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ADAPTATION OF TECHNICAL CONDITION MANAGEMENT SYSTEMS FOR TRANSPORT AND AGRICULTURAL MACHINERY UNDER THE GLOBALIZATION OF TECHNICAL DIAGNOSTICS AND CONTROL

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The efficiency of transport machinery (TM) and agricultural machinery (AM) defined by productivity, operating cost, and traffic safety largely depends on the technical condition of the rolling stock (RS). Therefore, optimal and effective technical operation of TM and AM, which consists in maintaining their reliability and technical readiness through maintenance (M) and current repair (CR), is a matter of national importance. The foundation for solving this problem lies in significantly improving M and CR based on the development of effective methods, instruments, and equipment for RS diagnostics.

Under modern conditions, the solution requires adapting M and CR of TM and AM to processes driven by the globalization of technical diagnostics (TD) and technical control (TC). Technical diagnostics is a field of knowledge that encompasses the theory, methods, and tools for determining the technical condition of objects; it also represents the highest level of TC, which involves verifying the compliance of the controlled object with established technical requirements. The main reasons for the global expansion of TD and TC include market liberalization and the increase in road accidents and catastrophes. The scale of accidents and catastrophes, as well as the associated ecological and technogenic safety, is critical for TM and AM. At the same time, access of both people and machinery to their operational environment remains largely liberalized. The growing number of machines on Earth within the environment where people constantly reside is governed by market laws and is not controlled by humans. TM and AM, as systems, are open to any person, and individuals have free access to the environment in which machinery operates. This process is only partially restricted for machine operators (driver's licenses are required), but in Ukraine, access for technical service personnel (ITS) is completely unrestricted due to the cancellation of mandatory certification of maintenance and repair services. The human factor places at the forefront the need to create a reliable system of technical operation of machinery (TOM), free from subjective human influence and adapted to the development of TD and TC within the M and CR system.

The general problem of creating TOM lies in the fact that its reliability has two inseparable components: technical and organizational. The first is sufficiently addressed by industry, which produces improved machinery. The second operation, preservation, and maintenance of machinery in a state of readiness depends entirely on humans.

In this work, using the example of an electronic engine control system (EECS), the foundations for implementing reliable TOM as a system of TD and TC methods and tools are formulated. The use of EECS in TM and AM improves engine power, environmental performance, and fuel efficiency. This is achieved through the implementation of a complex engine-control algorithm at the cycle level, taking into account numerous parameters of the working process and the presence of feedback loops.

However, the negative aspects of EECS implementation include their relative complexity and, consequently, the inability of the current TOM system to ensure proper RS operation. The core of the problem is the lack of connection between manufacturers and the TOM system as a whole. Today, TOM clearly lags behind the development of TM and AM design, especially the development of electronic control systems. In practice, this gap manifests as a shortage of TOM specialists capable of quickly and effectively understanding and working with electronic systems. Higher education institutions cannot keep pace with the rapid evolution and increasing complexity of electronic control systems. Another important reason is that EECS and other microprocessor control systems (MPCS) are foreign prototypes, while TM and AM are predominantly imported. Practically every manufacturer develops and implements its own systems, has proprietary technologies, and uses its own terminology. As a result, technical literature contains numerous overlapping technical terms, creating confusion and misunderstanding during the development of new machinery. The root cause is the absence of a unified foundation for designing control systems. New integrated system-engineering approaches are required. Therefore, EECS should be considered not as an isolated system but as a control system for TM and AM that includes all electronic subsystems, as well as a system for monitoring and ensuring the proper technical condition of machinery as a whole.

A key requirement for TOM is the ability to automatically obtain from the EECS accurate parameter values that determine operating conditions related to effective engine power. The engine is the primary element of machinery that converts operator commands into changes in state and motion of TM and AM.

The automation and accuracy of obtaining information about TM and AM operating conditions are ensured by EECS, which characterize the fundamental parameters of engine operation. It is established that the controlling parameters of engine operation are cylinder filling and the duration of the working cycle, determined by crankshaft rotational speed. In some cases, fuel injection per cycle is used instead of cylinder filling. Accordingly, for determining the technical condition of TM and AM, it is advisable to use total air consumption and total fuel consumption over a certain operating period, which comprehensively characterize operating conditions and RS utilization intensity. Supporting this, Prof. Hovorushchenko proposes using total fuel consumption to predict vehicle remaining life and maintenance intervals. Research shows that maintenance actions should be performed after reaching specific fuel-consumption thresholds. At the same time, the capabilities of EECS and MPCS must be considered when developing the theory of individualized M and CR systems.

In practice, for large-scale implementation of such individualized systems, the most promising hardware and system-level solution is not EECS itself but specialized external devices primarily onboard scanners (OS). These devices are relatively inexpensive and suitable for effective use on modern TM and AM. To solve TOM tasks, OS must incorporate specific algorithms and functions. By recording total air and fuel consumption over a given period, OS can generate a graph of consumption versus operating time. When consumption reaches predefined thresholds, the OS notifies the operator of the need for maintenance. Analysis of the consumption graph allows predicting maintenance timing and planning operations effectively. Therefore, the most convenient and promising approach for TOM is the automatic remote transmission of EECS data.

The most complete information about TM and AM operating conditions can be obtained from a graph of crankshaft rotational speed over time. Analysis of this graph reveals time intervals during which the engine operated in specific speed ranges. Acceleration and deceleration patterns allow accurate determination of operating conditions. It is possible to determine the duration and number of stops, gear-shift moments, and more.

If the EECS includes a speed sensor, a speed-change graph can be constructed. Based on speed values, braking distance, fuel consumption, operating cost, emissions, and other parameters can be calculated. Combined analysis of speed and crankshaft-speed graphs allows determining the

gear used, duration of operation, and speed profile. The goals of TOM remain unchanged: ensuring regularity, safety, and efficiency while fully utilizing the technical capabilities of TM and AM designs; ensuring required levels of operational reliability; optimizing material and labor costs; and minimizing negative impacts on people, personnel, and the environment. Under modern conditions, it is necessary to achieve internal compatibility between system elements and external compatibility between the system and its environment. It is also important to understand that modern TOM, as a field of practical activity, is a system-engineering human-machine complex whose effectiveness at all levels depends on the organization of positive and efficient interaction between humans and machinery. Within TOM, four levels of processes can be distinguished: micromodular, mesomodular, macromodular, and megamodular.

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