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SIMULATORS OF JOINT WORKING MODES OF FUEL AND FEED AIR TEMPERATURE CONTROL MEANS IN DIESEL ENGINES

V.F. Kalinin, A.V. Shchegolkov

Tambov State Technical University, Tambov

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Abstract: Necessity of joint fuel and feed air temperature control under low temperatures conditions is justified. Specific aspects of PDM parameters of PTC-heater power generation on the basis of simulation are considered.

Symbols: a, b, c, G_{ti} – correcting factors; C_1, C_{par} – a thermal capacity of PTC-heaters material and paraffin, J/(kg·ºC); C_T – a fuel thermal capacity, J/(kg·ºC); h_1 – heater height, m; c – fuel velocity, m/s; D_T – fuel consumption, m^3/s; F_1, F_2 – PTC-heater and fuel pipe surfaces, accordingly, m^2; K_{1-2} – factors of a heat transfer from PTC-heater surface, W/(m^2·ºC); K_{2-3} – heat transfer from paraffin in fuel in an environment, W/(m^2·ºC); N – correction factor; p – fuel pressure, Pa; p_{vent} – Pressure created by a ventilator, Pa; T_h – temperature of PTC-heaters, °C; T_{par} – paraffin temperature, °C; T_{top} – fuel temperature, °C; T_{okr} – an ambient temperature, °C; t – fuel time, s; P (T_2) – power of PTC-heaters, W; V_{top} – fuel volume, m^3; v – a velocity of a sound distribution a in fuel, m/s; x – fuel pipe, m; ρ, ρ_{20} – fuel density, fuel density at 20 °C, kg/m^3; ρ_1, ρ_{par} – density of a PTC-heater material and paraffin, accordingly, kg/m^3; τ – time, s; a ΔT – increment of fuel temperature, ºC.

The sustainable development of agroindustrial complex is difficult to achieve without effective operation of automotive park which plays a leading part in the major scope of technological processes and in some cases directly affects the economic efficiency of production. A combustion engine – the basic

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Калинин В.Ф. – доктор технических наук, профессор, первый проректор, заведующий кафедрой «Электрооборудование и автоматизация»; Щегольков А.В. – аспирант, инженер кафедры «Электрооборудование и автоматизация», e-mail: tort12t@mail.ru, ТамбГТУ, г. Тамбов.

element of automotive technique – as a rule works on a principle of ignition from compression and uses a diesel fuel in its operation. The diesel fuel quality characteristics such as, viscosity, pumpability and filterability depend on ambient temperature [1]. The deviation from optimal values of these characteristics results in the drop of efficiency of an air-fuel mixture combustion and this in its turn produces the raise of fuel consumption and exhaust gases toxicity. It should be especially mentioned the run-up of a diesel engine under low temperatures conditions which is obviously complicated by violation of an air-fuel mixture combustion. At this moment the efficiency of an air-fuel mixture combustion will be largely connected with the temperature of feed air.

That is why the development of technical solutions aimed at fuel quality characteristics optimization due to temperature control at engine run-up and idle stroke under low ambient temperatures is an urgent necessity [1–4].

Simulator, presented in a dynamic mode was elaborated to determine rational values of the system of fuel temperature control [3].

The elaborated simulator includes the differential equations describing changes of fuel temperatures in a fuel feed system of the diesel engine as well as defining of an unsteady fuel motion. It is assumed that fuel motion is one-dimensional, and the velocity of a pressure pulse (wave) distribution is constant:

$$\left.\begin{aligned} \rho_1 c_1 (h_1 F_1)\frac{dT(\tau)_1}{d\tau} &= P(T_{\text{par}}) - K_{1-2}F_1(T_h - T_{\text{par}}) - K_{1-2}^1 F_1^1 (T_h - T_{\text{ocr}}); \\ \rho_{\text{par}} c_{\text{par}} V_{\text{par}} \frac{dT(\tau)_{\text{par}}}{d\tau} &= K_{1-2}F_1(T_h - T_{\text{ocr}}) - K_{2-3}F_2(T_{\text{par}} - T_{\text{top}}); \\ \rho_{20} - N(T_{\text{top}} - 20)c_{\text{top}} \frac{dT(\tau)_{\text{top}}}{d\tau} &= \frac{K_{2-3}F_2(T_{\text{par}} - T_{\text{top}})}{V_{\text{top}}}, \end{aligned}\right\}$$

$$\left.\begin{aligned} \frac{\partial p}{\partial x} &= -\left(\rho_{20} - N(T_{\text{top}} - 20)c_{\text{top}}\right)\frac{\partial c}{\partial \tau} + 2kc; \\ \frac{\partial c}{\partial x} &= -\frac{1}{\upsilon^2\left(\rho_{20} - N(T_{\text{top}} - 20)c_{\text{top}}\right)}\frac{\partial p}{\partial \tau}, \end{aligned}\right\} \tag{1}$$

where T_{par}, T_h, T_{top}, T_{okr} – initial conditions; V, $P(T_{\text{par}})$, F_1, F_1^1, F_2, V_{top} – variation parameters.

For temperature control system connected to feeding collector

$$\left.\begin{aligned} \rho_1 c_1 (h_1 F_1)\frac{dT(\tau)_1}{d\tau} &= P(T_2) - KF_1(T_h - T_{\text{voz}}) - K^1 F_1^1 (T_h - T_{\text{ocr}}); \\ ((pM_w)/RT_{\text{voz}})c_{\text{voz}} \frac{dT(\tau)_{\text{voz}}}{d\tau} &= \frac{K_1F_1(T_{\text{okr}} - T_{\text{voz}})}{V_{\text{voz}}}; \\ ((p_{\text{vent}}M_w)/RT_{\text{voz},k})c_{\text{voz},k} \frac{dT(\tau)_{\text{voz},k}}{d\tau} &= \frac{K_2F_2(T_{\text{okr}} - T_{\text{voz},k})}{V_{\text{voz},k}}, \end{aligned}\right\} \tag{2}$$

where $T = (T_{\text{voz}}\ V_{\text{voz}} + T_{\text{voz},k}\ V_{\text{voz},k})/V_{\sum\text{voz}}$ – temperature of air entering from cylinders; T_2, T_{voz}, $T_{\text{voz},k}$, T_{okr} – initial conditions; V, $P(T_2)$, F_1, F_1^1, F_2, V_{voz} – variation parameters.

Simulator (2) considers properties of air as depending on temperature according to a following equation

$$\rho = (p_0 M_w)/(RT)\,, \tag{3}$$

where p_0 = 101,3 kPa; M_w = 0,0288 kg/mol, R = 8,314 J/(mol·K).

According to simulators (1) and (2) it is possible to develop the joint control system of fuel and feed air control means [2–4], on the basis of simulators graphic solution approximation.

The corresponding approximated expressions make up a mathematical basis of the supervisory controller software

$$P(T_2) = (a - b\exp(-c V_{\mathrm{top}}^{\mathrm{e}}))G_{ti}. \tag{4}$$

Realisations of voltage PDM of PTC-heaters are carried out by means of the controller [1] (Fig. 1, 2).

The controller, depending on of fuel and feed air current temperature, forms sequence of voltage impulses of with a certain porosity (A) (Fig. 3, *a*, *b*)

$$A = (\tau_1/(\tau_2 + \tau_1))\ 100\ \%. \tag{5}$$

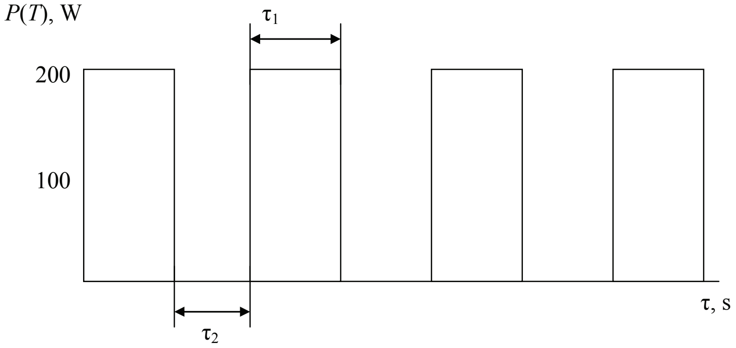


Fig. 1. PDM of heating elements power

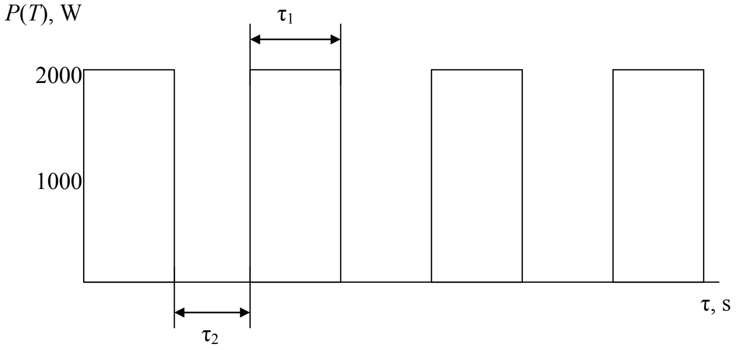
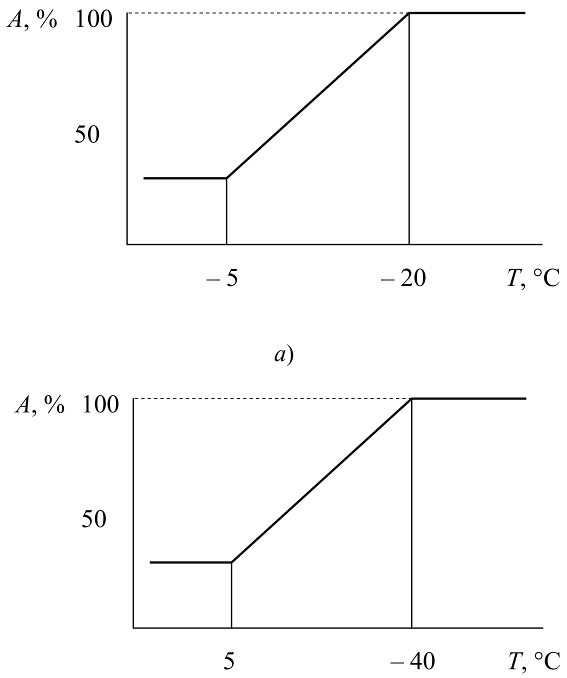


Fig. 2. PDM of heating elements power in the feed air temperature control device



a)

b)

Fig. 3. Dependence of the power porosity on temperature of:
a – a diesel fuel; *b* – feed air

Thus, on the basis of the presented simulators it is possible to define power PDM parameters of PTC-heaters and develop software for the supervisory controller. Thus the controller allows to set the optimized modes of the coordinated work of fuel and feed air control means in diesel engines.

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Математическое моделирование совместных режимов работы средств терморегулирования топлива и питающего воздуха в дизельных двигателях

В.Ф. Калинин, А.В. Щегольков

ГОУ ВПО «Тамбовский государственный технический университет», г. Тамбов

Ключевые слова и фразы: дизельный двигатель; математическая модель; терморегулирование топлива и питающего воздуха; широтно-импульсная модуляция.

Аннотация: Обоснована необходимость совместного терморегулирования топлива и питающего воздуха в условиях низких температур окружающей среды. Рассмотрены особенности формирования параметров широтно-импульсной модуляции мощности РТС-нагревателей на основе математических моделей.
