A SIMULATION STUDY OF THE INFLUENCE OF THE PARAMETERS OF INTAKE AIR ON THE WORKING CYCLE OF A SINGLE-CYLINDER DIESEL ENGINE

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Abstract: *In this article are presented and analyzed the results of the numerical experiments with the simulation model created to study the processes of the operating cycle of the internal combustion engine in a programming environment MATLAB with Simulink. The influence of the parameters of the incoming air on the working cycle and the power of a four stroke single-cylinder diesel engine under different weather conditions and supercharge. New relationships are derived to determine the engine power of the air temperature, altitude and air pressure at supercharge.*

Keywords: INTERNAL COMBUSTION ENGINES, WORKING CYCLE, ATMOSPHERIC AND SUPERCHARGED ENGINES, COMPUTER SIMULATION

1. Introduction

The mathematical model of the operating cycle of internal combustion engines (ICE), is a system of ordinary differential equations, derived from ICE theory, thermodynamics, hydrodynamics and mechanics.

With the system of differential equations are described the operating substance parameters during periods of intake process, compression, expansion and exhaust process. It includes the equation for the dynamics of combustion and heat and the equation of continuity [1, 2, 7].

The simulation model (fig. 1) of four-stroke ICE in Simulink [3, 4, 5, 6] is realized, based on mathematical description of the successively implemented processes of the operating cycle of ICE [1, 2, 7].

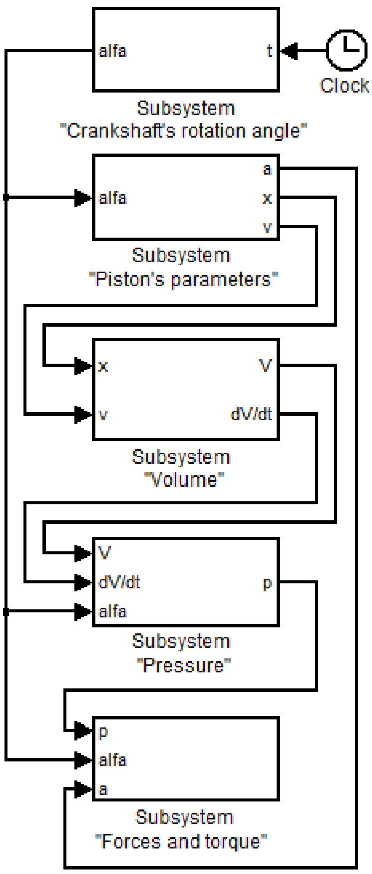


Fig. 1. *Simulation model of ICE*

In the auxiliary script file to the simulation model are described, initialized and calculated the necessary constructive and regime parameters of the engine and the operating substance.

In structural terms, the simulation model consists of several subsystems:

subsystem to determine the angle of rotation of the crankshaft as a function of time;

subsystem to determine the kinematic parameters of the piston – path, velocity and acceleration;

subsystem to determine the operating volume;

subsystem to determine the pressure of the operating substance;

subsystem to determine the forces acting on crankshaft mechanism units, as well as on torque of ICE.

Individual subsystems are described in details in [3].

The simulation model of ICE [3], allows possibility for calculating the parameters of four or two stroke ICE with valve timing, valve-contour or contour gas distribution [4].

To conduct numerical experiments with the simulation model are inserted the values for a single-cylinder, four-stroke diesel engine with direct injection and air-cooling [8].

The bore of the diesel engine is 86 mm and the here stroke is 72 mm.

The piston displacement volume of the engine is 0.418 l. Compression ratio is 19.

At atmospheric pressure 101330 Pa, temperature of 298 K and 3000 rpm of the crankshaft, the effective power of the motor is 5,7 kW, its average effective pressure is 546 kPa, the torque was 18,7 Nm and its specific consumption is 275,1 g/kWh.

A commencement of fuel is 17 ± 1^0 BTDC at 3000 rpm.

The rotation direction is anticlockwise.

2. Formulation of the problem

The aim of this work was to study the influence of the parameters of the incoming air on the processes of the operating cycle and the power of four stroke single cylinder diesel engine under different weather conditions and supercharge.

3. Influence of the inlet air temperature on operating cycle and power

With the simulation model are performed numerical experiments to determine the parameters of the working cycle and power at different temperatures and constant air pressure at sea level (p_0 = 101330 Pa).

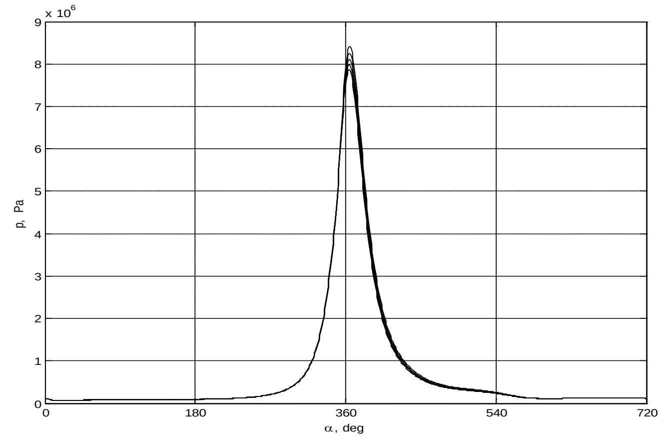


Fig. 2. *Influence of the air temperature on the working cycle*

Fig. 2 shows the indicator diagrams at various temperatures of the intake air. With increasing temperature, the maximum pressure of the operating cycle decreases.

The results obtained for the power of the internal combustion engine are shown in Table 1 and in Fig. 3.

Table 1

T, K	N_e, W
253,2	6982,8
268,2	6508,9
283,2	6085,4
298,2	5704,5
313,2	5360,3

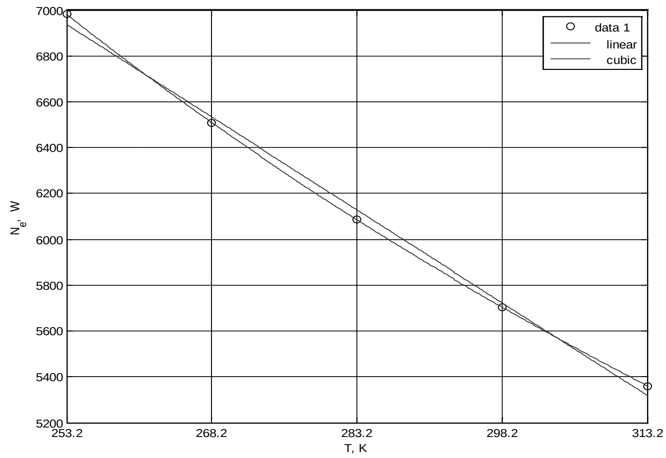


Fig. 3. *Graphs of the engine power on the cubic and linear dependences from the air temperature*

Engine power in case the temperature of the incoming air can be determined accurately by the cubic dependence

$$N_e = 5704,5.\left(5,9.10^{-8}.T^3 + 6,724.10^{-5}.T^2 - \right. \\ \left. -2,849.10^{-2}.T + 5,093\right), \quad (1)$$

or approximately linear relationship

$$N_e = 5704,5.\left(-4,736.10^{-3}.T + 2,4165\right) \quad (2)$$

which is illustrated in Fig. 3.

4. *Influence of the parameters of the air over the operating cycle and power*

By conducting numerical experiments with the simulation model, indicator diagrams and calculated values of engine power at different pressure and temperature of the ambient air, corresponding to a height are built (Table 2).

Table 2

H, m	p, Pa	T, K	N_e, W
0	101330	288,2	5959,2
500	95464	284,9	5541,1
1000	89877	281,7	5114,4
1500	84559	278,4	4704,6
2000	79499	275,2	4306,7

Fig. 4 shows the indicator diagrams of diesel engines for different heights.

With increasing altitude, the maximum pressure of the cycle of the engine decreases (Fig. 4).

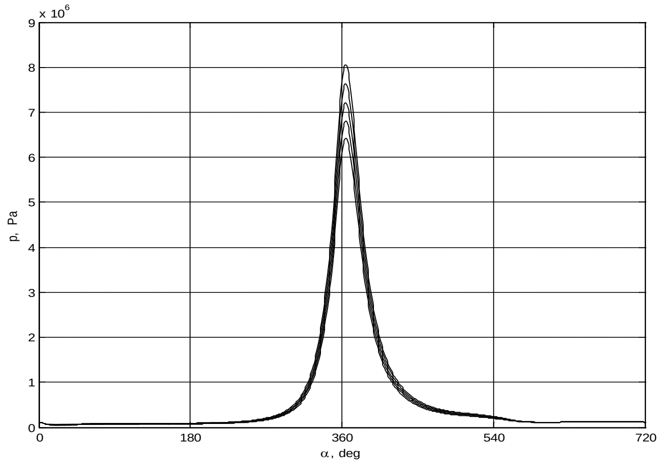
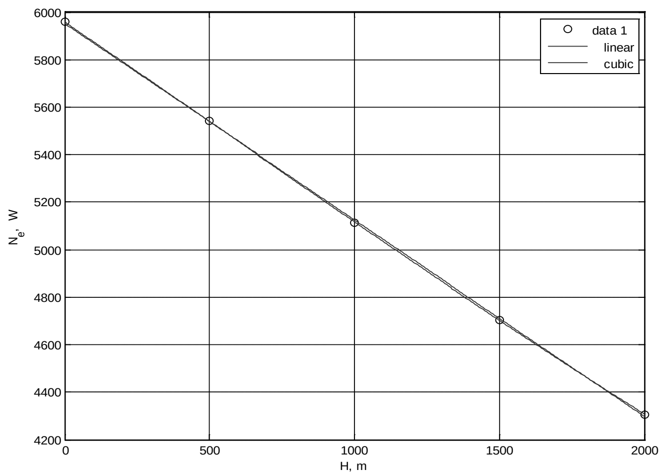


Fig. 4. *Influence of the parameters of the air on the working cycle*



Фиг. 5. *Graphs of the engine power on the cubic and linear dependences from the parameters of air at a given altitude*

Power of the engine at a given altitude can be determined accurately by the cubic dependence

$$N_e = 5959,2.\left(2,294.10^{-12}.H^3 - \right. \\ \left. -4.10^{-9}.H^2 - 1,39.10^{-4}.H + 1\right), \quad (3)$$

or estimated with sufficient accuracy by the linear relationship

$$N_e = 5959,2.\left(-1,39.10^{-4}.H + 1\right). \quad (4)$$

With increasing altitude, engine power decreases by approximately the linear relationship (3) shown in Fig. 5.

5. Influence of the air pressure in the turbocharged operating cycle and power

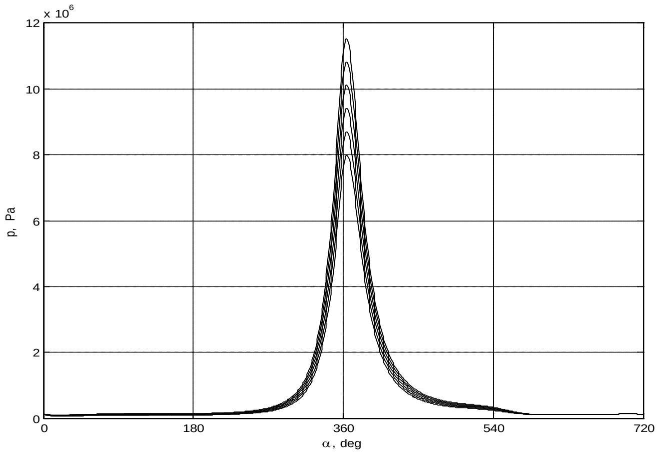
The results obtained for the engine output of the parameters of the incoming air at supercharge, without intermediate cooling are shown in Table. 3.

Table 3

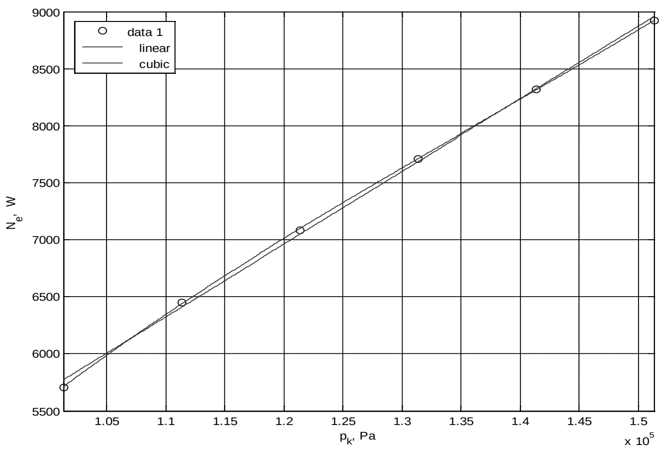
$p_к$, Pa	T_k, K	N_e, W
101330	298,2	5704,5
111330	306,5	6347,9
121330	314,2	6978,9
131330	321,6	7598,6
141330	328,5	8207,8
151330	335,1	8807,2

Indicator diagrams obtained at respective values of pressure and temperature of the intake air at supercharge, without intermediate cooling are shown in Fig. 6.

Upon increase of the pressure and the air temperature at supercharge, the maximum pressure of the cycle increases.



Фиг. 6. *Influence of the pressure and temperature of the air at supercharged on the operating cycle*



Фиг. 7. *Influence of pressure and temperature of air at the supercharged on the power*

By increasing the pressure of the filling and the corresponding value of the air temperature, the power is increased (Fig. 7).

The engine power, at a certain value of pressure of supercharge can be determined exactly by the cubic dependence

$$N_e = 5704,5.\left(8,2.10^{-16}.p_k^{\ 3} - 3,36.10^{-10}.p_k^{\ 2} + \right.$$
$$\left. +5,635.10^{-5}.p_k - 2,1143\right) \quad (5)$$

or approximately by the linear relationship

$$N_e = 5704,5.\left(1,118.10^{-5}.p_k - 0,12147\right). \quad (6)$$

6. Conclusion

With the created a simulation model, is researched the influence of the parameters of the incoming air on the processes of the working cycle and the power of the four stroke single-cylinder diesel engine under different weather conditions and supercharge.

New, accurate and approximate simple dependence on determination of the engine power by the air temperature, altitude, and air pressure at the supercharged are obtained.

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