Diagnosing the technical condition of the diesel cylinder-piston group

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Abstract. The reliability of locomotive diesel engines largely depends on a timely and objective assessment of the technical condition of its equipment during operation. The article proposes a technique for the integral assessment of the technical state of the quality of the working process in a diesel cylinder using on-board diagnostics.

1 Introduction

Improving the operational efficiency and reliability of diesel locomotives requires continuous monitoring of the technical condition of their equipment during operation. The problem of a reliable assessment of the quality of the working process in the cylinders of a diesel locomotive and the technical condition of the fuel equipment and the cylinder-piston group determining it is currently being solved by stationary and on-board diagnostic tools based on the analysis of the indicator diagram of the working process. The use of such an approach for continuous monitoring of the technical condition of a diesel locomotive in operation is impossible for several reasons, the main of which is the lack of technical capability to continuously measure the pressure in the diesel cylinder, which is necessary to remove the indicator diagram. In this regard, the task of developing methods for the integral assessment of the quality of the working process in the cylinder of a diesel locomotive using a limited set of parameters controlled by modern means of automatic control of the power plant of the locomotive is urgent [1-15].

One possible way to solve such a problem is to continuously monitor the characteristic dependencies connecting various diesel engine's working process parameters, invariant concerning the diesel engine operating mode but reacting to its technical state.

One of them is the dependence of the relative change $\overline{\Delta \mathrm{T}_{\mathrm{OG}}}$ in the exhaust gas temperature on the relative change $\overline{\Delta a}$ in the excess air ratio in the diesel cylinder.

It was shown in [1] the work that these quantities are related by a dependence of the form:

$$\overline{\Delta T_{OG}} = -b \cdot \overline{\Delta a}\,, \qquad (1)$$

Where b is the proportionality coefficient determined by the design and organization of the working process of a serviceable diesel engine.

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An increase in the cycle supply in the cylinder of a serviceable diesel engine leads to a decrease in the excess air ratio and an increase in the temperature of the exhaust gases at the outlet from the cylinder following relationship (1).

In the event of a violation of the normal course of the working process in the cylinder during operation (for example, due to a change in the fuel feed advance angle, deterioration in the quality of mixture formation due to a malfunction of the fuel equipment), the quality of mixture formation in the cylinder changes significantly, and this change is not associated with the value of the excess air ratio, as a result of which the value of the coefficient b in formula (1) changes. This can be used as a diagnostic sign of deterioration of the technical condition of the cylinder and serve as the basis for setting it for stationary diagnostic control [1, 9].

2 Methods

To verify the conclusions made, a study was made of changes in the parameters of the diesel engine working process during its operation according to load characteristics on a mathematical model of the working process. In the course of the study, the operation of a diesel engine with different crankshaft rotational speeds (at different positions of the driver's controller) was simulated with a change in the cyclic fuel supply and maintaining a constant boost pressure. The results are shown in Figures 1-3 [2, 3, 9].

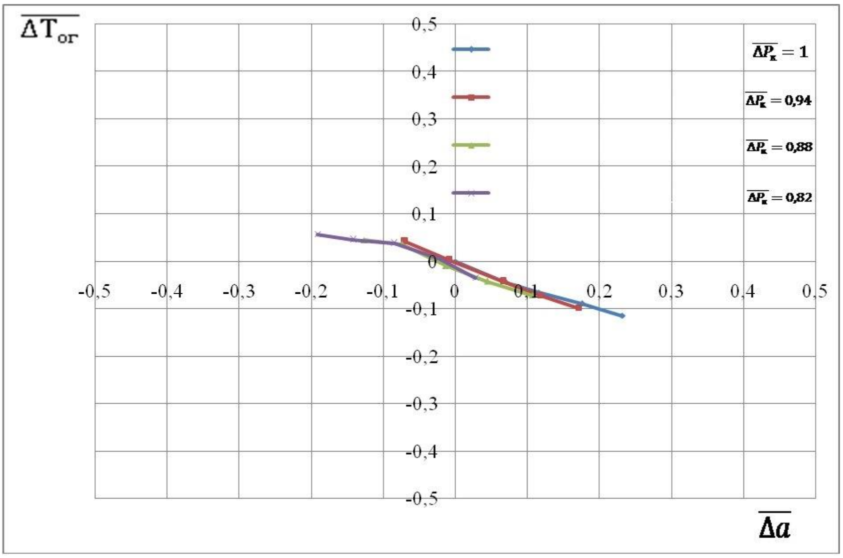

Fig. 1. Dependence of the relative change in the temperature of the exhaust gases on the relative change in the excess air ratio at 11 positions of the driver's controller

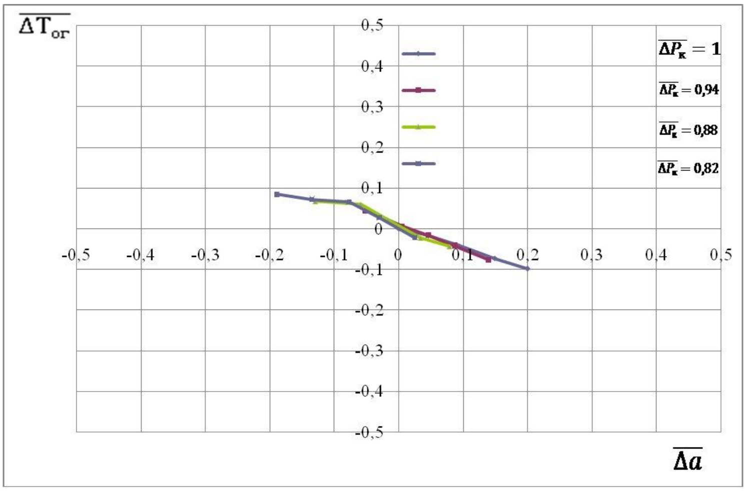

Fig. 2. Dependence of the relative change in the temperature of the exhaust gases on the relative change in the excess air ratio at 13 positions of the driver's controller

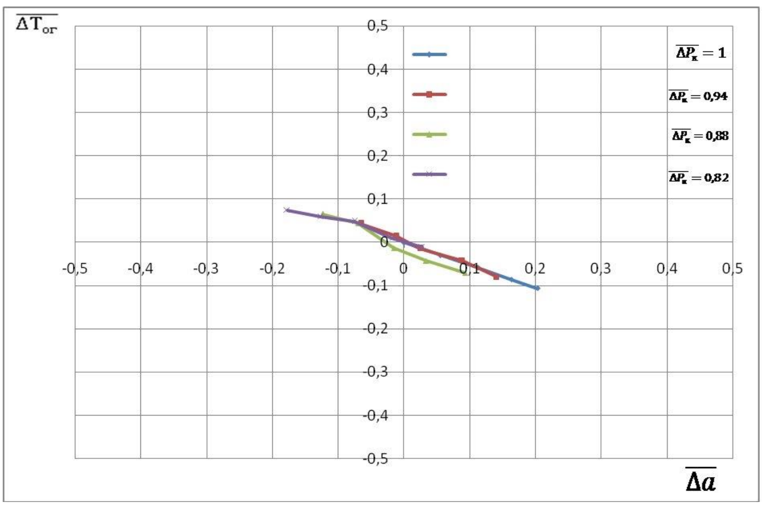

Fig. 3. Dependence of the relative change in the exhaust gas temperature on the relative change in the excess air ratio at 15 positions of the driver's controller

Their analysis shows that the relative change in the temperature of the exhaust gases of the diesel engine is practically proportional to the relative change in the excess air ratio in the cylinder and depends little on the change in the boost pressure.

To check the reliability of the results obtained on the mathematical model of the working process, experimental studies were carried out. The 1A-5Д49 diesel engine of the UzTE16M diesel locomotive was chosen as the object of research. The figure №4 shows the distribution of the operating time at the controller positions of the UzTE16M diesel locomotive driver [4, 9].

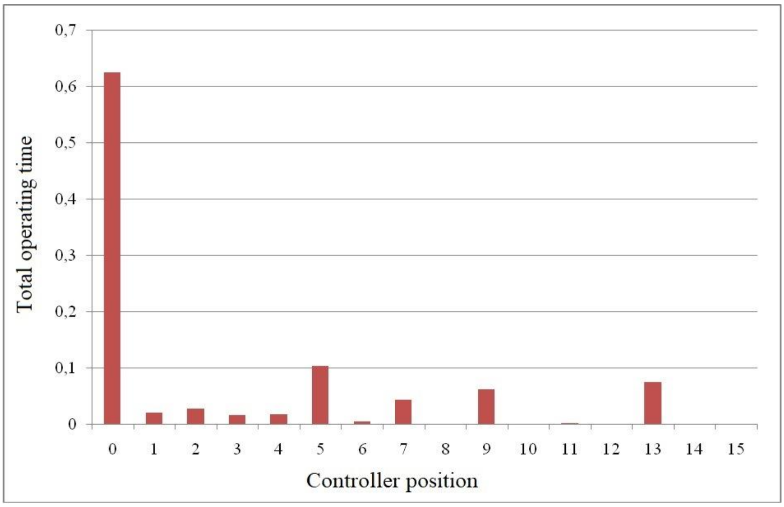

Fig. 4. Distribution of the operating time at the controller positions (the total operating time of the DE 620 was minutes).

Its analysis shows that the main part of the time, the diesel engine works in non-rated operating modes, and up to 62.53% of it falls on the idle mode. The main operating time of the diesel engine under load falls on the 5th, 7th, 9th, and 13th positions of the driver's controller.

The results of processing the data accumulated by the standard on-board recorder of the locomotive for the 13th position of the controller for one of the cylinders are shown in Figure 5.

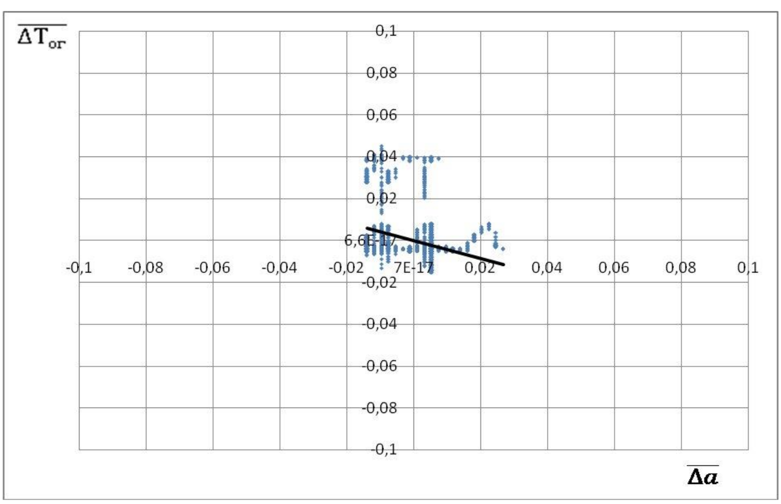

Fig. 5. Dependence of the relative change in the temperature of the exhaust gases on the relative change in the excess air ratio at 13 positions of the driver's controller in operation

The scatter of operating points in Fig. 5 is associated with the presence of transient processes caused by the switching on and off of auxiliary units of the locomotive, stages of weakening of the field of traction electric motors, the thermal inertia of thermocouples, and an error in measuring the values of the parameters of the state of the diesel engine. Nevertheless, statistical processing of the results of monitoring the operating modes of the locomotive, represented by the dots in Figure 5, indicates the presence of a relationship between the relative changes in the temperature of the exhaust gases at the outlet from the cylinder and the excess air ratio in the cylinder, which is close to proportional.

Small relative changes in the diagnostic parameters in Figure 5 are explained by the presence of a combined automatic control system of the diesel - generator set, which ensures the maintenance of a constant cycle fuel supply, independent of the technical condition of the diesel engine (position of the operating member of the diesel regulator) at each position of the driver's controller (at each speed crankshaft).

Under these conditions, a more effective practical implementation of the proposed method for assessing the technical state of the cylinder is to control not the dependence of the form (1), but the area in which the operating points of the diesel engine operating modes will be located on the plane - $\overline{\Delta T_{or}}$ - $\overline{\Delta a}$ (Figure 6). For one cylinder with a constant technical condition, this area remains approximately constant. In the event of a change in the technical condition of the cylinder, other values of the exhaust gas temperature will correspond to the given position of the operating element of the diesel regulator, which will lead to a shift in the area of the cylinder operating modes in the selected coordinate system.

The proposed method for the integral assessment of the technical condition of a diesel cylinder can be implemented as follows.

During rheostat tests of a diesel locomotive after repair or construction, or during trips in which the technical condition of the diesel generator can be considered satisfactory, the reference areas of the operating modes of each of the diesel cylinders are fixed on the coordinate plane $\overline{\Delta T_{OG}}$ - $\overline{\Delta a}$ for several controller positions [5-9].

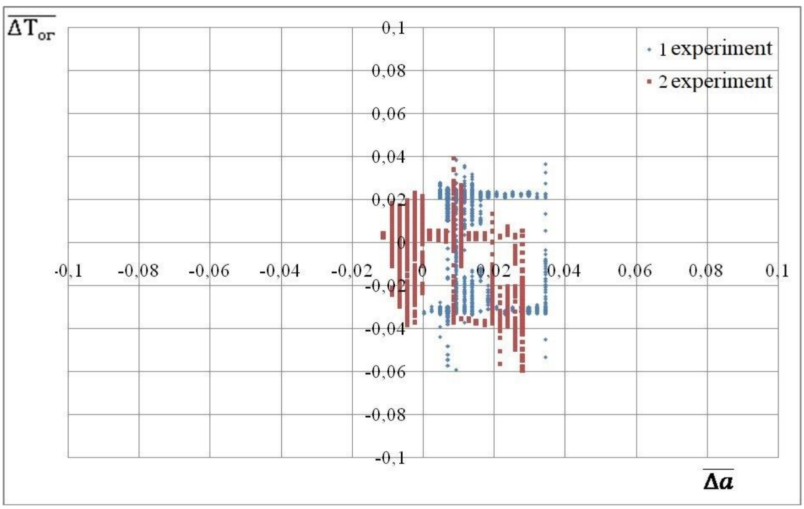

Fig. 6. Comparison of the experimental results relative to the standard during the operation of the diesel engine

3 Results and Discussion

In the course of further operation, the mutual position of the real working area ("spot") of the modes of each cylinder is monitored relative to the reference one for the corresponding positions of the driver's controller. The displacement of these areas will indicate a change in the technical condition of the cylinders.

The very nature of the displacement of the regions of modes for all cylinders will be a very informative diagnostic sign. So, the displacement of the centres of the regions ("spots") of the modes for all cylinders along the axis $\overline{\Delta a}$ with their constant position along the axis $\overline{\Delta T_{OG}}$ will indicate a change in the setting or technical state of the automatic control system of the diesel generator set, and the simultaneous change in the coordinates of the "spots" of the modes of all cylinders in one direction on the coordinate plane may indicate a change in the technical state of the diesel air supply system. Thus, the proposed method for monitoring the technical condition of a diesel engine is complex and allows you to control the change in the technical condition of a number of ДГУ systems. Its efficiency and information content can be significantly increased while simultaneously monitoring other parameters of the power plant, particularly the position of the operating element of the regulator and the power of the generator at each position of the controller.

The coefficient of air excess is one of the key parameters of the working process in the internal combustion engine, in many respects defining indicators of its reliability and profitability in operation.

Values of several other indicators of the working process of the engine are directly connected with the size of coefficient of excess of air, first of all, temperatures of the fulfilled gases. Compliance of relative changes of values of coefficient of excess of air and temperature of the fulfilled gases is the diagnostic parameter characterizing the technical condition of cylinders of the engine [7-9].

The continuous increase in the level of speeding up of diesels in modern locomotives at simultaneous toughening of requirements to their ecological indicators causes the need for improvement of quality of management of the power plant of a locomotive in transitional operating modes. The use of coefficient air excess as an integrated indicator of the current quality of working process in cylinders of the diesel is an essential reserve of improvement in the quality of transients of diesels.

Considering essential results in the measurement of coefficient of excess of air on the pressure of the measured environment (i.e., FG pressure), the optimum decision sensor installation on an exhaust pipe of a locomotive is represented. In this case, the static pressure of FG can be accepted equal atmospheric, and the amendment has to consider only a high-speed pressure of FG at the exit from a pipe which is rather insignificant.

Besides, the probability of excess limit temperature of the sensor significantly decreases at its use on the high-forced diesels. The heater's food chain was carried out directly from cans of the storage battery of a locomotive with a total voltage of 13.6 V.

As appears, the device practically represents Pitot's depressurized tube. Continuous restart-up of gas through the collector reached thanks to an opening 7, provides, on the one hand, the maximum speed of the measuring channel owing to a continuous supply of fresh gas to a sensitive element of the sensor 4, and on the other hand – additional decrease in excessive pressure of FG in a sensor installation site because of pressure losses on collector length. The increased diameter of a collector 5 provides a decrease in a high-speed pressure of gas in a point of installation of the sensor 4 and an increase in the surface of the heat exchange, excluding an overheat of the case the sensor and a connecting cable 6.

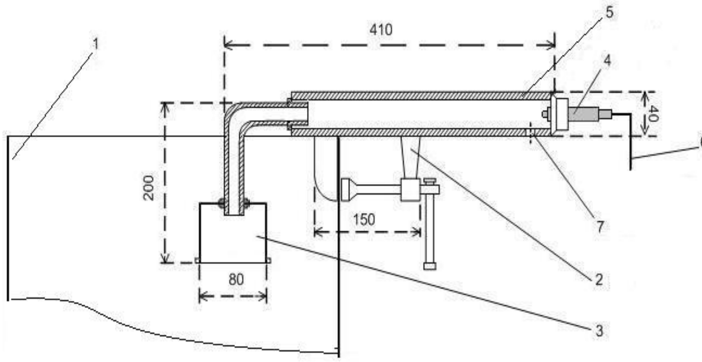

Fig. 7. Device installation for control of coefficient of excess of air on an exhaust pipe of a locomotive: 1 is exhaust pipe; 2 is clamp; 3 is gas intake; 4 is sensor; 5 is collector; 6 is connecting cable; 7 is opening.

As at sensor installation on an exhaust pipe, it controls the content of oxygen in the fulfilled gases at the exit from the diesel, the total coefficient of excess of the air, considering not only the oxygen which has remained from the reaction of oxidation of fuel but also the oxygen of blowing-off air will be the output parameter of the device.

In the course of the laboratory, researches of the device coefficients of K, K_d, and Ki of the PID-regulator were defined during the operation of the sensor in the open air.

The bench of tests on the device for controlling the size of coefficient air excess of the diesel was carried out on a locomotive UzTE16M of sec. No. 0036. Parameters of an operating mode of diesel-generator installation in the course of tests were determined by data of the on-board store of a locomotive. Synchronization of data on time was carried out through manual installation of identical time on the computer of the console device of indication of the locomotive, which is carrying out the accumulation of data, and on the computer of the device within ±0.5 sec.

In the course of tests, some sets of positions of the driver's controller (to the 10th) with the endurance of time on each position, the established operating mode of the diesel generator necessary for achievement was carried out.

In figure 8, the dependence of the total coefficient is presented destroyed air of the diesel 1A-5D49 of a locomotive UzTE16M from the frequency of rotation of a cranked shaft of the diesel during its work on the diesel characteristic [9].

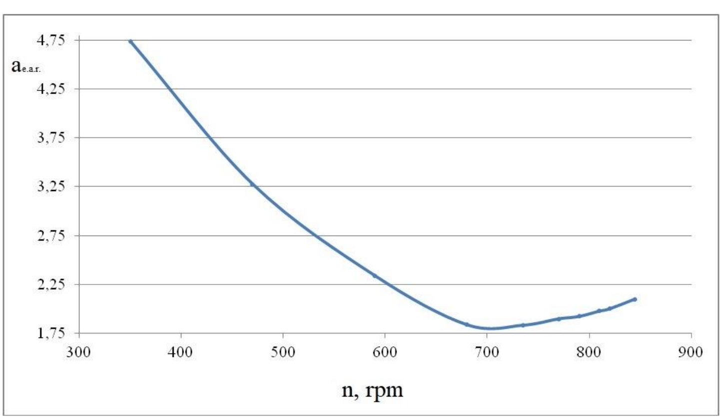

Fig. 8. Dependence of coefficient of excess of air on the frequency of rotation of a cranked shaft

4 Conclusion

The results of the work given in the article testify to the operability of the developed model sample of the device for control of coefficient of excess of air of the diesel. This device can effectively be used to manage the diesel-generator installation of a locomotive in transitional operating modes and for control of the technical condition of the diesel in on-board and stationary diagnostic aids.

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