DETERMINATION OF THE TOTAL EFFICIENCY FOR ENGINE WITH SPARK-IGNITION AND COMPRESSION-IGNITION

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Abstract

This paper presented of developing a power system for two fuel injection systems – spark ignition and compression ignition.

Two ways to initiate combustion process were used: initially the spark ignition, and after it turns off - the combustion is initiated by the injection of ignition injected fuel.

The composition of the ignition dose was developed through the research conducted in order to adjust the right proportions of chemical components to obtain the best parameters of the combustion process.

The study considered the performance of the ignition dose injected into the engine cylinder and its evaporation process, the charge stratification, the formation of toxic emission and the total efficiency of the engine.

Experimental studies were carried out on a test engine equipped with two injection systems and automatic mode change control management. The scope of research included:

- *determining the basic characteristics of the engine operation, taking into account the injection advance angle of the ignition dose,*
- *comparative studies of engine performance and exhaust gas composition, working with spark ignition and initiated by compression ignition of the ignition dose,*
- *determining the increase in the general efficiency of the two-circulation engine working with injection of ignition dose compared to conventional power system with the initiation of combustion process from the spark plug.*

Keywords: *two fuel injection systems, spark-ignition and compression-ignition engine*

1. Introduction

Research topics in the world of scientific - research is mainly focused on increasing of the general efficiency of engines, which directly results in lower specific fuel consumption [8]. Due to the increasingly stringent standards for maximum emissions of toxic gases, it is necessary to develop and test innovative design power systems for unconventional solutions, enabling the combustion engine in two ignition systems in conjunction with the two power supply systems [3, 7]. In addition, the rapid development of mechatronic systems allow the use of advanced electronic control of the injection process, combined with the use of two types of ignition, can be achieve higher general efficiency and the reduced toxic emissions. The end result of this study is to analyze the theoretical and engine performance about the advantages of both spark ignition engine and compression ignition assuming a reduction of the concentration of toxic gases and increasing of the total efficiency [4, 6].

2. Investigation object

The test stand was built on the basis of naturally aspirated, four-cylinder, four-stroke spark ignition engine of displacement 1.3 dm^3. In the engine uses 4 valves per cylinder with systems of variable valve timing for intake valves. The test engine was installed on dynamometer test stand with eddy current brake of type Automex AMX 200. Nominal power of this device equals kW. The brake is controlled by means of measuring - control system the same producer. Investigations whose results served for analysis of the total efficiency were carried out for rotational speed n=2500 rpm at fully opened throttle. Fig. 1 shows a diagram of the test stand.

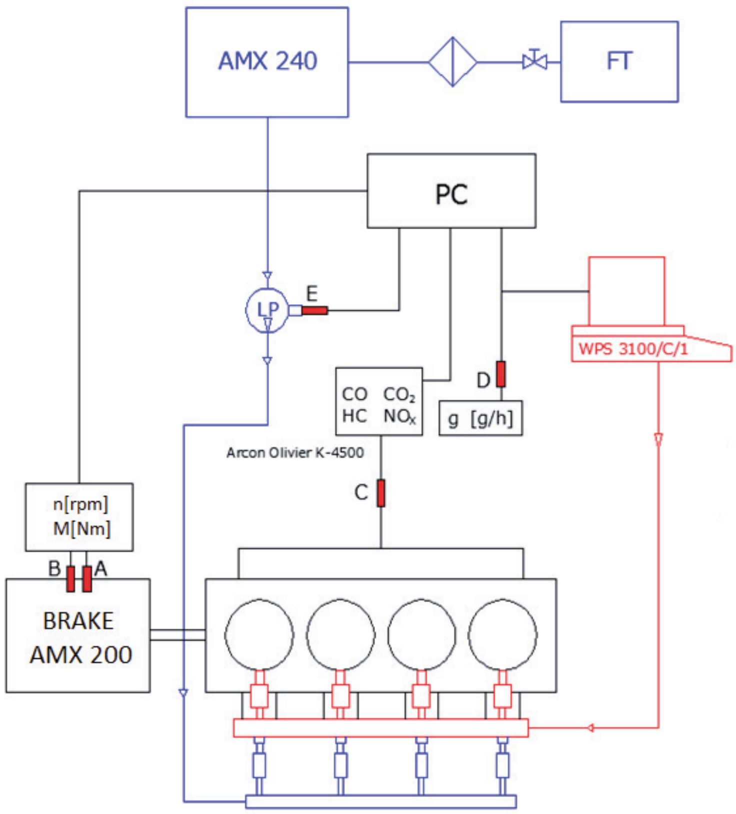

Fig. 1. Scheme of the test stand (symbols: A – meaurement of rotational speed, B – measurement of rotational moment, C – measurement of coefficient of air's surplus, and toxic components of exhaust fumes, D – measurement of mass expense of fuel, for injection of ignition dose, E – measurement of fuel's consumption of fundamental dose

3. System of power supply

Gravimetric fuel AMX 240 connected to the engine brake control system enables the measurement of fuel flow in the system of indirect fuel injection. Fuel flow rate in the fuel injection system directly measured using a laboratory scale Radwag WPS 3100/C/1 with graduations 10 mg. Weight is equipped with a tank in which there were fuel for the ignition direct injection dose. The path measurement is performed by a connection to a PC via the serial port RS232. The appropriate application developed in LabView environment enables the measurement of the current mass of fuel in the tank resting on the weight. In order to make high pressure injectors of direct injection system work properly the injectors were connected to the engine controller by a special electronic driver. This system permits supplying the injectors with increased voltage of about 100 V and it has the function of limiting the supply current to the injector after its full opening [1, 2].

During preliminary investigations of the engine the maximal constant value of the ignition dose injection pressure equalled 15 MPa. This restriction was forced by application in the ignition dose injection system of injectors applied in systems of gasoline direct injection in which the working pressure of fuel did not exceed 12 MPa. [5, 9] System of injection of fundamental dose was installed in head of engine, in approach lines before embranchment of ducts directed to every with two approach valves of respective cylinders. For the purpose of enabling injection of ignition dose directly to working space, in head of testing engine holes were built passing through water casing to every with four combustion chambers. In holes thin-walled sleeves were placed from stainless steel, in which high-pressure injection systems of ignition dose were installed. Sleeves were glued in holes by means of high-endurance epoxide resin with filler in form aluminium dust. Fig. 2 presented diagram of system of power supply.

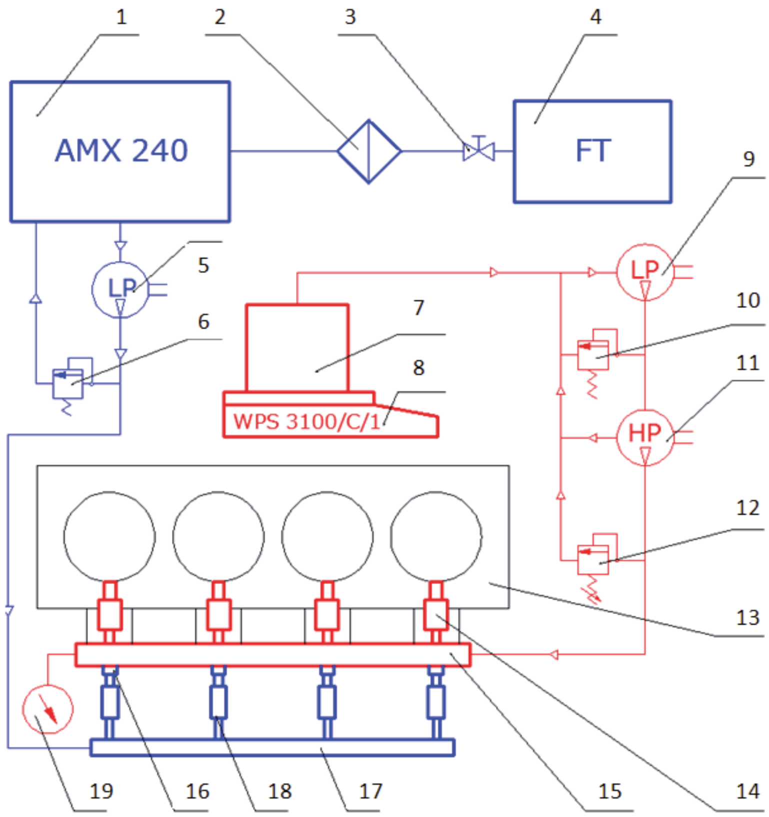

Fig. 2. System of power supply of testing engine (1 – grawimetric fuel's gauge, 2 – fuel's filter, 3 – cutting off valve, 4 – fuel's tank for system MPI, 5 – pomp of fuel of injection's petrol, 6 – controller of pressure of petrol's injection, 7 – fuel's tank for sytem of ignition dose,8 – laboratory scales ,9 – powering pomp system of ignition dose, 10 – controller of low pressure of circuit of ignition dose, 11 – pomp of high pressure, 12 – pressure's controller of injection of ignition dose, 13 – testing engine, 14 – injection system of ignition dose, 15 – fuel splint of injection systems of ignition dose, 16 – approach duct, 17 – fuel slat of system MPI, 18 – injection system of petrol for system MPI, 19 – manometer pressure's of injection ignition dose)

4. Experimental studies

Experimental studies of the engine aimed to determine the overall efficiency for the chosen point of the work by a change the way the spark ignition for compression ignition. Speed characteristics were determined for the specific fuel consumption, both the engine running in spark ignition mode and compression ignition. On the basis of a comparison of the total efficiency of the research engine.

4.1. Determination of the total efficiency engine working in spark ignition mode

In order to determine the characteristics of the total efficiency engine working in spark ignition mode, the following parameters defined:

- fuel dose: 0.022 g/cycle,
- beginning of ignition: 15° CA before TDC,
- pressure in the intake manifold 0.13 MPa.

The parameters are defined in such a way as to be usable for subsequent comparison obtained specific fuel consumption and total efficiency compared to the results obtained for the engine working in compression-ignition mode. Fig. 3 shows the course of the specific fuel consumption and total efficiency as a function of crank angle for the test engine working in spark-ignition mode.

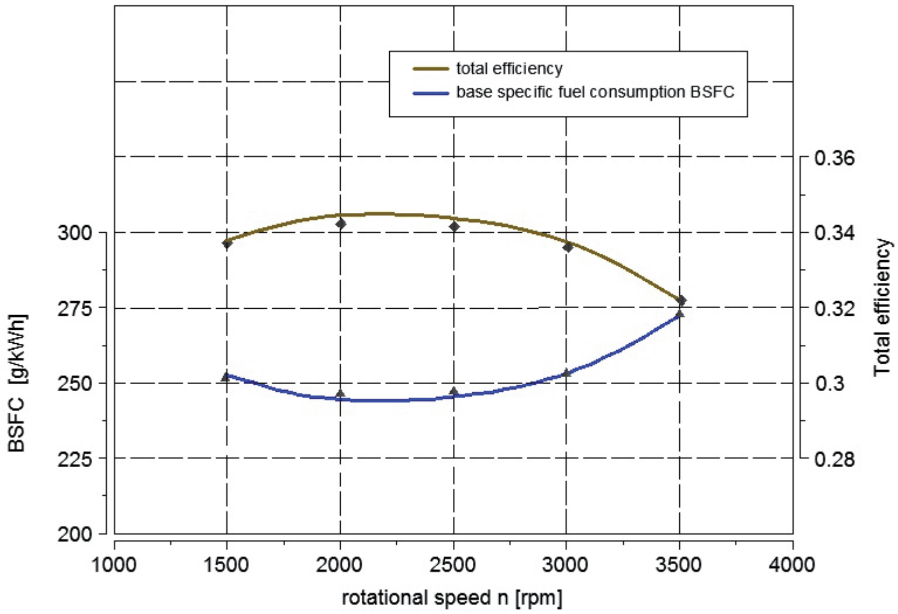

Fig. 3. Course of specific fuel consumption and total efficiency as a function of crank angle for the test engine working with spark ignition mode

The analysis must be observed that the maximum total efficiency of the test engine reaches 0.345 at a speed of 2000-2500 rpm, specific fuel consumption is about 245 g/kWh.

4.2. Determination of the total efficiency engine working in compression ignition mode

In order to determine the total efficiency engine working in compression ignition mode, the following parameters defined:

- fuel dose for SI 0.0208 g/cycle,
- fuel dose for CI 0.001 g/cycle,
- beginning of ignition: 15° CA before TDC,
- beginning of injection of ignition dose 28° CA before TDC,
- injection pressure of the ignition dose 15 MPa,
- pressure in the intake manifold (SI) 0.13 MPa,
- pressure in the intake manifold (CI) 0.14 MPa.

Composition dose ignition was developed during the research to the selection of the right proportions of chemical components to obtain the best performance of combustion and heat release. Due to patent application the chemical composition of the dose ignition, cannot be specified.

The proposed solution is to start the engine and operation at low speed and low load, using spark ignition. Increase the engine speed and load test disables the ignition and turning the direct injection ignition dose. Injected dose ignition to homogeneous charge because detonation of the total mixture contained in the cylinder.

Figure 4 shows a comparison of the fuel consumption per unit for the test engine working at a speed n=2500 rpm.

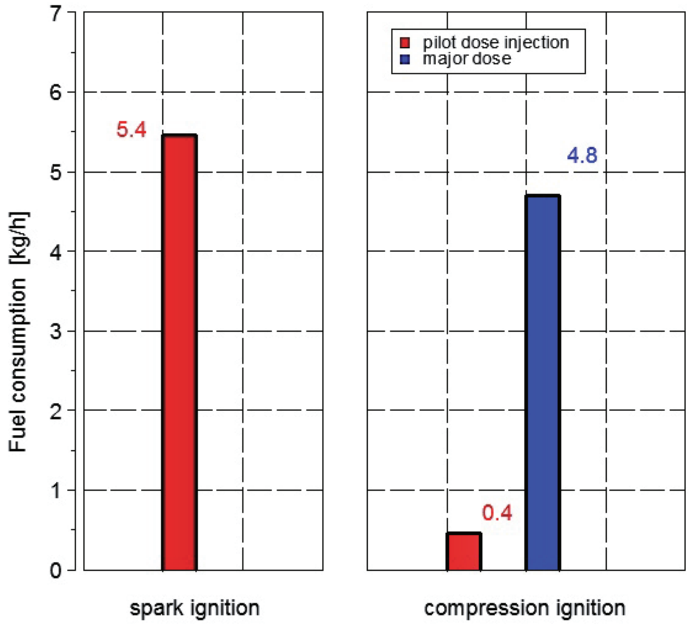

Fig. 4. Comparison of the fuel consumption the test engine working in spark ignition and compression ignition mode for the speed 2500 rpm

In Fig. 4 can be see that the engine working with spark-ignition engine consumes slightly more fuel per unit time. Reduction fuel consumption, where the initiation of the combustion process occurs at a dose of ignition (compression ignition) is 0.2 kg/h at a speed 2500 rpm, which, combined with the increase generated by the engine torque by about 6% translates into a reduction in specific fuel consumption.

Confirmation of the above considerations can be justified on bar graph shown specific fuel consumption in Fig. 5. Decrease specific fuel consumption when the engine is working with the initiation of combustion process ignition dose was 20 g/kWh, to give the reduction o 9% in relation to the obtained for the same engine operating parameters of the initiation of combustion process spark-ignition mode. Total efficiency was determined by the formula:

$$\eta_o = \frac{3600000}{W_d \cdot g_e}, \tag{1}$$

where:

W_d – calorific value of the fuel,
g_e – specific fuel consumption,
3600000 – coefficient depends on the units used.

For the determination the advantages for ignition-dose supply was compared the total efficiency obtained by the motor in consideration of both modes. Fig. 6 shows a comparison of the total efficiency of an engine working on the spark ignition and compression ignition.

The analysis the total efficiency of the test engine confirms increase it's carrying by using the supply of the injected dose of ignition. For this operating point is achieved increasing the total efficiency of about 8%.

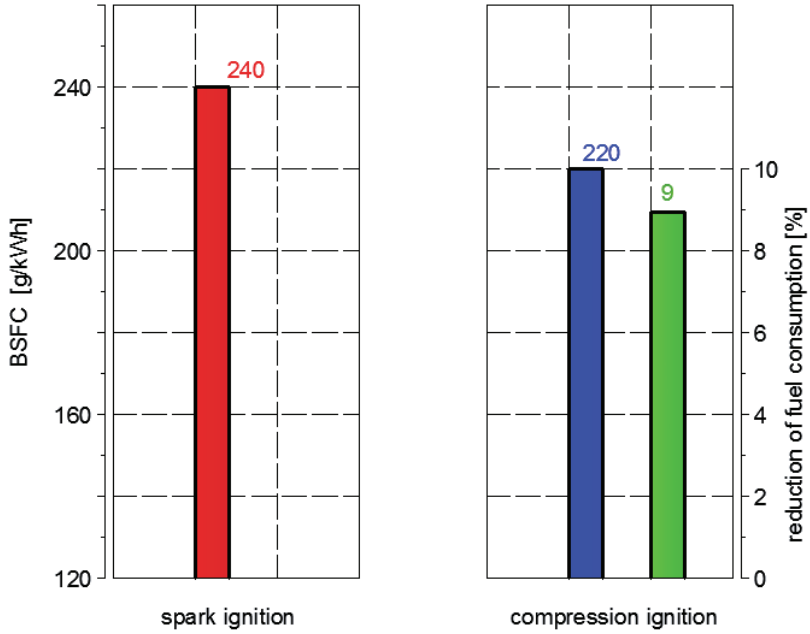

Fig. 5. Comparison of the specific fuel consumption the test engine working in spark ignition and compression ignition mode for the speed 2500 rpm

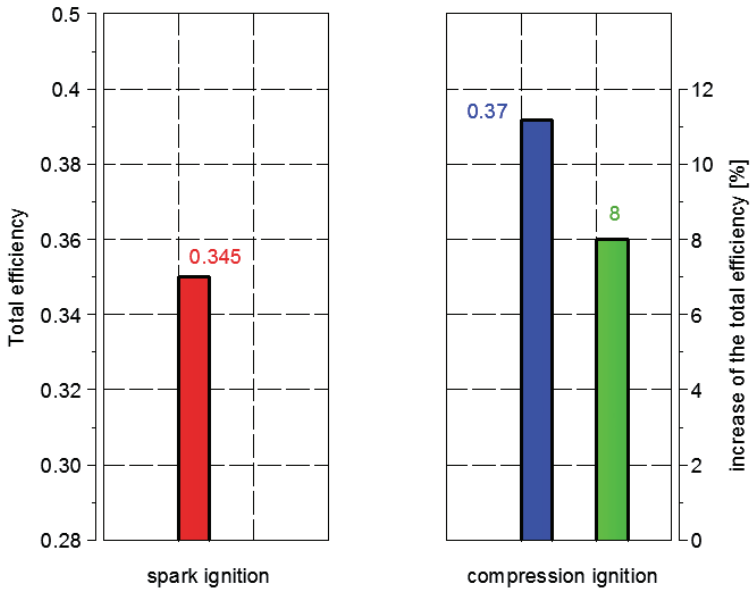

Fig.6. Comparison of the total efficiency the test engine working in spark ignition and compression ignition mode for the speed 2500 rpm

5. Comparison of toxic gas engine working with spark ignition and compression ignition

Measurement of toxic components, namely carbon dioxide CO2, carbon monoxide, nitrogen oxide, NO, O_2, and hydrocarbons HC was conducted using a gas analyser Arcon Olivier K-4500. The analyzer has a measuring chamber for the analysis of carbon monoxide CO and carbon dioxide CO_2 and hydrocarbons HC, and the measurement of their shares by volume is carried by NDIR (Non Dispersive stands for Infrared). With the help of electrochemical cells defined volumetric concentration of other ingredients such as O_2 and nitric oxide NO [5, 10].

Figure 7 shows the content of toxic gases, namely, carbon dioxide, carbon monoxide, nitrogen oxide and hydrocarbons for engine working with spark ignition and compression ignition.

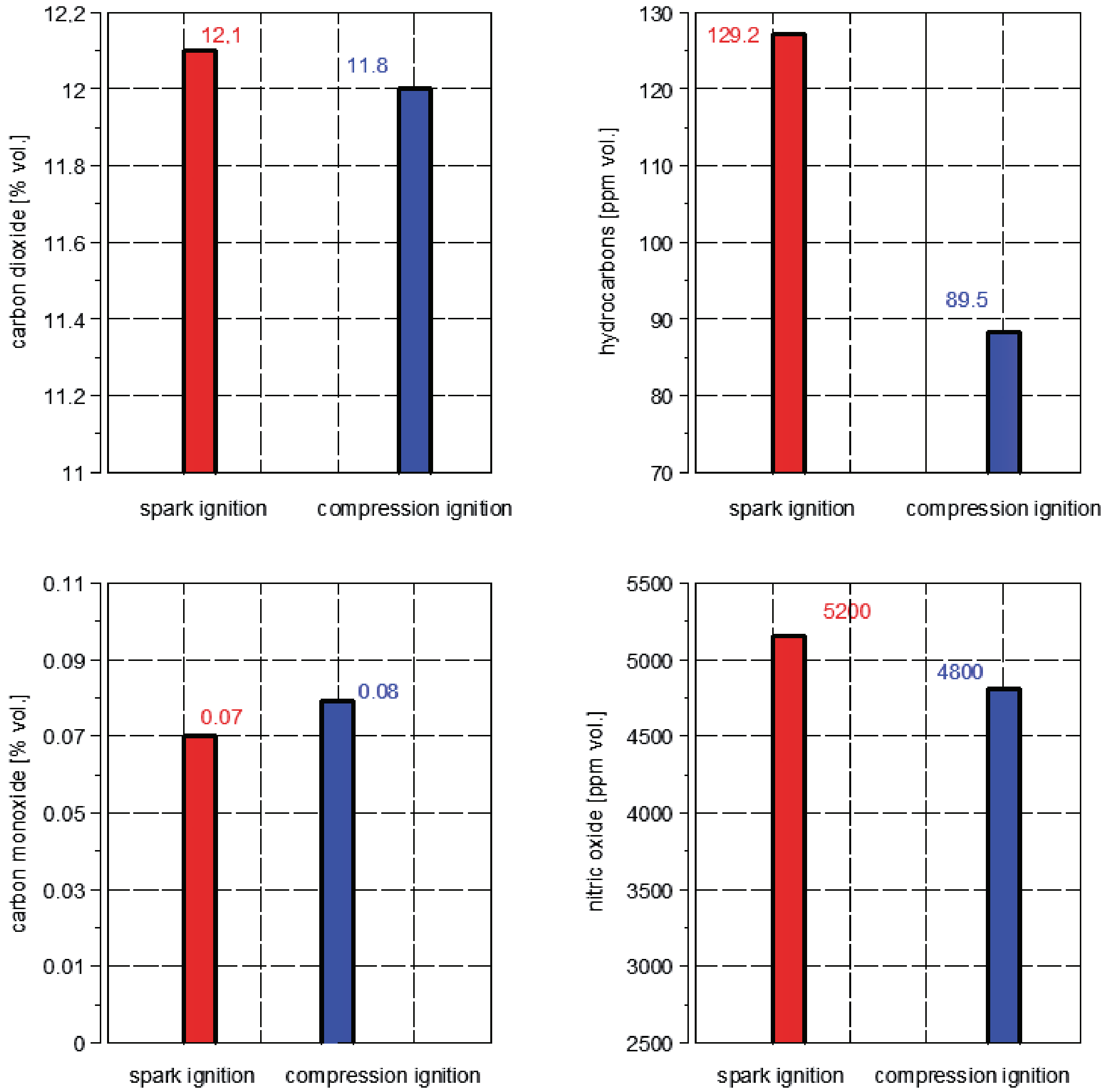

Fig. 7. Comparison of toxic gas engine working with spark ignition and compression ignition for the speed 2500 rpm

Analysis of the results of a spark ignition engine and compression based on the content of toxic exhaust gases for the two modes, presented in Fig. 7 has allowed define the following conclusions:

- injection of the ignition dose lowers the temperature of mixture in the cylinder which directly influences reduction of toxic gases
- in case the engine in the compression-ignition mode, the volume fraction of carbon dioxide is reduced, while the concentration of carbon monoxide is slightly increased,
- this phenomenon is probably related to the incomplete combustion of heterogeneous rich mixture which is formed around kernel injected dose ignition,
- in the exhaust gases engine working in compression-ignition mode are reduced hydrocarbon and nitric oxide concentration compared to the results recorded at engine working in spark ignition mode,
- neutralization of carbon monoxide in the catalytic oxidation reactor is not a problem due to the fact that the test engine is operating in the compression-ignition of the mixture global excess air ratio greater than unity.

6. Conclusions

Basing on analysis of results of carried out test bed investigations the following conclusions can be drawn:

1. In this point of the engine operating map transition to the mode of combustion initiation by means of ignition-injection is characterized by a much higher total efficiency at concomitant improvement of engine performance.
2. Increasing of general efficiency in case application of work mode of engine with initiation of combustion from ignition dose is caused decreasing of individual fuel's consumption.
3. Improvement of parameters of engine working with compression ignition results from intensification of the process of charge combustion. A shorter course of the combustion process of mixture influences positively on reduction of engine heat losses what is reflected directly in increase in total efficiency.
4. Engine with spark-ignition and compression-ignition with electronic control of the ignition type change demonstrated lower emissions of toxic exhaust components, particularly hydrocarbons and nitrogen oxide along with the increase of the overall efficiency in rotational speed compared to conventional spark-ignition and diesel engines.

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