Study on performance of compression engine operated by biodiesel fuel

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Introduction

The performance analysis of the biofuel energy efficiency in the combustion engine is as function of the fuel's composition and other physical-and-chemical parameters. Different models and analysis do not take into account the effect that the use of different bio-diesel fuels has on the operation of the engine. Refinement is needed in describing the physical processes taking place in the engine's cylinders. The aim of the study is the development of a mathematical model for the practical analysis of the efficiency of use of biofuel in diesel engines, which would take into account the fuel's composition. The developed model in the article is designed to develop the 4Ч11.0 / 12.5 diesel engine.

Materials and Methods

The methods is mathematical modelling of the physical and physical-and-mechanical processes taking place in the engine cylinder, which are taken into consideration one after another and related with each other in a cause-effect relationship. The mathematical model is corrected and checked experimentally. The mathematical model is characterized by 3 formulas.

Results

Formula 1. With the use of the formula the rated power can be determined for the two typical duties of the engine – the rated duty and the maximum torque duty.

$$N_e = \frac{\pi \cdot D^2 \cdot S \cdot n \cdot i}{120 \cdot \tau_{en}} \cdot \left[\frac{p_c \cdot \upsilon}{\varepsilon - 1} \cdot \left\langle \frac{p_z}{p_c} \cdot \left\{ k_1 + \frac{1+k_1}{k_2} \cdot \left[1 - \left(\frac{\varepsilon}{1+k_1} \right)^{-k_2} \right] \right\} - \frac{1-\varepsilon^{-n_1}}{n_1 - 1} \right\rangle - \left(a + \frac{b \cdot n \cdot S}{30} \right) \right],$$

where k1, k2 – simplification coefficients representing the position of the piston at the point z of the indicator diagram and the polytropic index of expansion less unity respectively.

Formula 2. After substituting the formula (1) into the equation the effective specific fuel consumption and taking into account the volume and mass rates of the cyclic injection depending on fuel density, the following equation for determining the specific fuel consumption is obtained:

$$g_e = \frac{1{,}44 \cdot 10^{-5} \cdot V_{fc} \cdot \rho_f \cdot D^{-2} \cdot (S \cdot \pi)^{-1}}{\left[\frac{p_c \cdot \upsilon}{\varepsilon - 1} \cdot \left\langle \frac{p_z}{p_c} \cdot \left\{ k_1 + \frac{1+k_1}{k_2} \cdot \left[1 - \left(\frac{\varepsilon}{1+k_1} \right)^{-k_2} \right] \right\} - \frac{1-\varepsilon^{-n_1}}{n_1 - 1} \right\rangle - \left(a + \frac{b \cdot n \cdot S}{30} \right) \right]}$$

The formula 2 allows determining the specific fuel consumption at the two typical engine duties – the rated duty and the maximum torque duty.

Formula 3. Substituting the cylinder displacement formula, with due account for the number of dimensions, relation exists between the volume and mass rates of the cyclic injection and the determined excess air factor, the quantity of moles of intake air charge with due account for the known stoichiometric relations Then, introducing the simplification coefficients, the following refined formula for determining the excess air factor is obtained:

$$\lambda = \frac{\pi \cdot D^2 \cdot S \cdot k_3 \cdot (1 - k_4) \cdot \left(1 - \frac{\varphi_c}{k_3} \cdot \frac{p_r}{p_0 - k_4} \right) \cdot \frac{p_0}{T_0 + \Delta T}}{6.315 \cdot 10^{-9} \cdot V_{fc} \cdot \rho_f \cdot \left(\frac{C}{12} + \frac{H}{4} + \frac{S}{32} - \frac{O}{32} \right) \cdot (\varepsilon - 1)}$$

where $k3$, $k4$ – simplification coefficients representing the product of the coefficient of additional charging by the compression ratio and the effect of the main parameters of the crank-and-rod mechanism, gas distribution mechanism and the ambient air parameters on the process of the cylinder filling, respectively; C, H, S, O – composition of the fuel in unit fractions representing carbon, hydrogen, sulphur and oxygen, respectively.

Experimental

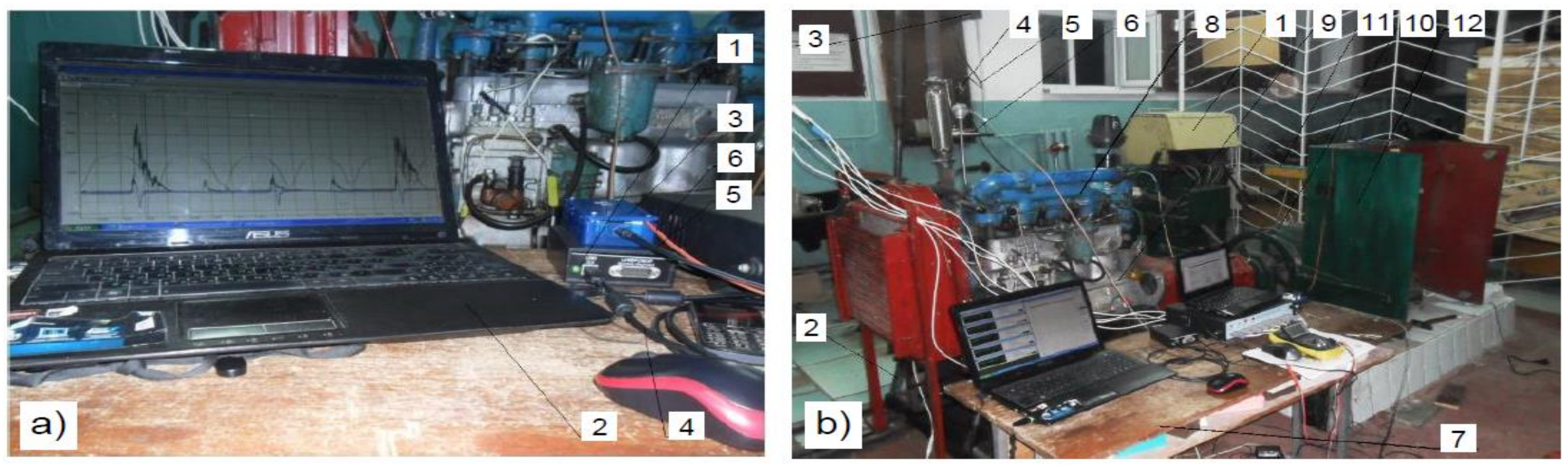

Figure 1. Equipment for laboratory experiments: a) ZETLab measurement module connected to 4Ч11,0/12,5 diesel engine: 1 – ADC DAC; 2 – PC; 3 – switching unit (SB); 4 – cable HS USB 2.0; 5 – power cable of SB (12 V); 6 – cable of input signals from transducers. b) КИ-5542 run-in check-out test bed for internal combustion engines: 1 – rheostat; 2 – stand; 3 – fuel tank; 4 – three-way valve; 5 – fuel supply line; 6 – weighing unit; 7 – measuring and recording equipment; 8 – diesel engine; 9 – linkage (cable) for driving governor lever of fuel injection pump; 10 – balancing electric machine; 11 – control panel; 12 – weighing system.

Indicator	Diesel fuel, model	Diesel fuel, experiment		Biodiesel fuel, model	Biodiesel fuel, experiment
		Special condition (p_0 = 0.098 MPa, T_0 = 273 K)	Standard condition (p_0 = 0.101 MPa, T_0 = 273 K)		
N_e, kW	49.62	50.61	55.61	50.60	52.01
p_e, MPa	0.57	0.581	0.639	0.581	0.597
M_e, Nm	215.4	219.7	241.4	219.6	225.8
g_e, g (kWh)$^{-1}$	248.0	243.1	245.6	253.3	245.4
λ	1.61	1.61	1.67	1.79	1.79

Table 1. Analysis results of the engine Ч11.0/12.5 performance parameters diagrams.

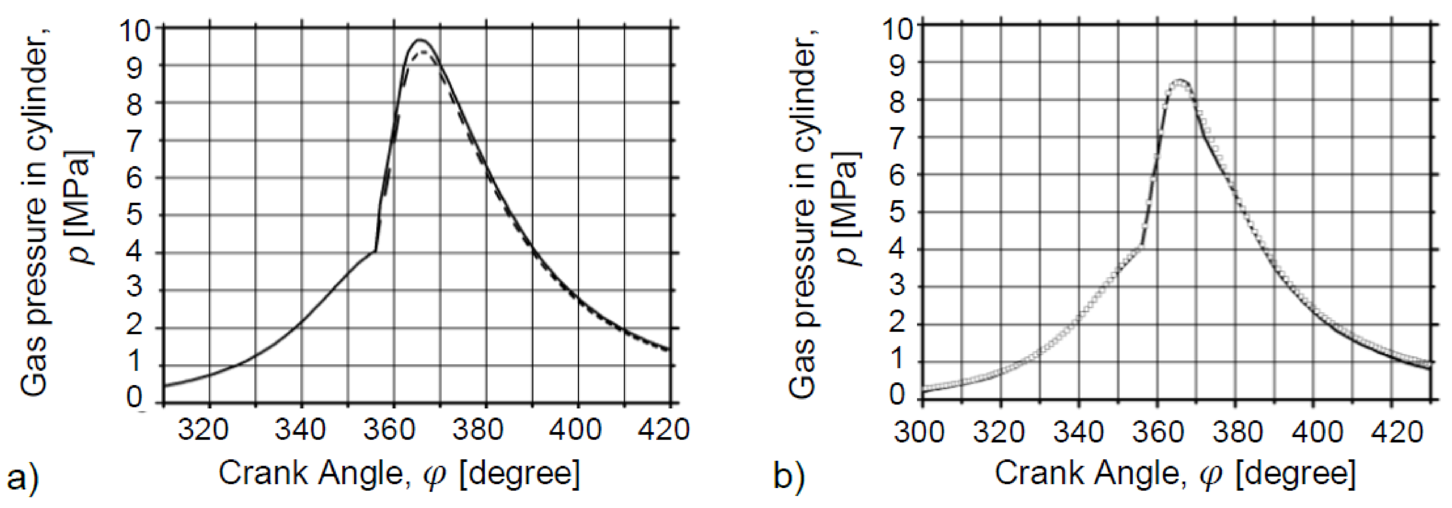

Figure 2. Relation between gas pressure in cylinder p and angular displacement of engine crankshaft φ: a) experimental data for operation with: --- diesel fuel; __ biodiesel fuel; b) for operation with diesel fuel: __ experimental; ☐ ☐ ☐ analytical.

Conclusions

1. A mathematical model that allows to determine the engine's efficient performance indices and operating duty cycle performance and to estimate the efficiency of its operation and the efficiency of fuel utilisation, including the use of bio-diesel fuel, has been developed.

2. The analysis of the indicator diagrams (Fig. 3) has proved that the mathematical model provides close agreement between the calculated data and the results of the experiments. The difference between the experimentally obtained and calculated values of the parameters is equal to: for pc – 0.1%, for pz – 0.77%, which makes reasonable using the mathematical model under consideration for the comparative calculation of the operating duty cycle parameters of the engine run on diesel and bio-diesel fuels.

3. Thus, the obtained mathematical model allows obtaining the values of the effective parameters of operation of the engine with a sufficient degree of accuracy and evaluating the efficiency of use of bio-diesel fuel by means of calculation and analysis.

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