful enough to process signals from almost any sensors at high speed and calculate diagnostic parameters [9].

Reliability management based on the rate of temperature change using digital diagnostic tools is a promising area of monitoring as measurement of dynamic parameters and subsequent assessment of technical condition, and the cost of control tools compared to the cost of objects is incommensurable and amounts to less than 0.001% [10, 11].

For clarity we would graphically display the hypothetical theoretical dependence of the coefficient *F(wa)* on temperature *(F(wa)(t)* and on load *F(wa)(P)*. For example, the temperature of the hydraulic fluid and the pressure, which is developed by the hydraulic unit (Figure 3).

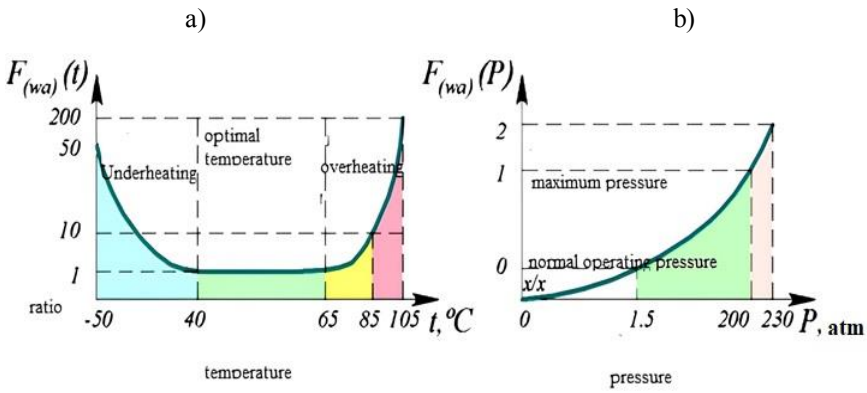

Fig. 3. Dependence of the coefficients adopted in the research that take into account the dynamics of wear depending on temperature (a) and working fluid pressure in the hydraulic unit (b).

Obviously in order to calculate the current residual life using this method a tracking electronic device is needed that continuously measures the conditions and operating parameters of the controlled unit, as well as recording its operating cycles [12].

A device has also been developed that allows the actual operating time to be adjusted taking into account the influence of external factors, and is also equipped with a data transfer function via data transfer interfaces common in industry. It also was developed in laboratory 9.1 of the Federal Scientific Agro-Engineering Center VIM (Figure 4).

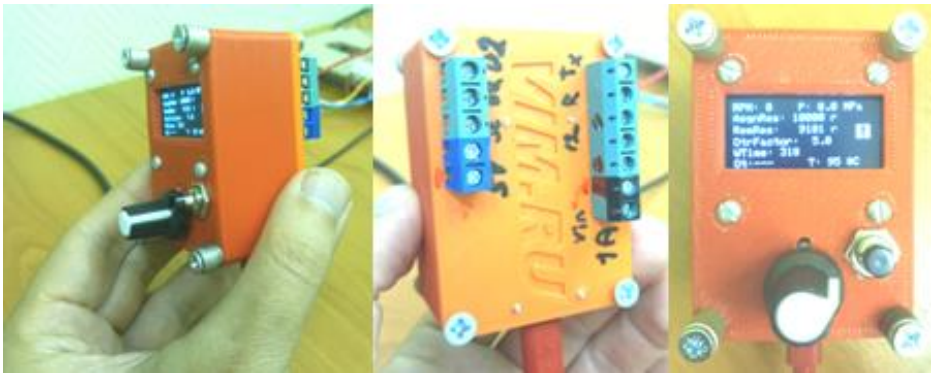

Fig. 4. Prototype of a compact electronic set for operating units and assemblies of machines, taking into account external factors.

The device is intended for developing and testing methods for transmitting data to telematic terminals. Depending on the quantity, format and required speed (frequency) of data transmission to the telematics terminal, the choice of interface and data transmission protocol may be different [13].

Different data transmission interfaces are differently resistant to interference and have different stability of operation, which is also checked when tested with different types of cables and different lengths [14].

Also, low power consumption allows for long-term testing powered by an external battery, increasing mobility with the function of data transfer to a telematics terminal via RS-485, CAN, I2C, 1-wire interfaces [15].

3 Results and discussion

The presented modules can work autonomously or be connected into a single network to collect and transmit data about the operation and condition of the machine to the memory unit and telemetry terminal. A logical diagram of the operation of the information and diagnostic tool can be used to assess the technical condition of elements of resource-determining components and assemblies.

When it is necessary to supply each important expensive component of the machine with developed electronic units this will allow for continuous monitoring of operating parameters, accurately calculating operating hours and conducting continuous self-diagnosis of the machine [16].

If necessary the presented modules can be connected into a single network to collect and transmit data about the operation and state of the machine to the memory unit and telemetry terminal. Currently, the developed modules are used for automatic measurements during staged experiments, for automatic calculation of parameters, their control andmanage of external units, and recording data on a PC.

Managing the reliability of agricultural machinery using digital diagnostic tools is to prevent emergency breakdowns and provide maintenance on demand by monitoring the condition of the equipment in real time, providing continuous analysis and instant response to deviations. Artificial intelligence algorithms can also help prevent breakdowns, for example, such as neural networks or randomforest. Since such diagnostic devices can collect a large amount of information, its processing will require modern methods of computer analysis [17].

4 Conclusions

The collected information using an application software product can be used for economic calculations and assessment of operating costs, as well as minimizing repair costs in the event of units' failure. All resource-determining elements of energy-intensive means during the digitalization of the agro-industrial complex must be equipped with tracking electronic units that conduct continuous monitoring, diagnostics, collection and transmission of data from diagnostic devices or from the on-board CAN bus installed by the manufacturer. Self-diagnosis of machines will significantly reduce the time and money spent on maintenance and repair of equipment [18].

Monitoring the actual operating time of individual units and assemblies is the most important task for determining the technical condition of the machine as a whole, its timely and rational maintenance, calculating the extent of the assigned resource used and the cost of operation. In this direction in the future the use of artificial intelligence algorithms will increase, which will increase the level of qualitative assessment of the state of agricultural machinery [19].

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