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Calculation Of The Control Circuit Of The Internal Combustion Engine Of The Vehicle With Account For The Mechatronic Adapter Of The Oxygen Sensor

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ABSTRACT

A control model and elements of the control system of an internal combustion engine are considered, which make it possible to adjust the fuel - air mixture in the intake depending on the operating mode of the internal combustion engine. The aim of the study is to evaluate theoretical ways to improve the performance of the control system for an internal combustion engine, allowing to improve the adjustment of the fuel-air mixture at the engine intake, depending on the mechatronic adapter of the oxygen sensor. Dosing of the amount of fuel depends on the duration and correctness of the signals supplied from the sensors of the mechatronic control system, and affects the ecology of the environment. The duration of the electric pulse of the injector control and the ignition moment are calculated by the microcontroller of the mechatronic engine control system (MSUD) depending on the sensor signals: the composition of the exhaust gases, the opening of the throttle valve, air temperature, engine temperature, engine speed, load and other sensors. The stability of the engine performance is largely determined by the speed of the mechatronic system.

KEYWORDS

Mathematical model, control system, internal combustion engine, fuel injection system, correction, ignition timing, injector response time, mechatronics exhaust gas toxicity.

INTRODUCTION

Fuel injection systems have a number of advantages over carburetor ones. The main thing is accurate metering of fuel and, as a result, more economical fuel consumption.

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Also, we must not forget about reducing the toxicity of exhaust gases and increasing the throttle response [1].

The efficiency of the injection engine operation largely depends on the mechatronic control system and its elements, which provide metered fuel supply to the engine cylinders and the ignition moment [1].

The disadvantages of one or another system of onboard electrical equipment can be eliminated by using adapted control systems. Let's consider them in more detail. PSS

Main part. The control system is an integral part of automotive electrical equipment and can be classified according to the field of application, purpose and type of installation object. Depending on the installation object, power supply systems can be divided into two groups: power supply systems for mobile and power supply systems for stationary equipment [2].

When operating under normal conditions, the performance characteristics of vehicles are significantly influenced by the settings of the electrical systems of vehicles. So, the starting system determines not only its reliability, but also affects engine wear, the fuel injection system, together with the ignition system, determine the composition and quality of ignition of the working mixture, affect the dynamics of the car, the completeness of fuel combustion, fuel efficiency and, consequently, on ecology of the environment.

The control voltage of the mechatronic elements of the internal combustion engine can fluctuate up to 5.5 V at 12 V on-board network [2].

Changes in the elements of the mechatronic system can lead to unstable operation of the fuel injection system of an internal combustion engine. Consider one of the elements, the engine oxygen sensor at the outlet. Depending on their signal, fuel is dosed, it is sprayed in the combustion chamber (intake manifold) and a fuel-air mixture is formed. When the catalytic converters are worn out, the oxygen sensors themselves are malfunctioning, or when the catalysts are replaced with another type of Euro standard, problems may arise with the adaptation of signals received from the sensors for determining oxygen in the composition of the exhaust gases [2].

The fuel injection system, together with the ignition system, determine the composition and quality of ignition of the working mixture, affect the dynamics of the car, the completeness of fuel combustion, fuel efficiency and, therefore, the ecology of the environment.

To correct the oxygen sensor signal, you can use an adapter for calibrating the signal supplied to the electronic control unit when using alternative types of catalysts in place of standard different types of Euro standards [2].

The work of mechatronic control is carried out as follows. In accordance with the built-in algorithm, the electronic control unit provides at the right time a voltage pulse is supplied to the injector and adjusts the ignition timing [7; 8; 9].

It would seem that the problem of adapting an oxygen sensor is solved in an elementary way: it is enough to connect an additional active resistance in series to the sensor wiring. However, such a decision is erroneous: with an increase in R, the tav time for signaling really decreases, but in the absence of adaptation, this can lead to an increase in fuel consumption.

The adaptation of the oxygen sensor of the mechatronic engine control system can be carried out using a signal converter, an adapter connecting it to the circuit, and sending a signal to the electronic control unit.

This work is aimed at evaluating possible ways to adapt oxygen sensor signals.

Let us establish the dependence of the current strength on time.

When the key is closed in the circuit shown in (fig. 1), damped oscillations occur, in which the current strength changes according to the law:

$$i(t) = I_m e^{-\beta t} \sin(\omega t + \varphi), \qquad (1)$$

where $\beta = \frac{R}{2L}$ - damping factor, $\omega = \frac{1}{\sqrt{LC}}$ - cyclic frequency.

We solve equation (1), taking into account the following initial conditions:

1) $t=0,\ i(0)=0$;

2) $t=0,\ U_C(0)=const$.

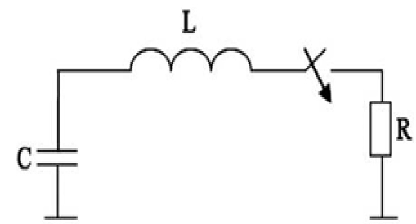

Fig. 1. Equivalent circuit of the oxygen sensor when connected to the adapter

As $i(0)=0$, which follows from the first commutation law, then $U_L(0)=U_C(0)$, hence, $U_C(0) = L\frac{di}{dt}(0)$ and $\frac{di}{dt}(0) = \frac{U_C(0)}{L}$

Substitute the resulting expression into the equation (1): $i(0) = I_m e^0 \sin(\omega t + \varphi) = I_m \sin\varphi = 0$.

From this equation we find $\varphi = 0$, then equation (1) will be written in the form: $i(t) = I_m e^{-\beta t} \sin\omega t$.

We find the derivative, and, expanding the exponent and sine into a functional series and performing mathematical transformations, we find the time during which the current signal reaches the value supplied to the converter of the electronic control unit of the mechatronic system:

$$\frac{U_C(0)}{\sqrt{\frac{L}{C}}} \cdot e^{-\beta t} \cdot \sin\omega t = I_{scecu}, \qquad (2)$$

Expressing time, we get the cubic equation:

$$t^3 + at^2 + bt + c = 0, \qquad (3)$$

To solve the resulting equation, we change the variable by substituting it into equation (3)

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and introducing the notation $p=-a^2/3+b$, $q=\frac{2a^2}{27}-\frac{ab}{3}+c$ we get:

$$y^3+py+q=0, \quad (4)$$

According to the Cardano formula, the solution to the resulting equation (4) is in the form:

$$y=\sqrt[3]{-\frac{q}{2}+\sqrt{\frac{q^2}{4}+\frac{p^3}{27}}}+\sqrt[3]{-\frac{q}{2}-\sqrt{\frac{q^2}{4}+\frac{p^3}{27}}}, \quad (5)$$

The obtained solution makes it possible to estimate the time of signal delivery from the oxygen sensor to the electronic control unit when it is working with the oxygen sensor adapter of the mechatronic control system [1; 12].

If the system is powered from a constant voltage source, the time for signaling the electronic control unit in order of magnitude will be:

$$t=\tau_k\cdot\ln\frac{E}{E-I_{scecu}R_\kappa}.$$

Here $E=12V$, $\tau_k=\frac{0{,}113}{11{,}3}=0{,}002s$, then

$$t=0{,}01\ln\frac{12}{12-0{,}2\cdot 11{,}3}=0{,}002c=2ms$$

Consequently, when the charged capacitor is discharged, the signal is supplied in a significantly shorter time for the signal than when the oxygen sensor is connected to a constant electromotive force source.

Note that for the implementation of a periodic transient process, it is necessary to fulfill the condition:

$$\omega_0^2>\delta^2, \quad (6)$$

Substituting into formula (6) the corresponding expressions for ω_0 and δ, we get:

$$\frac{1}{LC}\geq\left(\frac{R}{2L}\right)^2, \quad (7)$$

After mathematical transformations, we obtain an expression for calculating the resistance of the oxygen sensor adapter circuit:

$$R\leq\sqrt{\frac{4L}{C}}, \quad (8)$$

Let us estimate the resistance of the oxygen sensor adapter at different values of capacitance and inductance $L=10^{-2}$ Hn: at $C=10$ mkF, $R\leq 2\sqrt{10^3}$ Om $C=5000$ mkF, $R\leq 2{,}8$ Om.

Consequently, with the real parameters of the adapter, the transient process is usually close to aperiodic. For this reason, it was decided to increase the output voltage of the converter and include an active resistance in the adapter circuit in order to reduce the time constant of the circuit when constructing a circuit for a converter of electrical energy parameters.

With an increase in the speed of rotation of the crankshaft of the internal combustion engine, the time interval during which the

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signal from the adapter of the oxygen sensor [1] must be supplied decreases.

For the response time, in the first approximation, the following relation should be fulfilled:

$$t_{cp} = k \cdot \frac{60}{n},$$

where n - crankshaft speed, rpm/min k - proportionality coefficient.

The transient process at the real parameters of the adapter is usually close to aperiodic. For this reason, it was decided to increase the output voltage of the converter and to include an active resistance in the adapter circuit in order to reduce the time constant of the circuit when constructing a circuit for a converter of electrical energy parameters.

The functional diagram of the adaptive converter with the electrical energy parameter is shown in (fig. 2). The mechatronic engine management system receives a signal from the adapter, which supplies a converted signal from the oxygen sensor. The inductance current flows through the diode VD1 and charges the capacitor C. The process is repeated, and the voltage across the capacitor increases. The VD1 diode does not allow capacitor C to discharge to the on-board network. The voltage increases until the Zener diode VD2 breaks through, while the voltage at the output from the adapter becomes zero. Capacitor C is no longer charged. In this way, overvoltage protection is carried out.

The voltage control to which the capacitor C should be charged in the operating mode is carried out by a signal from the microprocessor control system of the engine and depends on the operating mode of the engine [1; 7; 9].

The automatic response time control system works as follows. The signal, the frequency of which is proportional to the speed of rotation of the camshaft, comes from the pulse sensors to the driver circuit. From the output of the shaper, rectangular pulses are fed to the waiting multivibrator, which generates pulses of constant duration.

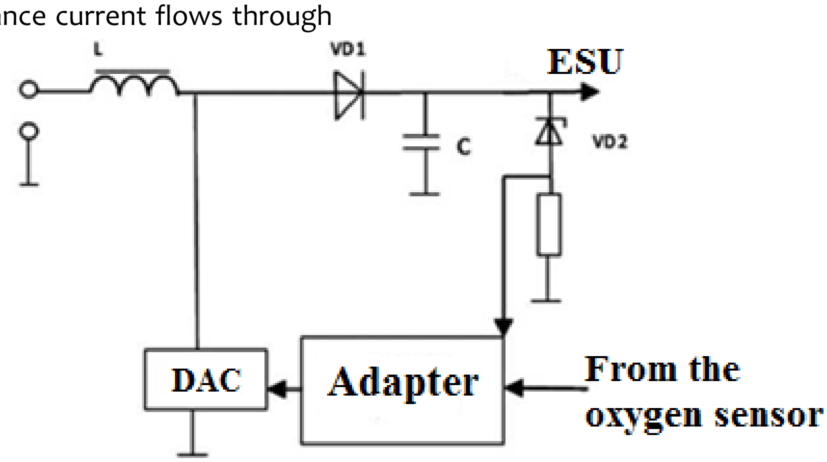


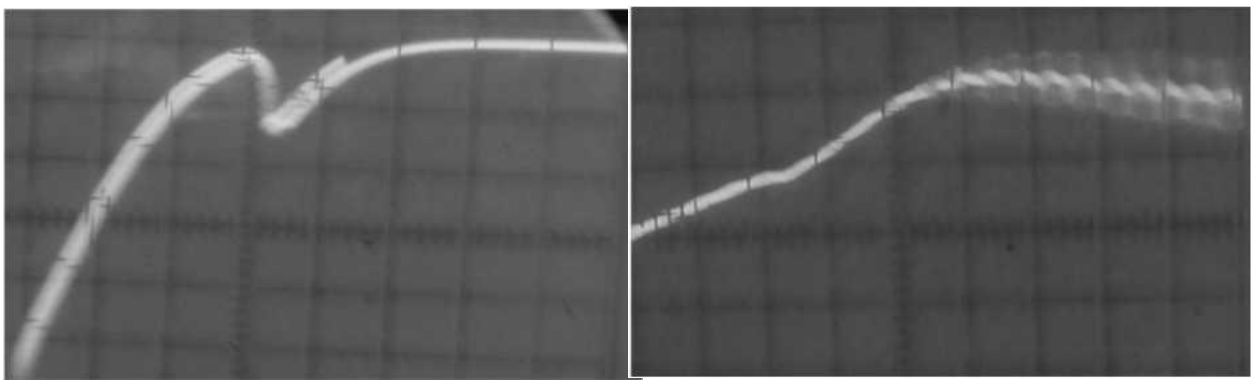
Fig. 2. Functional diagram of the adaptive converter electrical energy parameters.

The mid-level extraction circuit converts the pulse width to a specific voltage level, inversely proportional to the crankshaft speed. he comparator compares the received voltage with the reference voltage, and when the reference voltage is exceeded, it generates a

low output voltage level at the input. The role of the reference voltage is performed by the output voltage of the converter ((fig. 2), supplied through a voltage divider to the input of the adapter [1; 2].

RESULTS AND DISCUSSIONS

Thus, the required dependence of the output voltage of the converter is realized and, accordingly, the response time of the oxygen sensor adapter of the internal combustion engine in automatic mode.



a – sweep duration 0,5 ms/del   b - sweep duration 100 mks/del

Fig. 3. Adapter current oscillograms**: a -** nutrition from **12 V, b -** power supply from the output of the voltage converter

The results of experimental studies fully confirm the assumptions about the dependence of the response time of the oxygen sensor adapter on the voltage to which the output capacitor of the converter of electrical energy parameters is charged. The proposed adapter allows to reduce the response time of the system, which is confirmed by the oscillograms shown in (fig. 3).

CONCLUSION

It was theoretically established that it is possible to regulate the response time of the oxygen sensor adapter when it is powered from a voltage of a varying level. As a result of research:

1. The scheme of the experimental setup for research has been developed, manufactured, tested;
2. Experimental laboratory studies of the signal supply from the oxygen sensor when

   it is powered from an adaptive converter of electrical energy parameters with a constant adjustable output voltage level have been carried out;
3. Experimental laboratory studies of the oxygen sensor signal to the electronic control unit when it is powered by a charged capacitor powered by an adaptive

converter of electrical energy parameters have been carried out;

4. It was found that the optimal signal from the oxygen sensor from an adaptive converter of electrical energy parameters with a constant adjustable output voltage level.

With an increase in the supply voltage, it is necessary to proportionally increase the active resistance of the adapter circuit, which allows, while reducing the response time, to keep the average current level of the adapter unchanged, which contributes to maintaining the reliability of the system.

In the case of an oxygen sensor parameter converter, the signal from the adapter to the electronic control unit can be used.

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