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Features of Environmental Diagnostics of Heat Motors and Boiler Plants by Information Methods

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Abstract. Environmental friendliness is one of the most important indicators of the quality of modern heat engines and boiler plants, due to the significant negative impact of the chemical and physical nature of these objects on the environment. When creating modern measurement information systems to determine the environmental performance of boiler plants and heat engines, the following goals are set: ensuring a wide scope of use and a long life of equipment, increasing its compactness and mobility, ensuring the high accuracy and cost-effectiveness of using these systems. Therefore, the task of creating a universal system for the ecological diagnosis of heat engines and boiler rooms, which take measures to improve the efficiency of measurements, is appropriate. The purpose of the work was to create and experimentally work out an automated, non-versatile system for ecologically diagnosing heat engines and boiler installations of various purposes according to the indicators characterizing the material and physical pollution of the environment. The technical solution of realization of system of ecological monitoring and diagnostics of heat engines and boiler rooms by information methods is offered. The structure, composition and functional purpose of the basic modules of this system are shown: instrumental, test-demonstration and laboratory.

Keywords: Automotive transport · Diagnostic system · Pollution monitoring

1 Introduction

Today, environmental friendliness is becoming one of the most significant indicators of the quality of modern heat motors (HM), mobile ones and boiler plants (BP) used in the energy sector, industry, communal and other areas. This is due to the significant

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negative impact of HM and BP on the environment: the emission of greenhouse gases and pollutants (pollutants) into the atmosphere, acoustic pollution of residential territories, etc.

When conducting environmental diagnostics, HMs and BPs face the problem of the need to increase universality and accuracy of measuring equipment, which is due to the phased improvement of environmental regulatory documents, the expansion of the scope of environmental standards, and a decrease in the levels of monitored indicators. In these conditions, the creation of effective systems for the environmental diagnosis of HE and BI, corresponding to current and perspective regulatory requirements, with a wide application area is an actual direction for research [1–3]. Wherein, this system should have such properties as: universality: the ability to diagnose HM and BP; high accuracy of measurements at the minimum cost of equipment; compactness, mobility and convenience in operation; ability to improvement.

The purpose of this work was to create a system for the environmental diagnosis of HM and BP (called further as a diagnostic system) using information methods to increase the effectiveness of monitoring indicators of chemical and physical pollution of the environment. For this, the following tasks were solved: (1) the creation of a system diagnostic in accordance with the requirements of regulatory documents - UNECE Regulation R-49, R-83, R-96, ISO 8178, etc.; (2) the realization of information methods increase efficiency environmental performance monitoring HM; (3) experimental studies of the diagnostic system and information methods on full-scale objects.

2 Description of the Diagnostic System

Based on the world and their own experience in the creation and operation of equipment for the environmental monitoring of energy installations reflected in works [4–8], by the authors developed a universal, multi-functional diagnostic system, allowing to determine the following environmental indicators: concentration of pollutants in the exhaust gases of HM, flue gases BP and atmospheric air; mass, specific and average operational emissions of pollutants; noise levels, thermal pollution, vibration; surface concentrations of pollutants in atmospheric air, etc.

The diagnostic system consists of 3 functional modules (see Fig. 1).

The instrumental module is designed for execution directly monitor the technical and environmental indicators of the studied objects using: - a multi-channel portable gas analyzer OKSI-5 M, a compact PM emission control system - MKT-2 [9], a sound level meter-registrar DT-6652, a thermal imager Testo 871, a vibration meter VM6360 and etc.

Testing and demonstration module is intended for testing measuring of appliances and equipment, simulation modeling of selection and analysis gas samples, demonstrating the principles of operation, technical capabilities and operating rules for environmental diagnostics of HM and BP in the preparation of qualified specialists.

The laboratory module is intended for carrying out the qualitative and quantitative analysis of gas samples taken during the study of sources of environmental pollution using photometric, gravimetric, ionometric and other measurement methods.

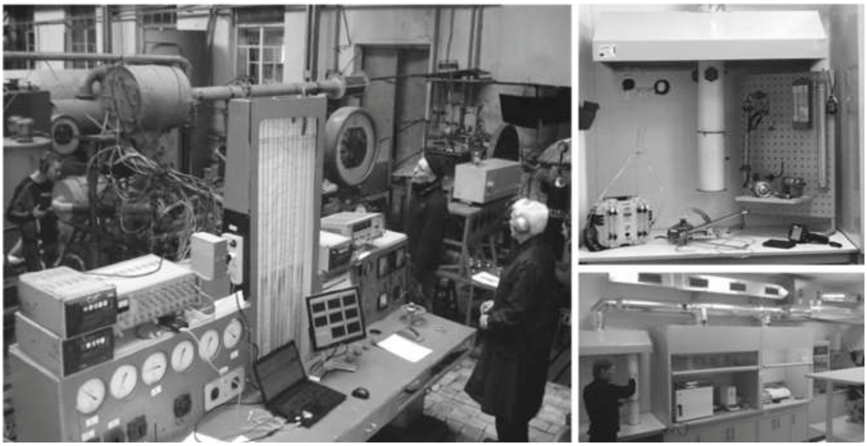

Fig. 1. Appliances and equipment of diagnostic systems.

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3 Information Methods to Improve the Efficiency of Control

In the diagnostic system are implemented information methods for monitoring and improving the accuracy of measuring the average operational emissions of gaseous pollutants and PM - indicators GAS and PT, measured in accordance with the requirements of the UNECE Regulation R-49, R-96 and standard ISO 8178.

3.1 Method for Assessing the Accuracy of Measurements of GAS and PT

This method allows you to determine the resulting measurement error of the indicated of these values – δGAS, δPT as the error of the result of indirect measurements [10]:

$$\delta y = \frac{1}{y} \cdot \left(\sum_{j=1}^{m} \left(\frac{\partial y}{\partial x_j} \cdot \partial x_j \cdot x_j \right) \right)^{0.5} \tag{1}$$

where: y - the value determined by calculation from the known dependence y = (x_1, x_2, …, x_m); x_1, x_2,…, x_m - values measured directly during the testing quantity m; δx_i - known error measurement of quantities of x_i.

As a result of applying this formula to the dependencies for determining the values of GAS and PT established by the ISO 8178 standard, the expressions:

$$\delta GAS = \sqrt{\delta M_{gasi}^2 \cdot \sum_{i=1}^{n} \left(WF_i \cdot k_{Mgas}\right)^2 + \delta P_i^2 \cdot \sum_{i=1}^{n} \left(WF_i \cdot k_{p_i}\right)^2} \quad (2)$$

$$\delta PT = \sqrt{\delta m_j^2 + \delta m_{sam}^2 + \delta G_{edf}^2 + \delta P_i^2 \cdot \sum_{i=1}^{n} \left(WF_i \cdot k_{p_i}\right)^2} \quad (3)$$

where: δM_{gasi}, δP_{ei}, δm_f, δm_{sam}, δG_{edf} – errors of direct measurements of quantities: mass emission of gaseous pollutants, engine power, mass of PM collected on the filter, sample weight and equivalent mass flow in the sampling system, respectively; n – number of test cycle modes; WF_i – weight coefficient of the i-th test mode; K_{Mgasi}, K_{Pei} – coefficients taking into account the influence of M_{gas} and P_e values on the accuracy of measurements of GAS and PT, determined experimentally.

The dependencies (2) and (3) can be used in the analysis the influence of errors of the measuring equipment for the accuracy of determining the GAS and PT values.

3.2 Method for Improving the Accuracy of Measuring the Indicator PT

This method is implemented in the MKT-2 microtunnel and makes it possible to increase the accuracy of measurements of the indicator PT due to accounting the methodological error of measurement of a given quantity - δPT_t, which arises due to influence of the sample temperature in front of the sampling filter - t_f on the measured PM mass emission - m_{pm} [4, 6] (see Fig. 2). The temperature t_f during PT control depends on the temperature of the air entering the tunnel – t_{dil} and the maximum sample temperature in the tunnel - $t_{f(max)}$, which, in accordance with the requirements of standard ISO 8178, can change in the ranges: t_{dil} = 20–30 °C and $t_{f(max)}$ = 42–52 °C.

Based on the analysis of the results of experimental studies of error δPT_t, given in the works [4–6, 11–13], the authors proposed a dependence for its determination [14]:

$$\delta PT_t = \sum_{i=1}^{n} k_{\mathit{mode}i} \cdot \cdot K_{Mpmi} \cdot \left(t_{fi} - t_{f0i}\right) \quad (4)$$

where: K_{modei} – a coefficient that takes into account the influence of the engine operating mode on the quantity δPT_t, determined by the method described in work [9]; K_{Mpmi} – coefficient equal to the ratio of the mass emission of PM in the i-th mode to the average per cycle of PM emission; t_{fi} – the actual value of the sample temperature in the i-th mode; t_{f0i} – sample temperature at the i-th mode, taken as the base temperature and corresponding to the values t_{dil} = 20 °C and $t_{f(max)}$ = 52 °C.

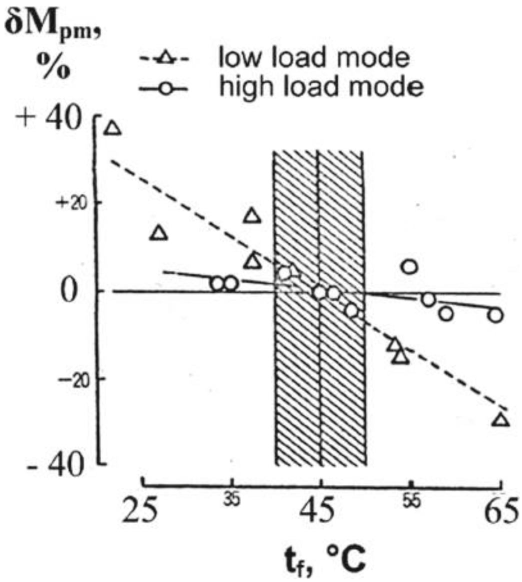

Fig. 2. Experimental data on the effect of t_f per measured mass emission PM [4].

4 The Analysis of the Diagnostic System Testing

The diagnostic system was tested on full-scale objects: transport diesels: automotive – 4CHN12/14, tractor - D65M, diesel locomotive - diesel train engine DEL-01 (see Fig. 3) and boiler units: gas - DKVR-20/13 and AOGV-100E and solid fuel - KCHM-2 M-4. As a result of tests of these engines in cycles established by the UNECE Regulation R49, R-96 and standard ISO 8178, the coefficients K_P, K_{Mgas} and K_{Mpm} used to assess the accuracy of measurements of GAS and PT (see Table 1) the resulting errors are investigated measurements of these quantities and the range of variation of the methodological error δPT_t was determined (see Fig. 4).

Analysis of the results shows the following.

The resulting measurement errors of the GAS and PT provided by the system diagnostic are: $\delta GAS = \pm 2.8\%$, $\delta PT = \pm 4.3\%$; at the same time, the greatest influence on the accuracy of measurements of the GAS has the error in measuring engine power - δP_{ei}, on the measurement accuracy of indicator PT - the measurement error of PM mass is δm_f; increase in the accuracy of measurements of P_{ei} and m_f 2 times values allows us to reduce the errors of δGAS and δPM by 17% and 21%, respectively.

The range of variation of the methodical error δPT_t is: -2.7–6.3%, with the greatest value exceeding 5%, this error takes when t_{dil} = 20–22 °C and $t_{f(max)}$ = 42–44 °C; to eliminate the error δPT_t and improve measurement accuracy PT in the tunnel can control the temperature of the sample.

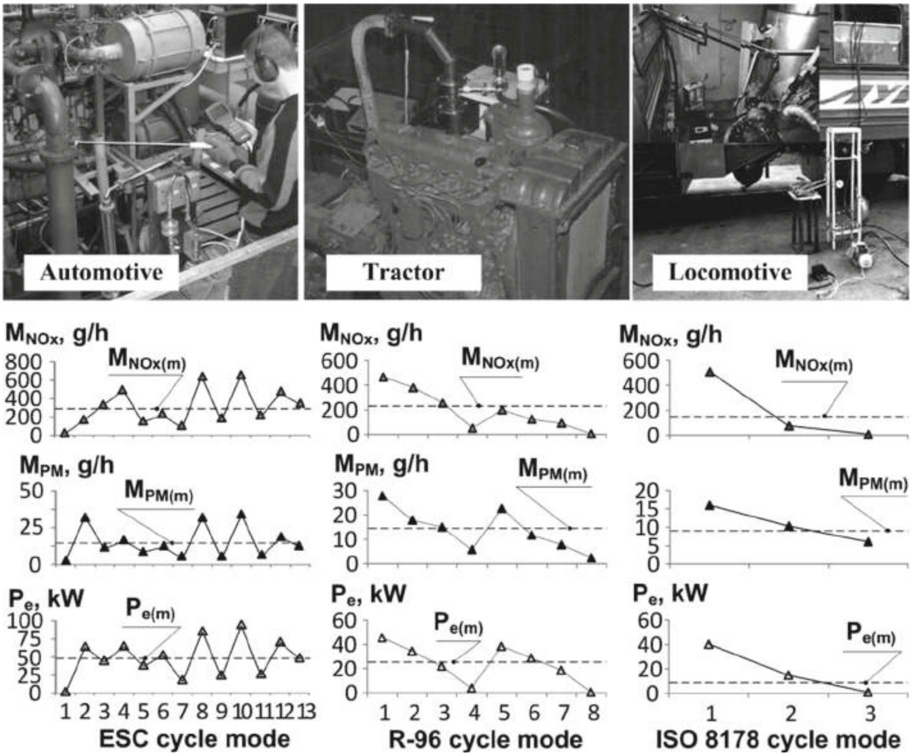

Fig. 3. The results of environmental diagnostics of transport diesel.

Table 1. The results of determining the coefficients KPi, KMgasi and KMpmi, during the tests of the diesel D65M on the cycle R-96.

Coefficient	Coefficient value in cycle mode R-96							
	1	2	3	4	5	6	7	8
KP	1,86	1,41	0,91	0,16	1,57	1,18	0,77	0,03
KMgas	2,19	1,78	1,19	0,25	0,94	0,59	0,44	0,03
KMpm	1,96	1,26	1,05	0,40	1,59	0,82	0,54	0,16

In modes 1, 3 and 8 three repeated measurements were made and the error in reproducibility of the experiment was determined by the method [10], which was: for the K_P – ± 3,7–5,5%; for K_{Mgas} – ± 2,2–4,8%; for K_{Mpm}, – ± 4,0–7,1.

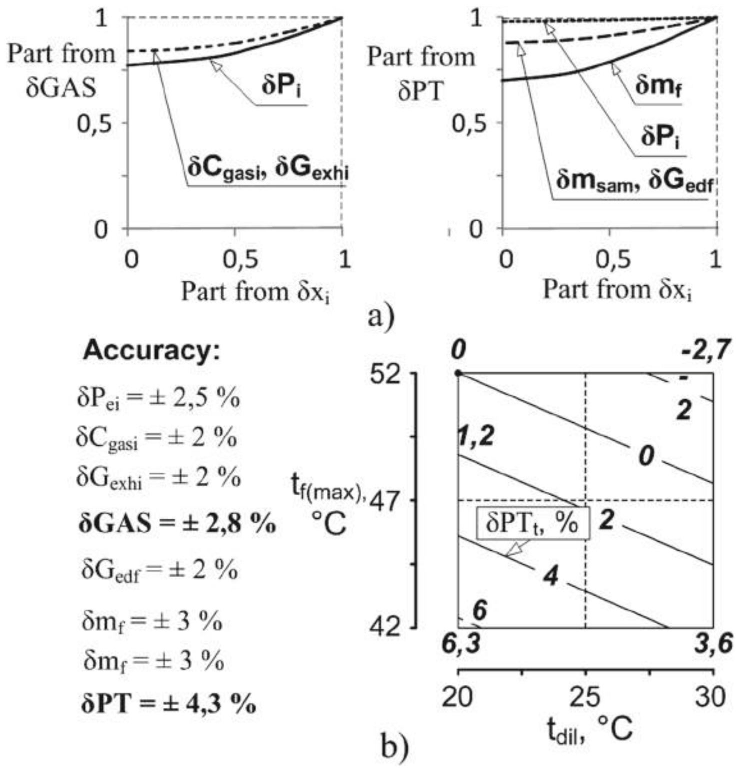

Fig. 4. The accuracy of the system diagnostic.

5 Conclusion

A universal, multifunctional system of environmental diagnostics of HM and BP has was created, allowing to determine indicators characterizing the chemical and physical impact of these objects on the environment: concentrations, mass, specific and average operational emissions of pollutants, noise, thermal pollution, vibration. This measuring system consists of instrumental, testing, demonstration and laboratory modules and, what allow use it like diagnostic tool, a training and test bench and laboratory; and apply it in various fields: transport, energy, environmental and educational fields.

The system diagnostic implements information methods for monitoring and improving the accuracy of measurements of average operational emissions of pollutants: a method for determining the resulting measurement errors of the average operational emissions of gaseous pollutants and PM - δGAS and δPT, which allows one to evaluate the effect on the data of the errors of the measuring equipment of the system diagnostic; a method for increasing the accuracy of measurements of the PT indicator by taking into account the methodological measurement error of this values - δPT_t, due to the influence of the sample temperature in the tunnel on the measured PM emission.

Carried out experimental studies of the system diagnostic and information methods on full-scale objects: transport diesels: automotive - 4CHN 12/14, tractor - D65M, diesel locomotive - diesel train engine DEL-01 and boiler units: gas - DKVR-20/13 and AOGV-100E and solid fuel - KCHM-2 M-4. Transport diesels were tested according to the cycles established by the Regulations R-49, R-96 and the ISO 8178 standard, which allowed us to obtain the following results: the coefficients K_{Pi}, KM_{gasi} and K_{Mpmi} used to calculate the errors δGAS and δPT were established; the values of these errors were determined when using the diagnostic system: δGAS = ± 2,8% and δPT = ± 4,3%; it was found that the greatest influence on the value of δGAS is exerted by the error in measuring engine power, and on the value δPT is the error in measuring PM mass; defined the range of variation of the error δPT_t –2,7– + 6,3%.

In the future, on the basis of the diagnostic system, an educational and scientific center will be created to study the environmental problems of transport and energy.

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