A SIMULATION STUDY OF THE INFLUENCE OF THE RELATIVE HEAT RELEASE DURING COMBUSTION ON THE INDICATOR DIAGRAM OF A DIESEL ENGINE

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Abstract

This article presents the results, obtained in MATLAB environment with a Simulink computer simulation model for the study of the processes of the working cycle of the four-stroke internal combustion engine, of numerical experiments conducted at three different values of the parameter in the Vibe function, whereby three versions of the relative heat release law are determined. After choosing the average pressure indicator of the working cycle for optimality criterion, the optimal values of the beginning of the heat release for the selected three variants of the relative heat release law are determined. After adoption of the limited maximum value of the pressure of the working substance, numerical experiments have been established under various values of the compression ratio and the filling pressure. The values of the compression ratio and the filling pressure are fixed, under which the resulting maximum pressure value of working substance is not greater than the permissible limits.

Keywords: *Internal combustion engines, diesel engines, simulation study.*

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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 operating substance parameters during periods of the intake process, compression, expansion and exhaust process. It includes the equation for the dynamics of combustion and heat and the equation of continuity [2, 8, 9, 10, 12, 13].

The simulation model (fig. 1) of four-stroke ICE in MATLAB with Simulink [1, 3, 4, 5, 6, 7, 11, 15] is realized, based on mathematical description of the successively implemented processes of the operating cycle of ICE [2, 8, 9, 10, 12, 13]. In the auxiliary script file to the simulation model is 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 and 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, 4, 5, 6, 10, 11].

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 [10].

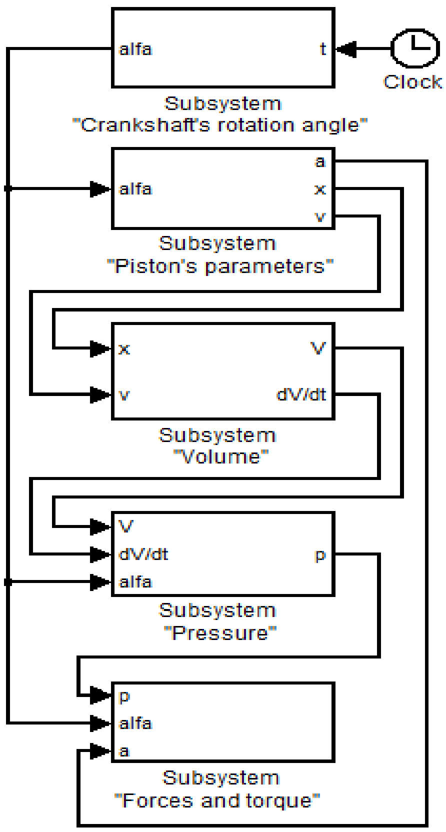

Fig -1: Simulation model of ICE

The purpose of this work is to study the influence of the relative heat release law during combustion and its beginning on the indicator diagram or the pressure of the working substance, in steady state operation of four-stroke diesel engine, through numerical experiments with the created simulation model [3] and the compression ratio and the filling pressure on the maximum pressure of the working substance.

2. A SIMULATION STUDY

After setting the parameters of a four-stroke single-cylinder diesel engine [14] and the working substance, described in the script file that is part of the simulation model, numerical experiments were carried out with it.

Different laws of relative heat release are specified - x by means of the value of the parameter in Vibe function [1, 3, 4, 7, 13] m = 0,5; 1.0; 1,5 at an initial angle - $\alpha_y = 10^o$ and duration - $\alpha_z = 50^o$. The results of the numerical experiments are presented in Fig. 2, 3 and 4.

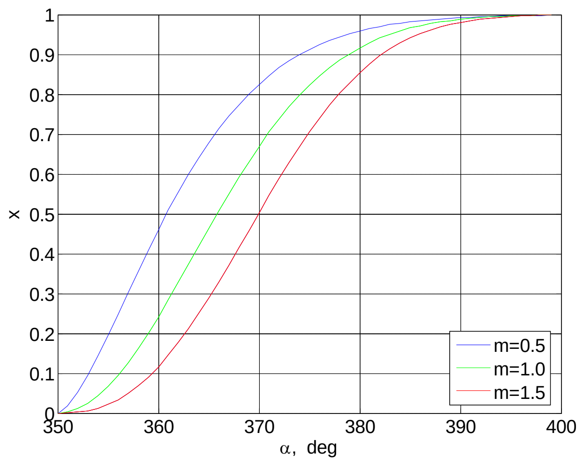

Fig -2: Relative heat release at m = 0,5; 1,0; 1,5; $\alpha_y = 10^o$ и $\alpha_z = 50^o$

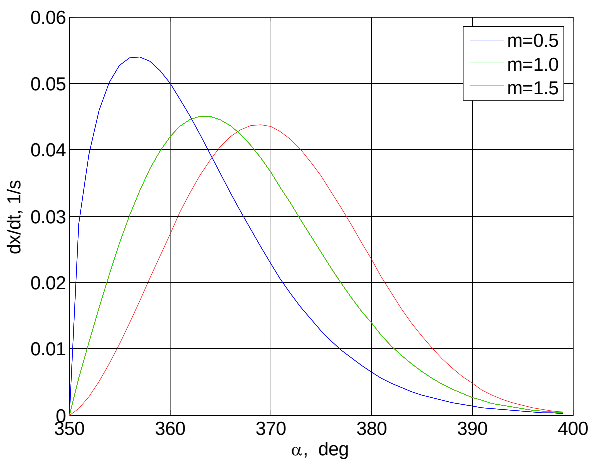

Fig -3: Speed of relative heat release at m = 0,5; 1,0; 1,5; $\alpha_y = 10^o$ и $\alpha_z = 50^o$

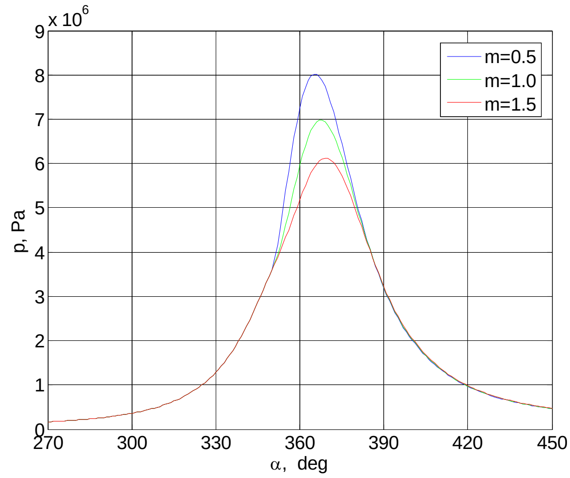

Fig -4: Indicator diagram at m = 0,5; 1,0; 1,5; $\alpha_y = 10^o$ и $\alpha_z = 50^o$

The optimum value of the relative heat release in the top dead center (TDC) at selected initial angle depends on many factors and can be determined by implementing the optimization procedure after selecting p_{imax} for criterion.

For each of the values of m = 0,5; 1.0; 1.5, using the adopted criterion p_{imax} for optimality of the relative heat release, are defined corresponding optimal values of the initial angle $\alpha_y = 9^o$; 11.5^o; 14^o. The results of the numerical experiments with the optimal values of the initial angle are shown in Fig. 5, 6 and 7.

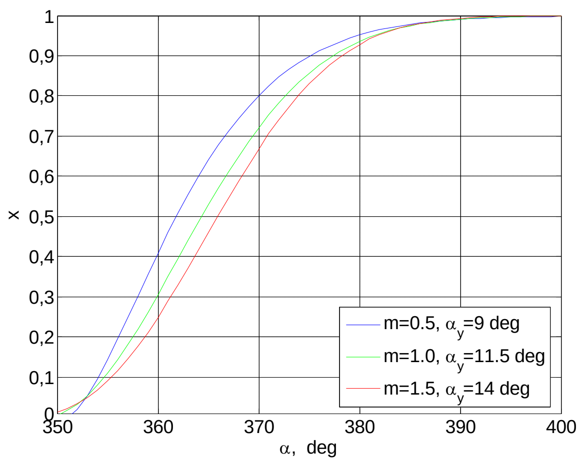

Fig -5: Relative heat release at optimal values of the initial angle

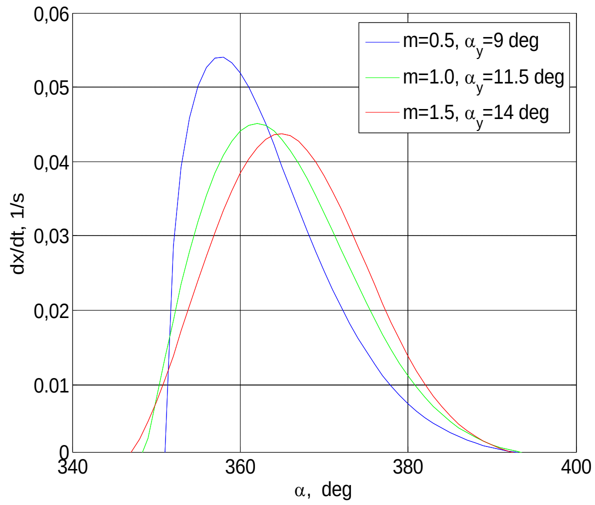

Fig -6: Relative heat release speed, optimal values of the initial angle

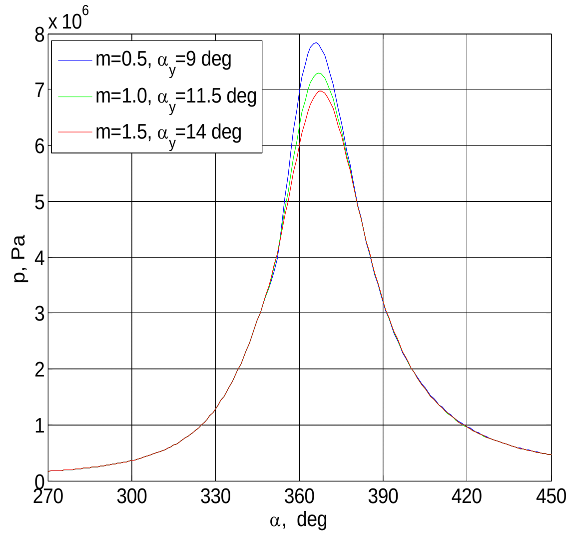

Fig -7: Indicator diagram at optimal values of the initial angle

After calculating and comparing the values of the average pressure indicator, obtained for the three values of the parameter m and the respective optimal values of the initial angle α_y, the variant with m = 0,5, $\alpha_y = 9^o$ and $\alpha_z = 50^o$ is selected. Numerical experiments are conducted with this variant at varying values of the compression ratio and the filling pressure.

The results obtained for the pressure of the working substance at ε = 17; 18 and 19, wherein the filling pressure p_k = 0,1; 0,12 and 0,15 MPa, are shown graphically in Fig. 8, 9 and 10. There it is shown that the maximum pressure of the operating cycle, which determines the maximum value of the gas force, assumes values within a wide range - from 7 to 9 MPa.

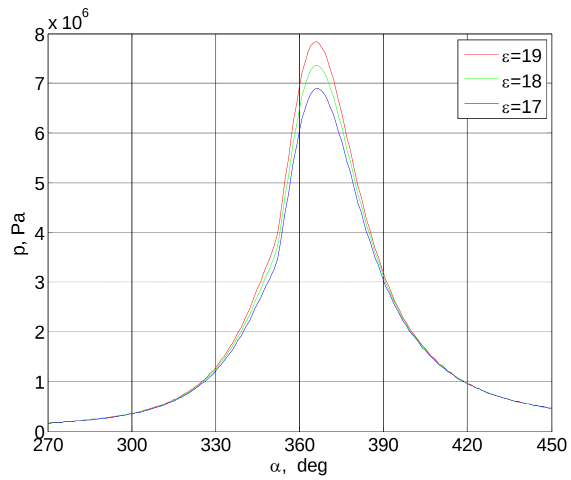

Fig -8: Indicator diagram at compression ratio ε = 17; 18; 19 and filling pressure $p_o = 0{,}1\,MPa$

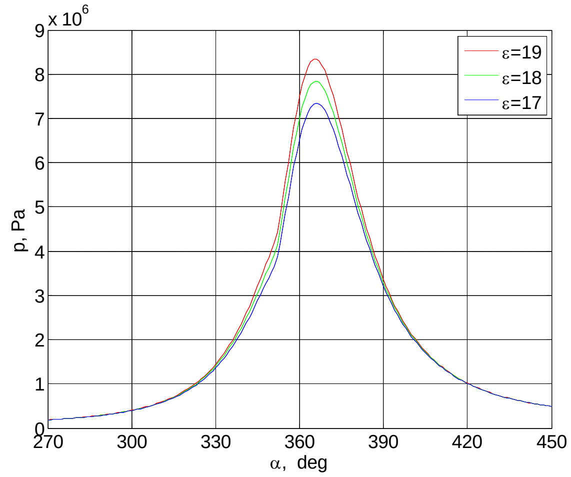

Fig -9: Indicator diagram at compression ratio ε = 17; 18; 19 and filling pressure $p_k = 0{,}12\,MPa$

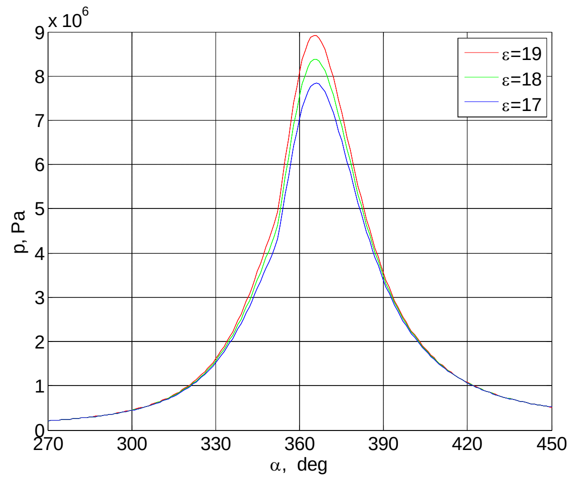

Fig -10: Indicator diagram at compression ratio ε = 17;18;19 and filling pressure $p_k = 0{,}15\,MPa$

With an assumed or imposed limitation of the maximum load of the gas force of the crank mechanism elements at various filling pressures, it becomes necessary to change the compression ratio.

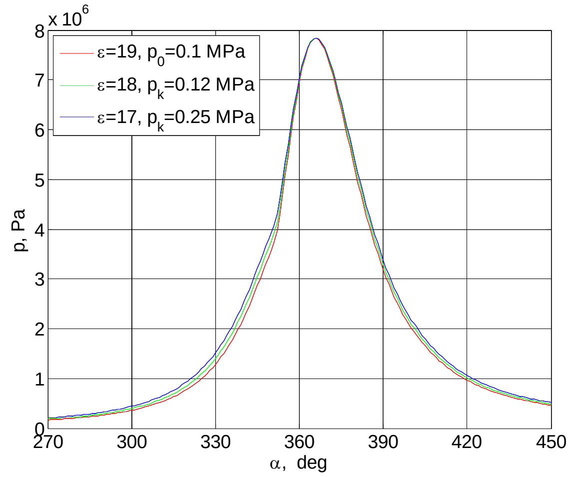

Fig -11: Indicator diagram at varying degrees of compression ratio and filling pressure

With a value of p_{max} in Fig. 11, are presented unfolded indicator diagrams, derived from the results presented in Fig. 8, 9 and 10, with the following combinations of values of the compression ratio and the filling pressure: 1) $\varepsilon = 17$, $p_k = 0{,}15$ MPa; 2) $\varepsilon = 18$, $p_k = 0{,}12$ MPa; 3) $\varepsilon = 19$, $p_o = 0{,}1$ MPa.

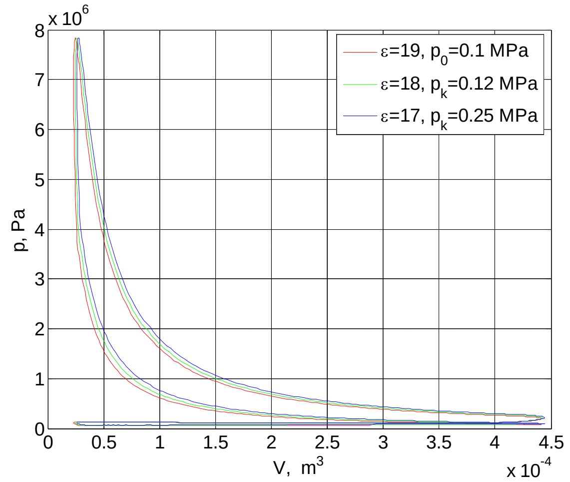

Fig -12: Indicator diagrams for different degrees of compression ratio and filling pressures and the same stroke of the piston

Fig. 12 shows the indicator diagrams with limited value of p_{max}, obtained at different values of the compression ratio by changing the volume of the combustion chamber and maintaining the same stroke of the piston, wherein the maximum volume of the operating space is changed. Such a change of the compression ratio can be realized by piston cylinder head devices, mechanisms for changing the top dead center of the piston or with a displacement of the cylinder head [7, 12].

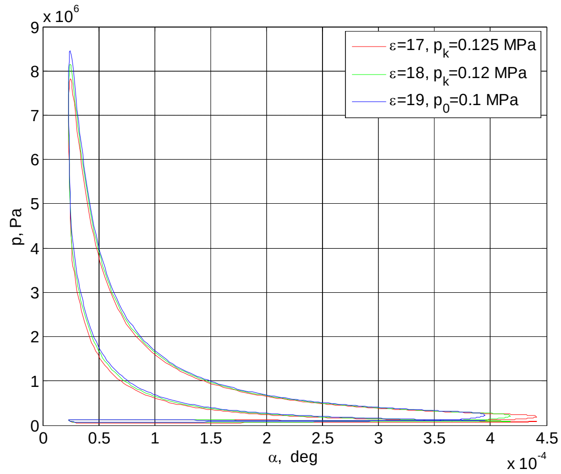

Fig -13: Indicator diagrams for different degrees of compression ratio and filling pressures and different stroke of the piston

In Fig. 13 are presented indicator diagrams obtained by changing the volume of the combustion chamber and piston stroke where the maximum volume of the workspace remains constant. Such a change of the compression ratio can be realized by a composite piston, the crown of which can perform a relative movement in relation to the piston base, or through a connecting rod with variable length of the body, and [7, 12].

3. CONCLUSIONS

With the help of the designed in MATLAB environment with a Simulink computer simulation model for the study of the processes of the working cycle of a four-stroke internal combustion engine are carried out numerical experiments with three different values of the parameter in the Vibe function, whereby there are determined three versions of the relative heat release law. After choosing the average pressure indicator of the working cycle for optimality criterion, the optimal values of the beginning of the heat release for the selected three variants of the relative heat release law are determined. After adoption of the limited maximum value of the pressure of the working substance, numerical experiments have been conducted under various values of the compression ratio and the filling pressure. The values of the compression ratio and the filling pressure are determined, under which the resulting maximum pressure value of working substance is not greater than the permissible limits.

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BIOGRAPHIE

Assoc. prof. Valyo Nikolov, PhD is lecturer in Internal Combustion Engines (ICE) and has professional experience and interests in the field of ICE, Dynamics and Vibrations of ICE, Cars, Vehicles and Machines.