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 an 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 used 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.

*Part of Ph.D. dissertation of the first author.

Received: 1/3/2018, Accepted: 6/5/2018

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

A. A. H. Al – Maidi1
Assist. Lecturer
D.V. Nikitin2
Assist. Prof.

Y. V. Rodionov2
Assist. Prof.

A. V. Shchegoglov2
Assist. Prof.

D.A. Chernetsov1
Prof.

N. V. Mikheev2
Prof.

1) Plant Protection Dept.; Coll. of Agriculture, Un. of Misan; Iraq.
2) Engineering Sciences Coll.; Tambov State Technical Univ.; Russia.

roditionow.u.w@rambler.ru
aa9090184@gmail.com
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-CH₄ 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).

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**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.
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:

\[ (Q_{1e} + Q_{2e}) + (Q_1 + Q_2) - Q_{top} - Q_{pot}, \ldots \] (1)

Where \( Q_{1e}, Q_{2e} \) - is the thermal energy obtained by converting electrical energy, J; \( Q_1, Q_2 \) - 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:

\[
\rho_i C_i (h_i F_1) \frac{dT}{d\tau} = \theta P(T_1) - \alpha_{1,2} F_1 (T_1 - T_2) \\
(p_{20} - N(T_2 - 20)) C_i \frac{dT}{d\tau} = \tau (\alpha_{2,3} F_2 (T_2 - T_3) - \alpha_{2,3} F_3 (T_2 - T_3)) \\
\rho_i c_F (\pi \cdot r^2 h_i) \frac{dT}{d\tau} = \alpha_{2,3} F_3 (T_2 - T_3) - K \cdot F_2 (T_2 - T_4)
\]

Initial Condition: \( T_1; T_2; T_3; T_4 \)

Variable Standards: \( D_1; P(T_2); F_1; F_2; F_3 \)

Where \((F_1, F_2, F_3)\) - the surface of the Peltier elements and body heat exchange (inside and outside), respectively, \( m^2 \). \((\alpha_{1,2}, \alpha_{2,3})\) - are heat transfer coefficients from the surface of the Peltier element and the heat exchange casing walls \( W \). \((m^2 \text{ C}^{-1})\). \( P \) \((T_2)\) 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 \( J/(\text{kg} \cdot \text{C}^{-1}) \); \( k \) - Heat transfer coefficient from fuel to environment, \( W \). \((m^2 \text{ C}^{-1})\). \((\rho_1, \rho_F)\) is the density of the material for the Peltier elements and the heat exchange body, respectively, kg. \(m^3\); \( h_i \) - height of the Peltier elements, m; \( r \) - radius housing thermal unit, m; \( h_i \) is the high thermal unit housing, m. Temperature transfer coefficients \( \alpha_{1,2}, \alpha_{2,3} \) and heat transfer \( K \) are determined by solving the boundary value problem in numerical form.

### Table 1. Parameter Value

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( F_1 ) \text{ kv. m}</td>
<td>0.02</td>
</tr>
<tr>
<td>( F_2 ) \text{ kv. m}</td>
<td>0.02</td>
</tr>
<tr>
<td>( F_3 ) \text{ kv. m}</td>
<td>0.02</td>
</tr>
<tr>
<td>( h_i ) \text{ cm}</td>
<td>15</td>
</tr>
<tr>
<td>( C_1 ) \text{ kJ/kg °C}</td>
<td>0.9</td>
</tr>
<tr>
<td>( C_F ) \text{ kJ/kg °C}</td>
<td>0.7</td>
</tr>
</tbody>
</table>

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

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

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

**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.**

<table>
<thead>
<tr>
<th>Maximum capacity of units of thermal control</th>
<th>Range of Energy Contrast (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel</td>
<td>Before The Filter</td>
</tr>
<tr>
<td>Tank</td>
<td>Filter</td>
</tr>
<tr>
<td>200</td>
<td>150</td>
</tr>
</tbody>
</table>

**Table 3. Approximation and correction coefficients.**

<table>
<thead>
<tr>
<th>No</th>
<th>Fuel Delivery Mode</th>
<th>Approximate Expression Coefficients</th>
<th>Correction Coefficient of Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>a</td>
<td>b</td>
</tr>
<tr>
<td>1</td>
<td>The Beginning</td>
<td>110</td>
<td>176</td>
</tr>
<tr>
<td>2</td>
<td>Sleep Mode</td>
<td>100</td>
<td>120</td>
</tr>
<tr>
<td>3</td>
<td>Loading</td>
<td>170</td>
<td>199</td>
</tr>
</tbody>
</table>

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

\[ P(T) = (a - b \cdot \exp(-c \cdot T_D^d)) \cdot G_n \]  \( (3) \)

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

Example calculation: \( T_D < 20 \)

\[ P(T_1) = (110 - 176 \exp(-0.09 \cdot 10^{0.9})) \cdot 1.1 = 26,202 \text{W} \] (consumption \( D_T = 101 \text{ l/h} \))

\[ P(T_2) = (100 - 120 \exp(-0.04 \cdot 8^{0.4})) \cdot 1 = 10 \text{W} \] (consumption \( D_T = 81 \text{ l/h} \))

\[ P(T_3) = (170 - 199 \exp(-0.11 \cdot 25^{1.2})) \cdot 0.9 = 152 \text{W} \] (consumption \( D_T = 251 \text{ l/h} \))

\[ T_D < 30 \]

\[ P(T_1) = (110 - 176 \exp(-0.09 \cdot 10^{0.3})) \cdot 1.2 = 28,82 \text{W} \] (consumption \( D_T = 101 \text{ l/h} \))

\[ P(T_2) = (100 - 120 \exp(-0.04 \cdot 8^{0.4})) \cdot 1.1 = 11 \text{W} \] (consumption \( D_T = 81 \text{ l/h} \))

\[ P(T_3) = (170 - 199 \exp(-0.11 \cdot 25^{1.2})) \cdot 1.2 = 185,77 \text{W} \] (consumption \( D_T = 251 \text{ l/h} \))

\[ T_D < 40 \]

\[ P(T_1) = (110 - 176 \exp(-0.09 \cdot 10^{0.3})) \cdot 1.27 = 30,25 \text{W} \] (consumption \( D_T = 101 \text{ l/h} \))

\[ P(T_2) = (100 - 120 \exp(-0.04 \cdot 8^{0.4})) \cdot 1.2 = 12 \text{W} \] (consumption \( D_T = 81 \text{ l/h} \))

\[ P(T_3) = (170 - 199 \exp(-0.11 \cdot 25^{1.2})) \cdot 1.4 = 236,4 \text{W} \] (consumption \( D_T = 251 \text{ l/h} \))

\[ T_D < 60 \]

\[ P(T_1) = (110 - 176 \exp(-0.09 \cdot 10^{0.3})) \cdot 1.36 = 40,5 \text{W} \] (consumption \( D_T = 101 \text{ l/h} \))

\[ P(T_2) = (100 - 120 \exp(-0.04 \cdot 8^{0.4})) \cdot 1.2 = 12 \text{W} \] (consumption \( D_T = 81 \text{ l/h} \))

\[ P(T_3) = (170 - 199 \exp(-0.11 \cdot 25^{1.2})) \cdot 1.4 = 236,4 \text{W} \] (consumption \( D_T = 251 \text{ l/h} \))

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 ± 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 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.
REFERENCES