MATHEMATICAL MODELING OF THERMO-REGULATION OF FUEL IN DIESEL ENGINES YaMZ-238*

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ABSTRACT

The Maintaining the temperature system for fuel diesel engine by mathematical modeling. Thermal control of fuel with objective of this research, Peltier thermal application and paraffin-based thermal batteries. A fuel system thermometer is assembled in the diesel engine and thermal controller. A thermal model for thermal control of fuel has been developed in the diesel engine. Mathematical model is a system of differential equations. The use of controller for thermal control system of fuel and engine oil depending on the software obtained by approximating the graphical solution of the system allow to maintain the temperature with a error of ± 3 ° C for fuel and engine oil, which corresponds to the values obtained experimentally . The upgraded thermal control system can be used for existing and newly designed diesel engines. The production tests for diesel engine YaMZ-238 (BF and Deutz BF 6M 2012 C analogue with water cooling) revealed an improvement in eco-ecological characteristics of diesel engine operation: a 20% reduction in fuel consumption during start-up and operation of deceleration from 7 to 15%, exhausted gas toxicity from 10 to 17%. The developed mathematical model could be use to analyze the temperature systems of dual-fuel diesel engines on diesel and gas.

Key words: thermal batteries, eco-energy indicators, fuel temperature control system.

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نمذجة رياضية لتنظيم حرارة الوقود في محركات الديزل نوع (YaMZ-238)*

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المستخلص

الهدف من البحث تقييم نموذج رياضي في تنظيم حرارة الوقود في محركات الديزل وتعد من الامور المهمة. جهاز التحكم الحراري للوقود مع تطبيق في البلتيير(Peltier) الحراري والبطاريات الحرارية المعتمدة على البارافين .معدلة أنابيب الكاربون النانوية. تم تجميع ميزان باستعمال حرارة لنظام تزويد الوقود في محرك الديزل وجهاز للتحكم الحراري. تم تطوير نموذج رياضي للتحكم الحراري للوقود في محرك الديزل. النموذج الرياضي هو نظام من المعادلات التفاضلية. إن استخدام المتحكم للسيطرة على نظام التحكم الحراري للوقود وزيت المحرك اعتمادًا على البرمجيات التي يتم الحصول عليها عن طريق الحلول البيانية التقريبية للنظام والذي يسمح بالحفاظ على درجة الحرارة وبنسب خطأ تتراوح بين 3± م° للوقود وزيت المحرك، وهو ما يتوافق مع القيم التي تم الحصول عليها تجريبياً. يمكن استعال نظام التحكم الحراري المطور لمحركات الديزل الحالية والمصممة حديثًا. أظهرت اختبارات الإنتاج لمحرك الديزل YaMZ-238 (أو BF Deutz BF 6M 2012 C analogue with water cooling) تحسنًا في الخصائص البيئية-الإيكولوجية لتشغيل محرك الديزل: انخفاض استهلاك الوقود بنسبة 20٪ أثناء بدء التشغيل وتشغيل التباطؤ من 7 إلى 15٪ ، وكذلك مستوى سمية غازات العادم من 10 إلى17٪. يمكن استعمال النموذج الرياضي المقترح لتحليل أنظمة درجة الحرارة لمحركات الديزل ثنائية الوقود على وقود الديزل والغازات.

الكلمات المفتاحية : البطاريات الحرارية، مؤشرات الطاقة البيئية، نظام التحكم في درجة حرارة الوقود.

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INTRODUCTION

Diesel engines are one of the main sources of energy for mobile vehicles and can also be used as stationary or mobile power sources (1,14). At the same time, the international ethos of the modern economy dictates diesel engine indicators to a full range of stringent technical and economic requirements (2,14). The need for different types of fuel for diesel engines is linked to an increase in their environmental standards, and safety. The important process in the diesel engine has its heat processes. Determination of Heat dissipation during the operation of a diesel engine, can be possible to verify the combustion of fuel mixture and air in the engine (12). Another characteristic treatment could be burning 50% of the fuel dose (combustible fuel block) (6). This indicator allows a relative determination of the combustion phase, as this indicates an angle position at 50% of the heat output. This indicator can be used to control combustion in the diesel engine, reducing the emission of toxic components and reducing diesel fuel consumption (5). Tillage is one of the main agricultural processes carried out on the soil to break the surface layer and create suitable conditions that allow water and air to pass through. Choosing the right tillage machine to create these conditions is of great importance to determine the quality. For the plowing and selection of the size of the appropriate machines must be accompanied by the choice of the best size tug to suit the withdrawal of these machines at the speed that suits them and the appropriate work, which leads to increased productivity and reduce the cost of agricultural production, which is the main goal of most agricultural researchers related to high fuel prices while achieving the optimal use of fuel Availability and completion of agricultural operations in the available time (15). The authors propose that when controlling the engine, the torque and fuel combustion criteria should be considered. The combustion control can be estimated using the fuel feed angle, where 50% of the heat is released (8). These authors have indicated effect of this control on the heat release rate in the micro-pregnancy zone. As a result of using the engine management strategy criteria, it is possible to obtain optimal settings for diesel and natural gas doses, where the pareto test is optimized. At the works of revealed, an impact assessment is performed on the performance of diesel engines with different percentages of injected fuel (3). Researchers were shown that the pre-blended mixture ignition mode is mainly controlled by the second injection of diesel fuel. The difference between NOx-CH_4 and NOx-CO is achieved by using cleft injections. Compared to one syringe (10 ° BTDC), the first injection time of 50 ° BTDC reduced emissions of unburned methane and carbon dioxide emissions by 60% and 63%, respectively, and increased thermal efficiency by 8.9%. However, nitrogen oxides emissions were maintained at the same level as single injection mode (10 ° BTDC). A pilot study was conducted by several Researchers to investigate the behavior of the expelled particles in the biodiesel diesel engine (16). The emissions of exhaust particulates in diesel / natural gas exhaust gases with the dual fuel engine with different loads were measured on the engine at a constant speed of the engine experimentally. The researchers found that the number of particles and mass of these particles is greatly affected by injection pressure and the ratio of energy substitution, but particle size distribution is not affected by the change of these parameters. In addition, the concentration of particulate matter in exhaust gas can be significantly reduced by increasing injection pressure in the fuel system as well as engine load. In addition, more than 60% of the particles emitted from diesel / natural gas with a dual fuel engine are highly dispersible particles, while they provide a block of particles not exceeding 10%. Chunhua and *et al* (7), concluded that the diesel engine book was studied with a dual throttle mode in order to find auxiliary treatment to evaluate the thermal effect coefficient (ηe) and nitrogen oxides (7). As a result of the study, the diesel injection time had a significant effect on the angle of combustion duration (α)which is closely related to ande and NOx. For low and medium loads, where α is close to the top dead center (TDC) and after TDC, ande and NOx are higher. However, when α reaches TDC, the result of nitrogen oxides emissions is the opposite. In this regard, optimal NOx emissions and ηe in low and medium loads would be the best way to change diesel injections to delay α and ATDC to provide α at ATOC at 1-2 ° CA. In (9), the combustion control algorithm is proposed in real time based on pressure control to reduce combustion dispersion of diesel engines. The proposed algorithm controls the main quantity and timing of the injection, as well as the angle position at the crankshaft gate, where 50% of the burned mass (MFB50) and the maximum heat output rate. This control algorithm reduces the dispersion of fuel combustion by monitoring the heat transfer curve for each running state. In their experiments, researchers found that there was an imbalance in torque of 30%, a decrease in emissions of 10% of emissions for NOx emissions and a decrease in PM emissions of 65%.The aim of this research is to increase the environmental energy indicators of diesel engines and reduce costs while maintaining engine capacity,. This is due to the fact that at critical fuel temperatures, physical chemical changes cause deterioration in their technological properties. This involves a reduction in the strength of the indicator, increased fuel consumption, exhaust gas toxicity and overall corrosion of the engine as a whole (10,11). Thus, the optimal fuel temperature system is an actual scientific and technical task.

MATERIALS AND METHODS

To investigate optimal fuel temperature conditions, thermal control system has been developed. The fuel thermal control system in a diesel engine (Fig. 1) consists of a main electric fuel unit 1 located after the fine filter 2; auxiliary units located in front of the soft filter 3 and in the fuel tank 4. Temperature monitoring is performed by sensors Temperature 5. The power supply lines for the electrothermal units and the information lines for auxiliary sensors and temperature are connected to the information power line 6 connected to the control system (13).

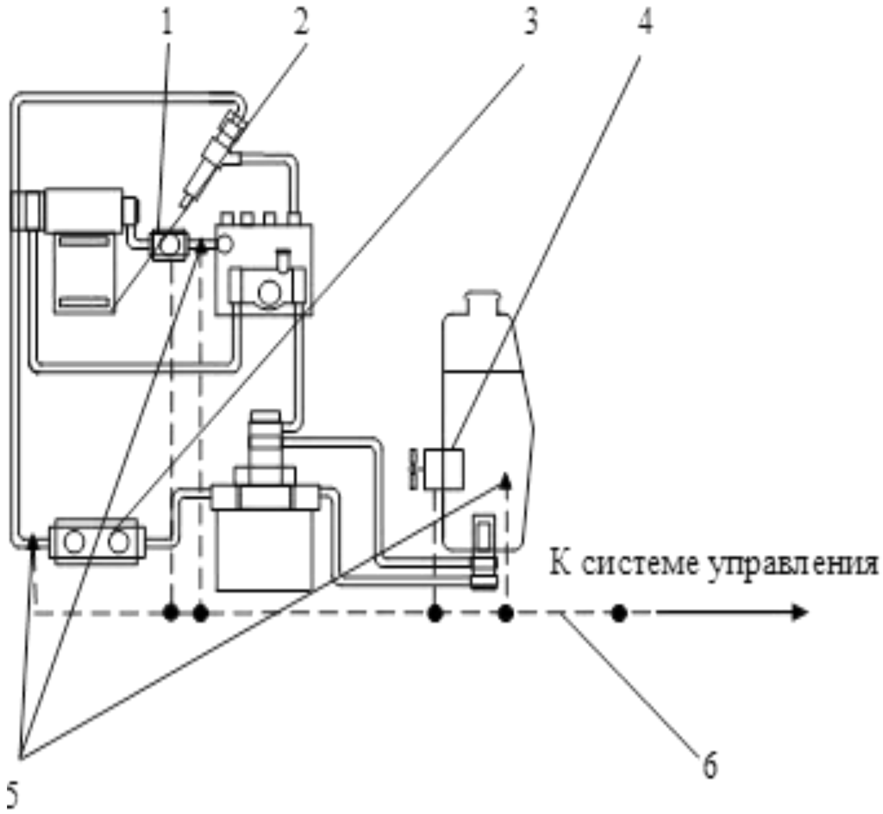


Figure 1. Diesel fuel thermal control system:

1 - The main Electric Fuel unit of fuel. 2 - Good candidate. 3 - Auxiliary units. 4 - Fuel tank. 5 - Temperature sensors.

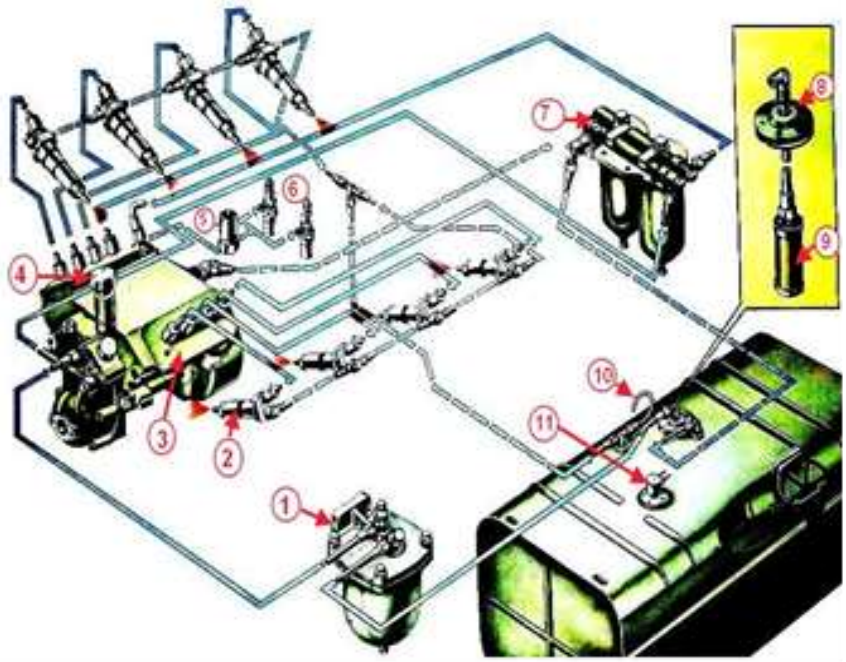


Figure 2. Thermal control system for diesel fuel

The scheme of the power supply system: 1-coarse filter Fuel, 2-nozzle, 3- High-pressure fuel pump 4-manual fuel pump, 5-3l. solenoid valve, b candle EFU 7-fine filter 8-receiver tank tub, 9 tank filter, 10 fuel tank breather, 11-sensor fuel level indicator.

Thermal regulation is carried out at the expense of energy from the normal power system of the diesel engine, which imposes a number of restrictions on energy consumption. In order to increase the energy efficiency of the thermal control, the control system of the electrothermal units includes a programmable logic controller. The thermal units consist of Peltier's elements and the heat exchange system in which the thermal exchange circuit regulation is used to regulate the thermal with periodic accumulation of thermal energy in thermal batteries. A characteristic feature of thermal accumulations is the presence of materials with a nano-structure with a phase transition that enhances thermal energy accumulation (A tonite, a nanotube with a diameter of 15-40 nm and a length of 2 μm) is used as nanomaterial (13). The decentralized arrangement of heat regulating units makes it possible to change the fuel temperature, making it possible to select energy more efficiently for a full range of engine loads and ambient temperatures, ie, the temperature in the fuel and oil circuit is the most suitable from the energy point of view. At the same time, power distribution occurs in the thermal control system in such a way that each unit coordinates its operation according to the other operation, based on the standard of reducing heat loss. When the loads are low, the power is not reduced to a level that corresponds to the current fuel consumption, but is periodically set to sufficient value to store heat energy in thermal storage.

Mathematical model method

The thermal balance in the thermal control of the ETN coolant layers and the thermal collector are:

$$(Q_{1e} + Q_{2e}) + (Q_1 + Q_2) - Q_{тор} - Q_{рот}, \dots (1)$$

Where Q_{1e} , Q_{2e} - is the thermal energy obtained by converting electrical energy, J; Q_{1a} , Q_{2a} - thermal energy stored during less carrier load periods, J; Q_{pot} is the thermal loss of the thermocouple device from excavator trench (ETH) to the environment, J; Q_{top} - Thermal energy, which must be reported for fuel to bring it to the desired temperature. Keep in mind the thermal balance of the thermal fuel system, while agreeing that the temperature distribution in the size of the heat regulator is uniform. Let the temperature change occur during dτ time with the value of DT, increasing the thermal energy in the measured fuel volume from: TT to TT + dTT. A mathematical model was established into account the main factors that affect the fuel temperature. First, the ambient air temperature is affecting the fuel temperature. Based on the scheme of heat flows and the characteristics of the device for thermal regulation of fuel, a system of differential equations was created:

$$\left.\begin{aligned} &\rho_1 C_1 (h_1 F_1)\frac{dT_1}{d\tau} = \tau P(T_2) - \alpha_{1-2} F_1 (T_1 - T_2) \\ &(\rho_{20} - N(T_2 - 20))C_T \frac{dT_2}{d\tau} = \frac{\tau(\alpha_{1-2}F_1(T_1 - T_2) - \alpha_{2-3}F_2(T_2 - T_3))}{D_T} \\ &\rho_F c_F (\pi \cdot r^2 h_F)\frac{dT_3}{d\tau} = \alpha_{2-3} F_2 (T_2 - T_3) - K \cdot F_3 (T_3 - T_4) \end{aligned}\right\} \quad (2)$$

Intial Condition: $T_1;T_2;T_3;T_4$.

Variable Standards : D_T; $P(T_2)$; F_1; F_2; F_3,

Where (F_1, F_2, F_3) - the surface of the Peltier elements and body heat exchange (inside and outside), respectively, m^2. (α_{1-2}, α_{2-3}) - are heat transfer coefficients from the surface of the Peltier element and the heat exchange casing walls W. $(m^2\ C^o)^{-1}$; P (T_2) is the strength of the Peltier elements, W; (T_1) is the temperature of the Peltier element C°, T_2 - fuel temperature, C°; T_3-temperature of heat exchange casing, C°; T_4 - ambient temperature, C°; C_1, C_F - heat capacity of Peltier and heat exchange shell J.$(kg \cdot C^o)^{-1}$; k - Heat transfer coefficient from fuel to environment, W. $(m^2\ C^o)^{-1}$; (ρ_1, ρ_F) is the density of the material for the Peltier elements and the heat exchange body, respectively, kg. m^{-3} ; h_f - height of the Peltier elements, m; r- radius housing thermal unit, m; h_f is the high thermal unit housing, m. Temperature transfer coefficients α_{1-2}, α_{2-3} and heat transfer K are determined by solving the boundary value problem in numerical form.

Table 1. Parameter Value

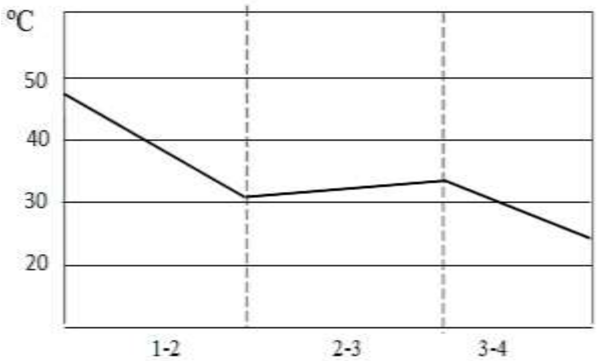
Parameter	Value
F_1, кv. м	**0.02**
F_2 кv. м	**0.02**
F_3 кv. м	**0.02**
h_1, см	**15**
C_1 kJ / kg ° C	**0.9**
C_F kJ / kg ° C	**0.7**

Mathematical model makes it possible to record changes at each stage in the case of fuel temperature in important parts of the main fuel. According to this mathematical calculation of the model shares in the points that correspond to each advance Fuel line parts: Part (1-2) from the tank to the thermal unit 3, Part (2-3) Heat unit 3 to Filter 2, Part (3-4) From filter 2 to the fuel pump of high pressure (Figure 1). At each stage, a dynamic change is determined in the temperature indicators taking into account the energy characteristics of the heat regulation units. The relationship of temperature changes to each stage is made on the basis of the initial conditions in the mathematical model (1). The solution of the system of differential equations is based on the Runge-Kutta method of the fourth rank.

RESULTS AND DISCUSSION

Mathematical Model Results And Analysis

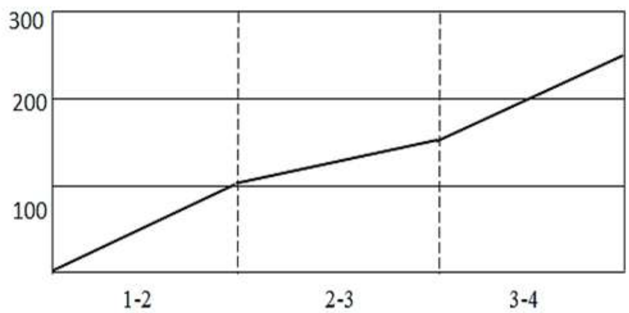
Figure 3 shows a temperature profile, which corresponds to the passage of fuel along the fuel line prior to injection. --- fuel line sectionFuel cycle at 50% load



fuel line section
Fuel cycle at 50% load

Figure 3.Temperature profile in the fuel supply system along sections (1-2; 2-3; 3-4)

The final temperature and temperature values at different stages can be adjusted depending on the efficiency of the diesel engine on a particular type of fuel, including biofuels



fuel line section
Fuel cycle at 50% load

Figure 4. Energy profile of thermal units

For thermoelectric units in the oil system, temperatures and power profiles are calculated in a similar manner. Based on experimental studies and a the mathematical model, the rational values of the energy parameters of the thermal control system where obtained (Table 2). After analyzing the temperature profiles and authorities, and also comparing the energy parameters, the solution of the equations system (1) is subject to approximation in the form of graphs.

Table 2 . Energy parameters of thermal control system.

Maximum capacity of units of thermal control			Range of Energy Contrast (%)			
			Load			
Fuel			x.x.	50%	75%	100%
Tank	Before The Filter	After The Filter	50	50	70	80
200	150	200				

Table 3 . Approximation and correction coefficients.

No	Fuel Delivery Mode	Approximate Expression Coefficients				Correction Coefficient of Temperature (G_{ti})		
		a	b	c	e	G_{t1} T_4<20	G_{t2} T_4<30	G_{t3} T_4<40
1	The Beginning	110	176	0.09	0.9	1.1	1.2	1.27
2	Sleep Mode	100	120	0.04	0.4	1	1,1	1.2
3	Loading	170	199	0.11	1.2	0.9	1.2	1.4

Approximate expressions of the corresponding type form the mathematical basis of the program from the control controller:

$$P(T_2) = \left(a - b \cdot \exp\left(-c \cdot D_T^e\right)\right) \cdot G_{ti} \qquad (3)$$

Where a, b, c, and e are rounding and correcting the control controller. The expression expressions (2) are displayed in Table 3.

Example calculation: T_4<20

P (T_2) =(110-176 exp (-0,09*$10^{0,9}$))1,1 = 26,202W (consumption D_T - 10 l / h)

P (T_2)= (100-120 exp (-0,04*$8^{0,9}$))1 =10W (consumption D_T - 8 l / h)

P (T_2) = (170-199 exp (-0,11*$25^{1,2}$))0,9=152 W (consumption D_T - 25 l / h) T_4 <30

P (T_2) = ((110-176 exp (-0,09*$10^{0,9}$))1,2=28,82 W (consumption D_T - 10 l / h)

P (T_2) = (100-120 exp (-0,04*$8^{0,4}$))1,1=11 W (consumption D_T - 8 l / h)

-P (T_2) = (170-199 exp (-0,11*$25^{1,2}$))1,2=185,77 W (consumption D_T - 25 l / h)

T_4 <40

P (T_2) = (110-176 exp (-0,09*$10^{0,9}$))1,27=30,25 W (consumption D_T - 10 l / h)

P (T_2) = (100-120 exp (-0,04*$8^{0,4}$))1,2=12 W (consumption D_T - 8 l / h)

P (T_2) = (170-199 exp (-0,11*$25^{1,2}$))1,4=236,4 W (consumption D_T - 25 l / h)

Table 4. Comparative indicators

Parameter	With the thermoregulation system	Standard version
Fuel consumption - operating mode, kg / h	25	28,75
Fuel consumption - start, kg / h	10	12
Total toxic emissions g/ kw ·h	30	35,1

It can be concluded that the use of a thermocouple control system for fuel and engine oil based on the software obtained by approximating the system diagram 1 allows temperature retention with a ± 3 ° C error for fuel and engine oil, Get it experimentally. The production tests for diesel engine YaMZ-238 (BF and Deutz BF 6M 2012 C analogue with water cooling) showed an improvement in eco-ecological characteristics of diesel engine operation: a 20% reduction in fuel consumption during start-up and operation of deceleration from 7 to 15% Exhaust gas toxicity from 10 to 17%. The developed mathematical model can be used to analyze the temperature systems of dual-fuel diesel engines on diesel and gas (2). The maximum power of the thermal control system is spent in section 3- 4 and reaches 250 watts. At the same time, the fuel temperature can be reduced to 25° C.

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