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Intensification of the combustion process in a gasoline engine by adding a hydrogen-containing gas

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ABSTRACT

The results of research on the impact of adding a hydrogen-containing gas obtained by water electrolysis to the air charge of a gasoline engine on the combustion process, the indicator values of the work process, fuel-consumption efficiency and environmental performance of the engine are provided in the paper. The indicator tests of the work process of the engine have been carried out and the key data on the indicator values of the work process of a gasoline engine have been calculated on the base of the obtained indicator-diagrams. It was found that adding a hydrogen-containing gas caused shortening of all phases of combustion and an improvement of the indicator values of the engine. If a hydrogen-containing gas is added to the air charge of a gasoline engine, fuel-consumption efficiency as well as its energy and environmental performance are improved.

Introduction

Internal combustion engines play a main role among power systems of engines vehicles. The most widely used engines of the said type include gasoline engines and diesel engines predominantly used in light engines vehicles; the number of such vehicles increasingly grows. During the history of its development (over one hundred years), the structure of gasoline engines passed abundant improvements. Nevertheless, the search for solutions related to improving their performance remains relevant in our time as well [1].

As it is known, the effective performance indicators of an internal combustion engine depend considerably on the character of run of the combustion process. The combustion process in internal combustion engines may be assessed according to the indicator-diagram of the pressure in a cylinder of the engine [2]. An engine achieves the maximum power and ensures the minimum fuel consumption, if the pressure in a cylinder achieves its maximum value when the crankshaft rotation angle is 12–15° after the Top Dead Center (TDC) and

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the moment of start of rapid growing of pressure conforms to the position of the shaft at 12–15° before TDC.

It is known that usual operating modes of vehicle engines are partial load and partial velocity modes. In course of reduction of the engine's power by throttling, the initial and final compressive pressures decrease and the degree of dilution of the combustible mixture with residue gas increases [3]. The said circumstance results in a considerable deterioration of the conditions of the mixture ignition by a spark and formation of an initial base of fire in it. It finally causes an increase of duration of combustion process and growing of the degree of its non-repeatability in some cycles, thus resulting in a deterioration of the fuel efficiency and the environmental performance of the engine [4].

One of the methods for improving the combustion process in gasoline engines in the modes of low loads and idle run is using additives of activating agents that intensify the combustion process. Such additives include hydrogen and hydrogen-containing compounds. Using the additive of hydrogen-containing gas (H2/O2) generated by electrolysis of aqueous solutions of alkali is perspective [5]. The said gas consists of hydrogen and oxygen molecules and atoms and its burning rate is considerably higher, as compared to the burning rate of gasoline. For example, the flame propagation velocity while combustion of gasoline-air mixture is 30 m/s and while combustion of gasoline-hydrogen mixture - 270 m/s [6], whereas the flame propagation velocity while combustion of hydrogen-oxygen mixture is 890 m/s [7].

At various research centres worldwidely, investigation of H2/O2 additive use for improvement of performance of vehicle engines takes place. The tests carried out on single-cylinder gasoline-powered plant [8] showed that adding the hydrogen-containing gas H2/O2 resulted in an increase of the torsion torque by 19.1% and a decrease of the specific fuel consumption by 14%, as compared to operation of the engine on gasoline only. The tests of four-stroke gasoline-powered engines [9–11] where a hydrogen-containing gas is fed to the intake manifold through a special nozzle showed that the H_2/O_2 additive results in a reduction of CO and CmHn emission. The tests of the engine operating on gasoline and liquefied petroleum gas in the mode of idle run at different speeds of the crankshaft [12–15] showed that H2/O2 additive results in a reduction of fuel consumption regardless of the type of the fuel. While operation of an engine on gasoline with a hydrogen-containing gas additive, it was found that the fuel consumption decreased by 9.65% on the average, and while operation of engine on liquefied natural gas – by 15.7%. In course of the investigation carried out at the Renewable Energy Center under the University of South Australia Advanced Technologies and Machine Building School [13], it was established that H2/O2 adding to the air charge of the diesel engine resulted in a reduction of fuel consumption and of emission of incomplete combustion products (CO и CmHn) with exhaust gases.

In course of the research work carried out upon use of a simulated model of the work process of a gasoline-powered engine developed upon applying the set of programmes AVL [14,16], it was found that H2/O2 additive results in an increase of the maximum pressure and temperature of a cycle and shortening the duration of the combustion cycle.

In earlier publications, no data on the results of experimental research works on the impact of adding H2/O2 to the air charge of a gasoline-powered engine upon the combustion process, a repeatability of working cycles and other indicators of the work process and of the performance of the engine as a whole were found [15–18].

Introducing HHO gas into combustion, both in terms of thermal efficiency and specific fuel consumption. It is noted that HHO gas improves combustion by increasing the engine's thermal efficiency and reducing specific fuel consumption. When comparing HHO gas with commercial gasoline, HHO is highly effective in terms of the chemical structure of the fuel. In water and oxygen, HHO exists as two atoms in one combustible unit with independent clusters, and gasoline fuel consists of thousands of large molecules of carbohydrates [19].

The concentration of HC in the exhaust gases is inversely related to the engine speed. This is due to an increase in the process of combustion of combustible and unburnt gas turbulence, which increases the oxidation velocity of HC. Also, a decrease in HC concentration in the exhaust gases due to the introduction of HHO is observed. This reduction in HC emissions increases with engine speed [20].

The goal of the work is an investigation of the impact of adding a hydrogen-containing additive to the air charge on the combustion process, fuel-consumption efficiency and environmental performance of a gasoline-powered engine [21,22].

The methodology of the experiment

For exploring the impact of the additive of hydrogen-containing gas on fuel-consumption efficiency and environmental performance of a gasoline-powered engine MeM3-245 (Table 1), the tests in the mode of the minimum frequency of the idle run (900 min^{-1}) were carried out. The changes of fuel consumption and the concentrations of harmful substances in the exhaust gas were examined dependently on the amount of the additive of gas H_2/O_2 that was varied from 0 to 1 L/minute [23].

The engine was installed on an engine load stand and equipped with all the required measuring instruments and a system for hydrogen-containing gas feeding (Fig. 1). Gas H_2/O_2 was generated by electrolysis of aqueous solutions of alkali (potassium hydroxide) upon applying electrolysis equipment "Lyga-02" fed by external 220 V power supply. The consumption of the hydrogen-containing gas was measured by a float rotameter, type P-10/5.

The principal scheme of the experimental plant is provided in Fig. 1.

1 – the engine load stand SAK–670 with the electric brake machine GPF a17 h (power 250 kW, maximum rotation frequency 3200 min^{-1}); 2 – the recorder of the value of the torsion torque and the rotation frequency; 3 – the equipment for measuring the rotation frequency of the crankshaft of the engine; 4 – the oil pressure sensor; 5 – the depression sensor in the intake collector; 6 – the air-flow meter RG-40; 7 – the weighing equipment for fuel consumption measuring; 8 – the device for measuring the ignition advance angle; 9 – the liquid coolant temperature sensor at the output from the blocks of the cylinders; 10 – the exhaust gas temperature sensor; 11 – the drier of exhaust gas samples; 12 – the throttle valve; 13 –