DOI: 10.12731/2658-6649-2025-17-6-2-1576 **EDN: JEPFMU**
UDC 621

Original article

THE ROLE OF DIAGNOSTICS IN IMPROVING THE OBJECTIVITY OF ASSESSING THE TECHNICAL CONDITION OF AGRICULTURAL MACHINERY

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Abstract

Background. During operation, the condition of the machine is subject to constant changes, occurring unpredictably and depending on a multitude of operating factors that affect the wear and tear of individual machine components to varying degrees, requiring different amounts of repair and maintenance for each piece of equipment. Preliminary diagnosis of the entire system or its individual parts helps to accurately determine the amount of maintenance or repair required. This study analyzes methods for improving the accuracy and reliability of machine technical condition assessment. Also considered are the key factors of technical diagnostics that provide assessment of the current parameters of the object and prediction of the state on the basis of data obtained through direct or indirect measurements. The authors propose a method of evaluating the efficiency of diagnostic procedures taking into account various combinations of influencing factors. The influence of the marginal cost of diagnostics on the total specific repair costs is shown.

Purpose. The purpose of the research is to study the role of diagnostics in the issues of improving the objectivity of the assessment of the technical condition of machines

Materials and methods. Availability of information on specific values of controlled parameters allows to control the threat of disturbance of normal operation of machines. Assessment of the state of machinery is carried out by comparing the actual values of parameters with the specified norms. Detailed control requires methods of monitoring the monitored parameters, including the collection of additional data on how these parameters change over time. Modern technical devices are equipped with a continuous condition monitoring function, which makes it possible to continuously monitor the operation of machines and equipment. Early fault detection includes a set of measures to identify emerging defects, determine

their root causes, and carefully analyze the nature and degree of development of these problems. Technical diagnostics consists in assessment and forecasting of the object state based on the results of direct or indirect measurements of state parameters or diagnostic parameters.

Results. The results of this study show that diagnostics allows management at two levels: technical state and technological process. At the first level, diagnostics is directly related to maintenance (TO), while at the second level it is more related to the organization of technological processes.

Conclusion. Application of modern methods, tools and approaches to diagnostics in the system of maintenance and repair will increase its efficiency due to more complete utilization of operational characteristics of each individual object.

Keywords: technical diagnostics; technical condition assessment; reliability; safety; machine

For citation. Popov, S. I., Dontsov, N. S., Rudoy, D. V., Olshevskaya, A. V., Teplyakova, S. V., Prutskov, A. S., & Marchenko, J. V. (2025). The role of diagnostics in improving the objectivity of assessing the technical condition of agricultural machinery. *Siberian Journal of Life Sciences and Agriculture*, *17*(6-2), 730-745. https://doi.org/10.12731/2658-6649-2025-17-6-2-1576

Научная статья

РОЛЬ ДИАГНОСТИКИ В ВОПРОСАХ ПОВЫШЕНИЯ ОБЪЕКТИВНОСТИ ОЦЕНКИ ТЕХНИЧЕСКОГО СОСТОЯНИЯ СЕЛЬСКОХОЗЯЙСТВЕННЫХ МАШИН

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Аннотация

Обоснование. В процессе эксплуатации состояние машины подвергается постоянным изменениям, происходящим непредсказуемо и зависимо от множества эксплуатационных факторов, в разной степени влияющих на износ отдельных компонентов машин, что требует различного объема ремонта и обслуживания для каждой единицы оборудования. Предварительная диагностика всей системы или ее отдельных частей помогает точно определить объем необходимого обслуживания или ремонта. В рамках данного исследования

проведен анализ методов улучшения точности и достоверности оценки технического состояния машин. Также рассмотрены ключевые факторы технической диагностики, обеспечивающие оценку текущих параметров объекта и прогнозирование состояния на основании данных, полученных через прямые или косвенные измерения. Авторами предложен метод оценивания эффективности применения диагностических процедур с учетом различных комбинаций воздействующих факторов. Показано влияние предельной стоимости диагностирования на суммарные удельные затраты на ремонт

Цель. Цель исследования заключается в изучении роли диагностики в вопросах повышения объективности оценки технического состояния машин

Материалы и методы. Наличие информации о конкретных значениях контролируемых показателей, позволяет контролировать угрозу нарушения нормального функционирования машин. Оценка состояния техники осуществляется путем сравнения фактических значений параметров с заданными нормами. Для детального контроля необходимы методы мониторинга отслеживаемых параметров, включающие сбор дополнительных сведений о том, как эти параметры меняются со временем. Современные технические устройства оснащены функцией непрерывного мониторинга состояния, что дает возможность постоянно контролировать работу машин и оборудования. Обнаружение неисправностей на ранних этапах эксплуатации включает в себя комплекс мероприятий по выявлению возникающих дефектов, определению их первопричин, а также тщательный анализ характера и степени развития этих проблем. Техническая диагностика заключается в оценке и прогнозировании состояния объекта на основе результатов прямых или косвенных измерений параметров состояния либо диагностических параметров.

Результаты. Результаты проведенного исследования показывают, что диагностирование позволяет осуществлять управление на двух уровнях: техническом состоянии и технологическом процессе. На первом уровне диагностика напрямую связана с проведением технического обслуживания (ТО), тогда как на втором она больше касается организации технологических процессов.

Заключение. Применение современных методов, инструментов и подходов к диагностике в системе обслуживания и ремонта повысит её эффективность благодаря более полному использованию эксплуатационных характеристик каждого отдельного объекта.

Ключевые слова: техническая диагностика; оценка технического состояния; надежность; безопасность; машина

Для цитирования. Попов, С. И., Донцов, Н. С., Рудой, Д. В., Ольшевская, А. В., Теплякова, С. В., Пруцков, А. С., & Марченко, Ю. В. (2025). Роль диагно-

стики в вопросах повышения объективности оценки технического состояния сельскохозяйственных машин. *Siberian Journal of Life Sciences and Agriculture*, *17*(6-2), 730-745. https://doi.org/10.12731/2658-6649-2025-17-6-2-1576

Introduction

Modern tendencies of machine building development are aimed at constructive complications and, as a consequence, increasing the cost of technical systems. Therefore, in order to ensure the required level of technical characteristics during the operation of machines, there is an inevitable need to solve diagnostic tasks, including determination of their technical condition, identification of possible failures and determination of residual life. Taking into account the growing requirements to increase the productivity of technically complex devices, the process of diagnostics must meet high quality standards. The use of complex and expensive automated systems for controlling technical objects requires qualitative analysis of their technical condition, accurate identification of failures and reliable prediction of remaining service life. Improving the efficiency of machine operation remains an urgent task, which is directly related to the level and quality of applied diagnostic methods and tools [1].

Technical diagnostics plays a key role in ensuring safety, reliability and efficiency of technical systems, helps to reduce maintenance costs and losses caused by downtime due to breakdowns and early repair of equipment [2-5].

Diagnostics allows not only troubleshooting, but also controlling the quality of maintenance and repair of machinery and equipment. In addition, the effectiveness of the measures taken is evaluated, compliance with the established standards and norms is checked, and the compliance of the results achieved with the planned indicators is analyzed. Diagnostics helps to predict the remaining life both for individual components and modules of the system and for the whole plant, to plan in advance the necessary repairs, to reduce the probability of emergencies and to optimize operating costs.

Different diagnostic methods are used for a more accurate assessment of the current state of the equipment. For example, the D-1 procedure is performed before and during the first technical service (TO-1) to assess the condition of the main units and assemblies that affect the safety of use and availability of the vehicle. A D-2 diagnosis is performed prior to the second maintenance (TO-2) to analyze the overall condition of all critical system elements such as units, assemblies and vehicle systems. This makes it possible to determine the amount of maintenance and repair work required.

Modern methods and means of technical diagnostics allow to improve the processes of solving many tasks important for the production process. The most important tasks include the reduction of operating costs by reducing labor costs and time for repair work and failure prevention, as well as increasing service life by early detection of defects [6-9].

Materials and methods

The key tasks of machine condition diagnostics systems are primarily focused on the observation of measured parameters. This function allows continuous monitoring and analysis of the main characteristics of the machine or equipment operation. The process includes the collection of information about the key performance indicators of machinery [10-12].

The next, no less important task of the systems for diagnosing the technical condition of machines is aimed at identifying malfunctions in machines and equipment. Identification of specific problems or failures in the operation of machinery is necessary not only to detect the malfunction, but also to establish the causes of its occurrence. In this case, the control is aimed at wear and tear of components, violation of operating rules, adjustment errors or the influence of external factors on the functioning of equipment [13].

The third task of technical condition diagnostics is aimed at predicting potential changes in the operation of machines or equipment over time. By analyzing actual data, it is possible to predict the behavior of machinery, which allows planning preventive measures or repair work in advance before the onset of serious breakdowns [14-15].

Thus, for successful performance of basic diagnostic manipulations it is necessary to have data on changes and permissible limits of key operating parameters. Availability of information on specific values of controlled parameters allows to control the threat of disturbance of normal operation of machines.

Assessment of the state of machinery is carried out by comparing the actual values of parameters with the specified norms. In other words, when diagnosing or analyzing equipment performance, real data (such as temperature, pressure, speed, etc.) are compared with the normative values set by technical documents or the manufacturer. Any deviation from the standard values is considered as an indication of a defect or problem.

Detailed control requires methods of monitoring the monitored parameters, including the collection of additional data on how these parameters change over time. Therefore, more advanced monitoring techniques are envisioned that not only record current parameter values, but also track their changes over a peri-

od of time. This approach helps to identify defect trends before they cause serious consequences, as well as to predict possible failures and plan prevention in advance.

Modern technical devices are equipped with a continuous condition monitoring function, which makes it possible to continuously monitor the operation of machines and equipment. This process facilitates the timely detection of deviations from normal operation and the taking of corrective action before problems become a serious threat. Continuous monitoring prevents unexpected damage, accidents or sudden breakdowns, and reduces the risk of critical machinery-related situations.

Early fault detection includes a set of measures to identify emerging defects, determine their root causes, and carefully analyze the nature and degree of development of these problems. Forecasting of possible changes in the technical condition of the equipment allows effective planning of preventive maintenance and repair work. As a result, it is possible to respond to emerging problems in a timely manner and prevent serious breakdowns, thereby increasing the level of reliability and extending the service life of the equipment used.

Technical diagnostics consists in assessment and forecasting of the object state based on the results of direct or indirect measurements of state parameters or diagnostic parameters. Diagnostic parameter by itself does not allow to estimate the technical state of the object. It is important to take into account both the current state of the object D_{fact}, and its normative technical value $D_{\text{n.–t.}}$. The difference between the actual and reference values of diagnostic parameters is called diagnostic symptom Δ.

$$\Delta = D_{fact} - D_{\text{n.–t.}} \quad (1)$$

The technical condition of an object is assessed by the value of a diagnostic symptom and comparison with acceptable technical or design parameters. In order to carry out condition assessment, appropriate information is required.

For systematic maintenance and repair, reliability information is collected and processed in the format of statistical variation series of controlled indicators, and diagnostic information, which is individual when considering a particular object. Reliability data are formed by collecting information through the analysis of failures of typical components or machines, and individual diagnostic information is formed directly by measuring the parameters of a particular object.

The collected statistical information allows to make intermediate conclusions on the volume of regularity of maintenance with a certain degree of probability.

Based on the diagnostic information obtained, the parameters are adjusted for a specific vehicle. Such sequence of actions allows to reduce labor and, as a consequence, economic costs for routine maintenance of vehicles and their restoration after failures. Specifically, the amount of savings in scheduled maintenance works depends on the coefficient of variation of vehicle resource, the cost of emergency repairs, the cost of preventive maintenance and diagnostics.

Figure 1 in nomogram format shows the graph of dependence of diagnostics efficiency and its cost. Thus, it is visually demonstrated how the economic efficiency of using different diagnostic approaches changes when combining different factors affecting technical diagnostics.

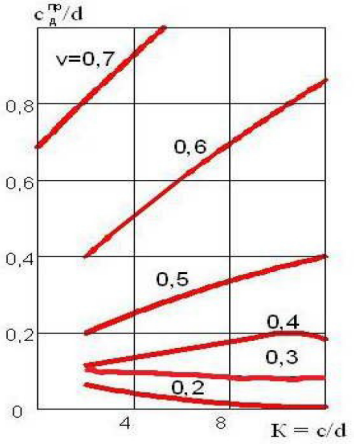

Fig. 1. Nomogram of marginal cost of diagnostics

Nomograms are based on the assumption that total costs of repair, preventive maintenance and diagnostics cannot exceed the unit costs of repair and preventive maintenance alone, excluding the costs of diagnostics:

$$\frac{cq_d + d(1-q_d) + c_d n_d}{I_l^{fact}} \leq \frac{cq + d(1-q)}{I_{\text{p}}^{fact}} \quad (2)$$

where c – emergency repair costs; q_d and q – probabilities of occurrence of emergency failures during maintenance with and without diagnostics; I_l^{fact} и I_p^{fact} weighted average actual mileage before restoration with and without diagnostics; n_d – number of diagnostics before recovery; d – maintenance costs.

In accordance with the character of curve changes, it can be stated that the efficiency of diagnostics depends on the increase in the coefficient of variation

of resource and probability of unit failure during scheduled maintenance and the growth of costs for elimination of such failures.

Nomograms help to determine the marginal cost of diagnostics of a certain mechanism under given conditions, exceeding which makes it more profitable to use scheduled maintenance without preliminary diagnostics. It has been previously found that the use of diagnostics can reduce vehicle maintenance and repair costs by 10-25%.

Another significant benefit of diagnostics is the ability to improve the resource utilization of assemblies and components through accurate information support in the planning and execution of various operations such as repair, procurement, fuel economy, road safety and other tasks.

Vehicle diagnostics is a key aspect of integration of modern maintenance and repair technologies, focused on optimizing the use of internal resources by fully unlocking the potential and technical characteristics of the equipment. The efficiency of diagnostics of various units and systems is directly related to testability – the property of the vehicle that allows diagnostics to obtain accurate information about the current technical condition with minimal labor, time and material resources. In order to assess maintainability, a simple measurable output parameter is defined that demonstrates a change in performance characteristics. Parameters allow the collection of detailed information on the performance of each device and element of a technical system, taking into account its unique characteristics. Accordingly, diagnostics are organized in the same manner as maintenance and repair procedures (Figure 2).

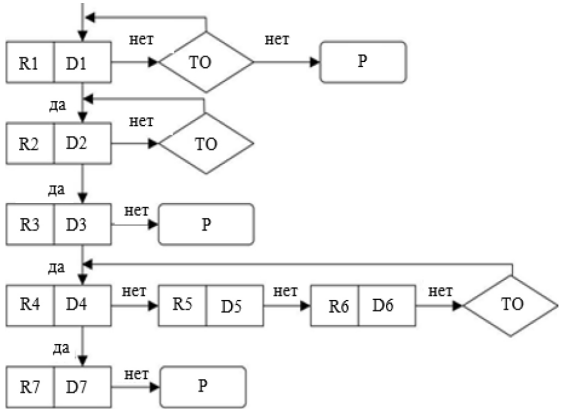

Fig. 2. Diagnostics algorithm scheme: R and D – diagnostics by parameter D1- D7 in R1- R7 mode; TO – maintenance service; P – repair

The technical condition of the vehicle is monitored by means of built-in diagnostics, and daily maintenance is carried out by means of control inspections. During Maintenance and Repair TO-1, comprehensive diagnostics of the main systems affecting safety is performed. Advanced diagnostics of assemblies and units is carried out before maintenance and repair TO-2, and during the elimination of detected defects within the framework of TO the system of DR diagnostics is used. To ensure intermediate and final quality control of adjustment and repair work, diagnostic procedures are combined with maintenance and repair operations.

Results

The results of this study show that diagnostics allows management at two levels: technical state and technological process. At the first level, diagnostics is directly related to maintenance (TO), while at the second level it is more related to the organization of technological processes. In the further development of diagnostics it is supposed to create automated diagnostic tools that will be part of automated production management systems, as well as the introduction of embedded diagnostics. This will allow to use diagnostics for operational management of maintenance and repair processes. Application of modern methods, tools and approaches to diagnostics in the system of maintenance and repair will increase its efficiency due to more complete utilization of operational characteristics of each individual object.

Conflict of interest information. The authors declare that they have no conflict of interest.

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Поступила 01.07.2025 Received 01.07.2025
После рецензирования 20.08.2025 Revised 20.08.2025
Принята 29.08.2025 Accepted 29.08.2025