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DETERMINING THE TECHNICAL CONDITION OF DIESEL LOCOMOTIVE DIESEL ENGINE USING DIAGNOSTIC TOOLS

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Abstract: The article deals with effective ways of assessing the technical condition of diesel locomotive diesel engine units, which allow timely detecting malfunctions and taking measures for their elimination. Modern means of diagnostics prevent faults in locomotive devices, provide reliable forecasting of changes in the technical condition of the main units of equipment, determine their residual life, develop and improve effective methods of data processing from the locomotive. Diesel locomotive, unlike stationary and marine diesel engines, has specific features due to the limited size of the diesel room, the presence of strict requirements for traffic safety and a large number of operating units. These features exclude the possibility of installing large-sized and expensive diagnostic equipment on the locomotive, but at the same time require prompt information on the technical condition of the main units and parts of the power plant.

Keywords: Fuel equipment, cylinder-piston group, workflow, determination of technical condition, experimental, analyses, fuel - carbon monoxide, diesel locomotive engine.

Introduction. Fuel equipment and cylinder-piston group are one of the most complex components of diesel engine from the point of view of the possibility of continuous control of their condition. One of the most widespread methods of such control is the estimation of intensity of wear of parts by the content of wear products in oil and exhaust gases. Theoretical and experimental studies of the dynamics of accumulation of impurities and wear products in the engine oil of diesel locomotive diesel engines have established [1, 2] that the concentration of wear products in the oil is in linear dependence on the intensity of wear of parts. Periodic control of oil condition allows both objective assessment of the current technical condition of diesel friction units and reliable forecasting of its change.

Until recently, the design of instrumentation used to analyse oil properties allowed to use them only in stationary version, and they were usually concentrated in road chemical-technological laboratories. The need to deliver oil samples from locomotive depots, as well as the large number of analyses performed did not allow to provide the level of efficiency required for continuous control of the technical condition of diesel engine components [3].

In recent years, on-board oil condition monitoring devices based on multifunctional oil parameter sensors have become widespread. The most advanced of them (but also the most expensive) can directly monitor the content of metal particles of wear products of ternium units in the oil, the size of metal particles, the content of water and soot in the oil, its alkaline number and a number of other parameters.

Methods. A sharp change in these properties in operation indicates a change in engine operating conditions, oil condition or water leakage from the water system into the oil, and may be the basis for performing a refined analysis of the oil composition using stationary or local means. The latter (i.e. localized) is also becoming increasingly common in diesel vehicle operation.

Thus, control of diesel oil condition in operation is one of the most promising and effective ways of operative integral assessment of technical condition of engine friction units (primarily cylinder-piston group and crank mechanism), as well as the oil itself.

Periodic control of the technical condition of the fuel equipment should be carried out by means of its dismantling and checking on special stationary stands. However, due to the absence or incompleteness of such stands in the majority of depots, as well as significant time costs of dismantling, inspection and subsequent installation of fuel equipment, the efficiency of this method of control is very low.

The parametric method of complex assessment of the technical condition of the main diesel engine systems according to the parameters of the indicator diagram is characterized by significantly higher reliability. To measure the indicator indicators of the diesel engine operating process several methods have been developed, the peculiarities of each of which determine the varieties of parametric method of diagnostics [4].

Analysis of the parameters of the indicator diagram of the engine cylinders allows you to identify and localize dozens of faults injector, high-pressure fuel pump, gas distribution mechanism, as well as violation of their adjustment. The values of the average indicator pressure obtained in this process can be used to calculate the power spent on mechanical losses, mechanical efficiency of the diesel engine and the average value of the mechanical loss pressure.

Technical means of the diagnostics and adjustment complex are organized in such a way as to facilitate and simplify the technological process of diesel engine inspection as much as possible, including reducing the duration of this process. The main method of diagnostics is comparison of the reference and indicator diagram of fuel injection. It allows to determine the following faults: injector leakage, fuel nozzle damage, high-pressure fuel pump discharge valve damage, deviation of the fuel delivery start moment, fuel pump plunger pair wear, injector damage, poor fuel quality, injector nozzle clogging, piston ring wear or damage, reduced charge air pressure, intake valve leakage.

The disadvantage of methods based on the analysis of indicator diagrams is the possibility of their implementation only by stationary means of diagnostics, since the specifics of the process of direct measurement of pressure in the diesel cylinder excludes the possibility of continuous removal and control of the indicator diagram in the process of diesel locomotive operation. There are known attempts to determine indicator indicators of the diesel engine by the value of stresses in the studs of the main bearing cap fasteners, but the accuracy of measurements allows only to estimate the cylinder load difference.

Results. Exhaust gas analysis is performed to determine the number of products of incomplete combustion of fuel - carbon monoxide and soot. Increased content of these components indicates deviations in the mixing and combustion processes, which may be caused by deterioration of the technical condition of both fuel equipment and cylinder-piston group. To estimate the soot content in the exhaust gases, smoke meters are used, which evaluate the exhaust gases in the lumen [5]. The opacity of exhaust gases is determined by the presence of soot particles, unburned fuel, engine oil and water vapors. A serviceable diesel engine at idle speed emits almost no soot particles (particulate matter). Increased emission of particulate matter or unburned fuel indicates combustion disorders caused by poor preparation of the fuel-air mixture, e.g., due to faulty injector atomizers, incorrectly set start-up or high oil consumption due to wear of the cylinder-piston group components. Such a method of assessing the technical condition of the fuel equipment and cylinder-piston group can be effective in stationary conditions, but the realization of continuous monitoring of diesel exhaust smoke is very difficult.

To control the quality of assembly, running-in and tightness of the super piston space of internal combustion engines use a method based on the comparison of crankshaft speed irregularity indicators, within the rotation angles corresponding to the compression stroke of specific cylinders, when cranking the engine shaft from a post-renewable energy source, first in the absence of compression in the cylinders, and then in its presence. This method makes it possible to identify engine defects that depend on friction forces in the moving joints and to assess the tightness of the super-piston space. The main disadvantage of the method is the difficulty of localizing the fault within the cylinder.

Existing methods and means of monitoring the performance of diesel fuel equipment, depending on the type of information obtained and diagnostic signs can be divided into the following groups [6]: by the nature of the injector needle lift; by the nature of pressure changes in the pipeline; by vibroacoustic parameters; by the pressure and temperature of gases in the diesel cylinder; by the chemical composition and smokiness of exhaust gases.

The main scope of work related to inspection, adjustment and diagnostics of fuel equipment is performed in depot conditions on stationary stands with its removal from the diesel engine.

Vibroacoustic methods of fuel equipment operation control, based on the analysis of variograms and their comparison with reference ones, have become widespread and continue to be improved [7]. However, despite the variety of methods of diagnostics of fuel equipment, most of them cannot be used for continuous operational control of the technical condition of fuel equipment in operation, because they require its removal from the diesel engine or installation of special equipment.

In the practice of operation of transport multi-cylinder diesel engines, methods based on the use of so-called simplexes, i.e. calculated criteria that depend on a set of values of a certain set of parameters, have become widespread. Simplexes are invariant with respect to the operating mode of the diesel engine, but react to changes in its technical state. In particular, in [8], the expediency of using as such a simplex the ratio of the pressure at the end of compression P_C to the exhaust gas temperature at the outlet of the T cylinder was substantiated. According to the data of bench thermomechanical tests, it was established that on a number of low-speed powerful diesel engines the value of $C_U = P_C/T$ practically does not change at loads 80-100 % of nominal. The technical condition of the diesel engine in the period of delivery tests can be assumed to correspond to its serviceable condition, and the value of C_U obtained in this case-nominal. Deviation of C_U from the nominal value during operation indicates a change in the general technical condition of the diesel engine and can serve as a basis for putting it on diagnostic control.

When changing the operating mode of a serviceable diesel engine, the exhaust gas temperature at the outlet of all cylinder's changes, which leads to changes in the exhaust gas temperature before the turbine, turbine output, boost pressure and, consequently, the pressure at the end of compression. In the event of a disturbance in any of the cylinders (e.g. due to a deterioration in the quality of fuel atomisation by the injector), the temperature of the gases at the outlet of this cylinder will increase. However, this will not significantly change the temperature of the gases upstream of the engine turbine, so that the boost pressure and end of compression pressure in that cylinder remain unchanged. The value of the P_C/T simplex will decrease, indicating a deterioration in the technical condition of the cylinder. This change in the simplex value will be caused by wear of rubbing parts of the cylinder-piston group (piston rings and cylinder sleeve) and the resulting decrease in end-compression pressure.

The value of the P_C and T parameters included in the simplex C_U is affected by the condition of five main components of the diesel engine: cylinder-piston group, turbocharger, fuel equipment, air and gas exhaust ducts. The main difficulty in using this method is the impossibility of continuous control of compression pressure in the diesel cylinder [9].

To determine the technical condition of a diesel locomotive diesel engine in operation, the relative change in the exhaust gas temperature to the relative change in the excess air ratio in the diesel cylinder can be used as a simplex. The value of this simplex when changing the mode of operation (cycle fuel supply) of a serviceable engine remains constant at each position of the driver controller. But in case of violation of the normal course of the working process in the cylinder (for example, due to changes in the advance angle of fuel supply, deterioration of the quality of mixing due to a malfunction of the fuel equipment) during operation, the value of the simplex deviates from the nominal value, which indicates a change in the general technical condition of the diesel engine and serves as a basis for putting it on stationary diagnostic control.

The efficient use of diesel locomotives requires, in particular, their high reliability in operation, minimal maintenance and repair costs, and maximum use of resources and energy potential. In this regard, a special role is given to technical diagnostics.

The current reliability of a diesel locomotive at any given moment in its use depends on a number of factors operating in the period of time preceding that moment. For example, the reliability of a newly built locomotive depends on the level of research and development, the quality of manufacturing of components and parts, as well as their assembly and adjustment.

To increase the level of reliability of technical equipment, it is necessary to both improve structures and improve the system of their maintenance and repair [1]. The locomotive industry has a planned preventative maintenance and repair system. The system provides for types of maintenance and repair of locomotives and regulates volumes and overhaul runs.

The comprehensive assessment of the technical condition of diesel locomotive structural elements relies on the measurement and evaluation of numerous input, internal, and output parameters. This process hinges on identifying functional correlations between defects and diagnostic parameters, as well as understanding the patterns of their variation due to typical operational factors. Degradation of an object's condition can occur due to natural wear and tear, improper operation, poor-quality production or repair, and accidental operational impacts.

Effective management and decision-making in locomotive systems necessitate access to various types of information about the system's state. Given the complexity and scale of locomotive systems, a systematic approach is essential for developing a diagnostic control system that can address multiple issues using uniform technical means and a single information base. The primary focus of our research is to enhance methods for diagnosing the technical condition of locomotive power plants.

The assessment of the technical condition involves monitoring the heat transfer of the diesel engine crankshaft. As the crankshaft rotates, its temperature increases, providing insights into the locomotive's condition. The key objective is to detect overheating caused by sliding surface friction promptly, thereby preventing costly breakdowns of the crankshaft. Our diagnostic system, which currently lacks analogues, plays a crucial role in achieving this goal.

To assess the technical condition of the crankshaft's heat transfer, we utilize two main components: a crankshaft temperature indicator unit and a display. The temperature sensor is positioned as close as possible to the measured part of the crankshaft to detect temperature differences between the sliding part and other crankshaft journals promptly. This approach enables timely identification of overheating, mitigating the risk of crankshaft failure and breakdowns.

Continuous monitoring of the technical condition of used locomotives is conducted through the utilization of diagnostic tools and methodologies. Within railway transport, the operation of locomotive heat and power systems in a technically deficient state leads to excessive fuel consumption. The employment of diagnostic methods in this process enables the identification of alterations in the technical state of thermal power systems, thereby facilitating the documentation of such changes for repair planning purposes. Contemporary diagnostic methodologies play a pivotal role in ensuring the sustained quality of locomotives.

The failure rate of components within the cylinder-piston group and the crankshaft connecting rod mechanism exceeds a staggering 50%. This alarming statistic is primarily attributed to the intense dynamic and thermal stresses these parts endure during engine operation. The reliability of their functionality is intricately linked to a multitude of external factors, including the effectiveness of lubrication and cooling systems, the quality of water and oil, the purity and volume of air entering the combustion chamber, as well as the pressure and temperature conditions within the chamber itself. Among the prevalent malfunctions plaguing diesel engines are bearing damage, bearing spinning, babbitt casting rubbing, cylinder liner cracks and erosion, piston ring fractures, and corrosion. Furthermore, excessive wear of rubbing parts significantly contributes to these failures.

Discussion. A highly efficacious method for diagnosing the technical condition of diesel engines lies in the analysis of diesel oil compositional indicators. This approach boasts several advantages, notably early detection of malfunctions without necessitating vehicle downtime or disassembly of the diesel engine, timely identification of the need for oil changes, and preemptive measures against diesel failure due to contamination and component wear. Widely utilized across various diesel locomotives, this diagnostic methodology demonstrates remarkable technical and economic efficiency. The deterioration of oil quality stems from factors such as incomplete fuel combustion, combustion of diesel components, atmospheric dust, and cooling water. Moreover, under high-temperature conditions, oil undergoes rapid oxidation and evaporation, resulting in the accumulation of by-products that significantly alter its properties. Consequently, comprehensive insights into diesel engine performance can be gleaned from analyzing oil friction particles, which provide invaluable information regarding developing defects in parts and assemblies, as well as the operational efficacy of oil, fuel, cooling, and air filtration systems.

To ensure the reliability of diesel engine condition assessments, it is imperative to not only monitor the dynamics of corrosion-formed particle concentrations in the oil but also adhere to stringent requirements in selecting and analyzing oil samples.

Conclusion. The methodology for evaluating the technical condition of a diesel locomotive's crankshaft has been enhanced through the determination of temperature parameters. This enhancement enables the establishment of principal criteria for assessing the technical state of a diesel locomotive's crankshaft by ascertaining the requisite temperature parameters essential for both inter-repair operation intervals and scheduled maintenance and repair events (TI, TR, and CR). Consequently, through extensive theoretical and empirical investigations, it has been discerned that the innovative technical solutions developed will enable the precise determination of temperature parameters for diesel locomotive engine crankshafts under diverse operational conditions. This advancement holds the potential to bolster reliability and preempt diesel locomotive failures attributable to crankshaft malfunctions.

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