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Locomotive Diesel Engine Excess Air Ratio Control Device

Mukhammad Valiev, Khusan Kosimov

Summary— ***The wide-band exhaust gases oxygen content sensor can be used for continuous monitoring of the air excess coefficient in the locomotive diesel engine cylinders. This type sensors are widely used in automotive diesel engines control systems. It means for indirect estimation of the engine cylinders mixture quality by the exhaust gases oxygen content***

Keywords: Oxygen sensor, air ratio, fuel injection equipment, the cylinder-piston group

I. INTRODUCTION

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

Values of a number of other indicators of 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 (FG). Compliance of relative changes of values of coefficient of excess of air and temperature of the fulfilled gases is the diagnostic parameter characterizing technical condition of cylinders of the engine [1].

The continuous increase in level of speeding up of diesels in modern locomotives at simultaneous toughening of requirements to their ecological indicators causes need of 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.

On "Locomotives and Locomotive Economy" chair of Tashkent Railway Engineering Institute which is based on the means of communication, organized the model sample of continuous control of size coefficient of air excess in diesel. On the basis of the broadband sensor of the content of oxygen in the fulfilled gases is developed, made and tested. In article features of a design of the device are described and some results of its tests are given.

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1 . The oxygen content sensor in the fulfilled gases of the diesel

Basic element of the device is the sensor of the content of oxygen in the diesel the fulfilled gases (FG). Now such sensors (oxygen sensor) are widely applied in control systems of automobile engines to optimize the process of regulation of fuel feeding both in established models, and in transitional operating modes. So-called narrow-band sensor which is the effective detector of stochiometric composition of the mix, allowing modern control systems of automobile engines to maintain value αs=1 with an accuracy of ±1%. are more often used in the petrol engines. Both high fuel profitability of the engine, and increase in a resource of work of catalytic converters are reached in this process.

However, the use of it to control the value of coefficient of air excess in poor mixes (αs> 1) is almost impossible. So-called broadband sensors of the content of oxygen are applied to these purposes in FG (fig. 1).

Broadband sensors have two cells - measuring 1 and a cell of a rating 2. The cell of a rating represents a galvanic cell with the firm ceramic zirconium electrolyte. Both electrodes are washed by the fulfilled gases. The external electrode is shipped in a stream of FG of a final collector, to an internal electrode of FG are brought through a special opening (a diffusive barrier) 3 in firm electrolyte. Putting tension to electrodes of a cell of a rating (entrances of Ip and Vs/Ip in fig. 3), it is possible to operate transfer of ions of oxygen between cell electrodes.

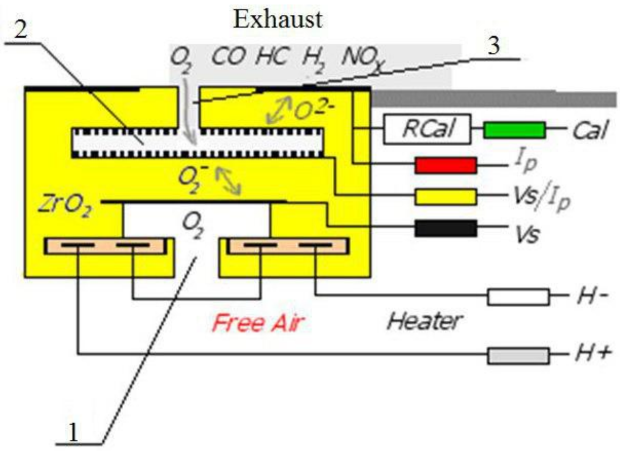

Fig. 1. Scheme of the zirconium broadband sensor of oxygen.

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1 – measuring cell; 2 – rating cell; 3 – opening in electrolyte.

At the positive potential of an entrance of Ip concerning an entrance Vs/Ip transfer of oxygen will be carried out from an internal electrode of a cell of a rating to external, at the negative potential of IP - in an opposite direction. Changing the size of current IP (tension between electrodes of a cell rating), it is possible to achieve removal from a cell of all oxygen. The size of current Ip is necessary for this purpose and it will depend on the content of oxygen in FG. Thus, constantly supporting in a rating cell the zero maintenance of ions in oxygen, it is possible to estimate the size of IP.

The measuring cell of 1 sensor is intended for controlling the content of oxygen in a cell of a rating 2. Its external electrode is in a rating cell, owing to what the output tension of Us of a measuring cell characterizes a ratio of concentration of oxygen in a cell of a rating and atmospheric air. In the absence of oxygen on an external electrode of a zirconium galvanic cell this tension is equal 450 mV. Thus, supporting US tension of equal 450 mV due to change of current of a rating of IP, it is possible to estimate in size of this current the content of oxygen at diesel OG.

To produce the model sample of the control unit of diesel air excess coefficient and also to carry out pilot studies the broadband LSU 4.2 sensor of BOSCH [2] firm was chosen.

The calibration curve of the sensor for temperature 20’C, temperatures of a ceramic basis of the sensor 750’C and zero excessive pressure of the measured environment is presented in fig. 2.

In the presence of excessive pressure of the measured environment (the fulfilled gases) the result of measurement has to be corrected. Correction is carried out by reduction of real value of current of a rating of IP to normal conditions with use of the following dependence:

$$I_P(P_O) = \frac{I_P(P)}{\frac{P}{k+P} \cdot \frac{k+P_O}{P_O}} \qquad (1)$$

where equivalent value of current of a rating for normal conditions (Ro of =1,013 bars), мA;

the valid value of current of a rating for excessive pressure P, мA;

correction coefficient, for αЦ> 1 k=0,47 of bars.

The main absolute error when measuring the coefficient of excess of air at αЦ =1.7 according to firm – the manufacturer for temperature of the measured environment 20’C, temperature of a ceramic basis of the sensor 750 C and zero excessive pressure of the measured environment is presented in table 1.

Tab. 1

Main absolute error of measurement of the LSU 4.2 sensor

	New sensor	After an operating time of 200 h	After an operating time of 2000 h
$\Delta\alpha_Ц$	±0.05	±0.1	±0.15

For other values of coefficient of excess of air the main absolute error of measurement can be estimated on a formula:

$$\Delta\alpha_Ц = \frac{\alpha_Ц}{\alpha_Ц - 1.7} \cdot \frac{\Delta I_p}{I_P} \qquad (2)$$

where αЦ – the current average measured value of coefficient of excess of air;

IP – the current average value of current of a rating, мA;

ΔIP - a mean square deviation of current of a rating, мA.

The relative main error of measurement will make:

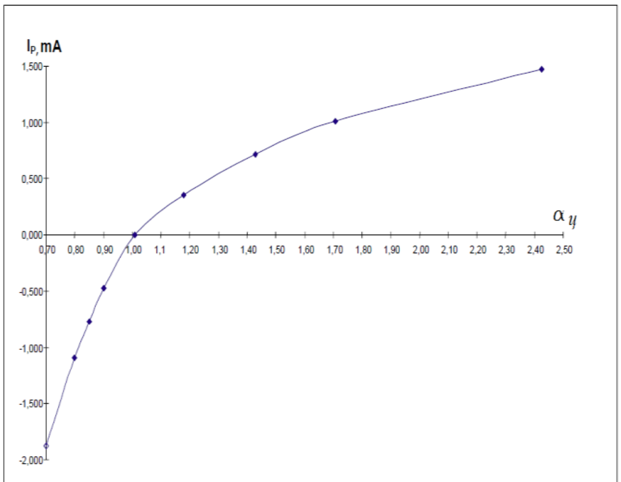
$$\overline{\Delta}\alpha_Ц = \frac{1}{\alpha_Ц - 1.7} \cdot \frac{\Delta I_P}{I_P} \qquad (3)$$

II. CONTROL SYSTEM OF THE SENSOR & RESULTS

As appears in point 1, process of measuring the coefficient of excess of air by the broadband sensor of oxygen assumes stabilization of tension of Us at the corresponding exit of the sensor. It is due to change in current IP and control of size of current. Thus, the scheme of management of the sensor has to represent the regulator of tension of Us which operates influence on current rate of IP.

The block diagram of a control system is submitted by the sensor in fig. 3. It represents astatic PID – the tension regulator of US at the exit of the sensor under the same name. Ballast resistance of RB of 62 Ohms together with the internal calibration resistance of the RCAL sensor provide formation of the standard calibration characteristic of the sensor (fig. 2).

In the model device the regulator was realized on PEVM, thus for controlling the size of tension of US and formation of operating influence of IP, and also managements of current heater of the sensor the interface module which is based on the scheme multipurpose USB – the controler of input-output of USB-4702 of advantech firm was developed and made.



$\alpha_ц$	0,70	0,80	0,85	0,90	1,009	1,18	1,43	1,70	2,42	207
I_P, mA	-1,85	-1,08	-0,76	-0,47	0,00	0,34	0,68	0,95	1,40	2,55

Fig. 2. Calibration curve of the LSU 4.2 sensor for normal conditions.

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III. SENSOR INSTALLATION IN FINAL SYSTEM OF THE DIESEL

Considering essential results in measurement of coefficient of excess of air on 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. Food chain of the heater of the sensor was carried out directly from cans of the storage battery of a locomotive with a total voltage of 13,6 V.

As appears from fig. 4, 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 decrease in a high-speed pressure of gas in a point of installation of the sensor 4, and also increase in a surface of the heat exchange, excluding an overheat of the case of the sensor and a connecting cable 6.

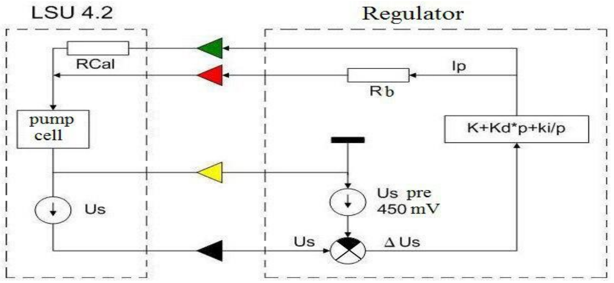

Fig. 3. Block diagram of a control system of the LSU 4.2 sensor.

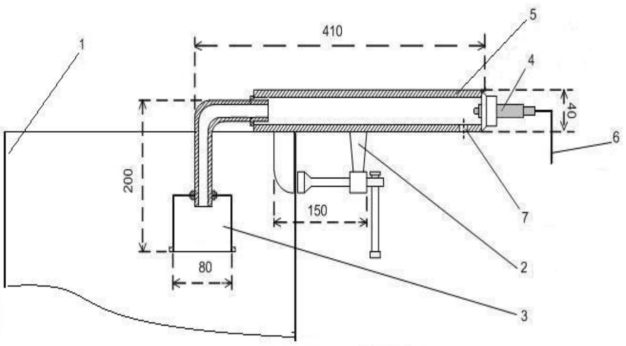

Fig. 4. Device installation for control of coefficient of excess of air on an exhaust pipe of a locomotive: 1 – exhaust pipe; 2 – clamp; 3 – gas intake; 4 – sensor; 5 - collector; 6 – connecting cable; 7 - opening.

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 reaction of oxidation of fuel, but also oxygen of blowing-off air will be the output parameter of the device.

IV. DEVICE TESTS

In the course of laboratory, researches of the device coefficients of K, Kd and Ki of the PID-regulator (fig. 3) were defined during the operation of the sensor in the open air.

Bench of tests on the device for controlling size of coefficient air excess of the diesel were carried out on a locomotive 2TE116U of sec. No. 0036.

Parameters of an operating mode of diesel-generator installation in the course of tests were determined by data of the onboard store of a locomotive. Synchronization of data on time was carried out by means of manual installation of identical time on the computer of the console device of indication of the locomotive which is carrying out accumulation of data, and on the computer of the device to within ±0,5 sec.

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

In fig. 5 dependence of 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.

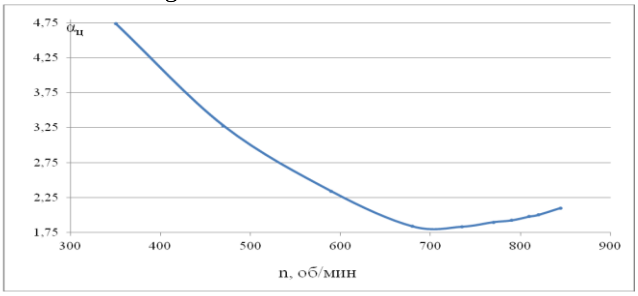

Fig. 5 Dependence of coefficient of excess of air on the frequency of rotation of a cranked shaft

Change of coefficient of excess of air and some other parameters of working process of the diesel in transient is given in fig. 6.

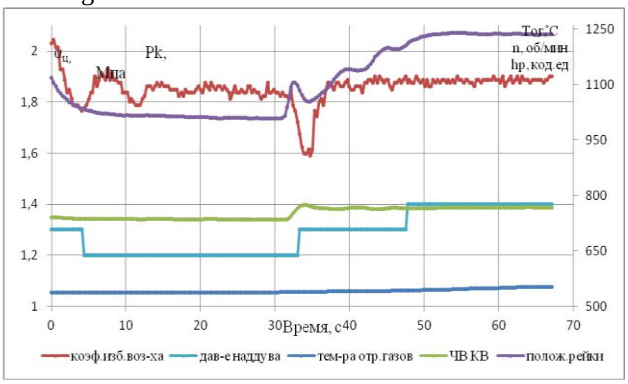

Fig. 6 Transitional the process caused by the translation of the handle of the controler with 5 on 6 controller position.

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V. CONCLUSION

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

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