The influence of adjustment parameters on the performance of the combustion process

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Abstract. The paper analyzes the use of natural gas as a motor fuel for an automobile diesel engine of 4CHN 11.0/12.5 dimension and its effect on the indicators of the combustion process depending on the change in the value of the installation angle of advance of fuel injection. It was found that when switching to gas engine fuel, the installation angle of the fuel injection advance can be maintained at the level of basic modification, which makes the conversion process technically simple from the point of view of operation. The values of the parameters characterizing the combustion process when converted to natural gas are within acceptable limits, and a number of parameters even improve their value.

1. Introduction
Due to the constantly deteriorating environmental situation throughout the world, including in Russia, all manufacturers of automotive equipment are required to take measures to reduce the harmful effects of vehicles on the environment. First of all, we are talking about air pollution, especially in megacities, where the level of many hazardous substances exceeds the maximum permissible concentrations [1-7].

One of the ways to reduce emissions of harmful substances from vehicle exhaust is to abandon traditional petroleum fuels in favor of an alternative, more environmentally friendly one. One such fuel is compressed natural gas. Due to the simpler chemical structure of the fuel molecule, it is prone to greater completeness of combustion and, accordingly, less pollution of the atmosphere [8-12].

However, the transfer to a new fuel of engines originally designed to operate on liquid fuel requires serious research and the development of specific technical solutions that will allow this to be done without compromising its power and efficient performance, while improving environmental performance. Since, in the internal combustion engine, fuel is burned to obtain mechanical work, then, first of all, it is necessary to study the indicators of the combustion process, since all other performance indicators will depend on their effective course [13-17].

And first of all, it is necessary to determine the optimal time for supplying fuel to the cylinder in order to ensure its complete combustion, creation of the maximum work of expanding gases, but at the same time, so that these parameters do not go beyond the maximum allowable limits for a particular engine, avoiding a decrease in its reliability and durability work [18, 19].
2. Experimental
In accordance with the conducted experimental studies on the impact of the use of compressed natural gas as a motor fuel on a D-245.12C diesel engine on effective and environmental performance, we obtained the following results.

Considering the effect of natural gas on the performance of the combustion process, we draw the following conclusions. To determine the most suitable value of the angle of advance of fuel injection at the nominal operating mode, we examined several values of this angle and analyzed the indicators when working both on diesel fuel and on natural gas. When operating on diesel fuel, the value of the installation DFVT changed from 5 to 17 p.k.v. Naturally, with an increase in the value of this angle, that is, an earlier supply of fuel, the maximum temperature of the gases in the cylinder increases from 1750 to 2250 K, that is, by about 30%. This, in turn, leads to an increase in the maximum pressure of the working mixture in the cylinder from 9 to almost 12 MPa, that is, by the same 30%. A change in the value of the installation UOVT leads to a change in the rate of increase in the pressure of the mixture in the cylinder, the so-called rigidity of the combustion process. The greater the angle of advance of fuel injection, the faster the pressure of the mixture rises in the cylinder. So, when you change the installation UOVT from 5 to 17 about p.k.v. the rate of increase in pressure almost doubles. At the same time, such an indicator as the ignition delay period is reduced by almost 10% [20-26].

After we began to use natural gas as a fuel, we also checked the engine performance at these UWT values. Due to the difference in the motor properties of diesel fuel and natural gas, engine performance will also change. Thus, the maximum temperature from 2250 to 2600 K with a change in the UWT from 5 to 14 about p.p.w., the maximum pressure of the mixture in the cylinder will increase by more than 20%, the highest pressure increase rate will increase almost 1.5 times. The duration of the IDR will be reduced by almost a quarter [27, 28].

After analyzing the data we come to the conclusion that it is advisable to leave as a working installation UOVT at the level of 11° p.k.v. both when working on a diesel process, and when working on gas engine fuel. With such adjustments at the nominal operating mode, that is, the crankshaft rotational speed of 2400 min-1, the considered parameters of the combustion process are within acceptable limits for this type of engine, and the values of the maximum temperature and pressure in the cylinder suggest a high efficiency of fuel combustion, which means efficient and economical diesel operation [29, 30].

Of course, the use of other fuels leads to an increase in the highest temperature in the cylinder by almost 20%, an increase in the peak value of gas pressure by almost 10%, rigidity of the combustion process by 12%, and thus more rapid ignition of the air-fuel mixture.

This is explained by the better preparedness of natural gas for combustion, the greater amount of heat generated during the combustion of a unit mass of gas compared to diesel fuel, its lower cetane number.

Figure 2b shows the dependences of the same indicators on the value of the installation UOVT but already at a crankshaft rotation speed of 1900 min-1, which corresponds to the maximum torque regime for a given engine., i.e., the engine overload mode. This mode is one of the design for automobile engines, therefore it must also be taken into account along with the nominal operating mode [31-36].

If we increase the UOVT from 5 to 17° p.k.v., when the engine runs on diesel fuel, then the maximum temperature of the mixture burning in the cylinder will increase by a quarter and reach 2300 K, which will increase the pressure to 12 MPa. An earlier supply of fuel will contribute to a faster increase in pressure buildup, so increasing the angle by 12 degrees, we will double this speed. Although at the same time, the IDR will be reduced.

If, instead of diesel fuel, we supply natural gas and change the installation UWT at this speed, then the results will be much more noticeable. The maximum temperature will increase by almost 30%, the maximum pressure will increase by a quarter, and the stiffness of the combustion process will increase to unacceptable values with a significant reduction in the ignition delay period [37-44].
After analyzing the obtained experimental data, we came to the conclusion that even at a rotation speed of 1900 min⁻¹, the optimum value of the angle of the beginning of the fuel supply would be an angle of 11° to the top dead center. Of course, the considered parameters when switching to gas will differ from similar parameters when working on diesel fuel, but they will be within acceptable limits, which means that the engine performance will be at the level of the basic modification, and even surpass it in a number of indicators [45-49].

It should be remembered that the diesel in question has a turbocharger, like all diesel engines now produced, and this favorably affects when it is converted to gas engine fuel. This is probably due to better mixing of the gas-air mixture when passing through the compressor blades, and a more homogeneous mixture has a higher burning rate. The absence of re-enriched zones in it improves the completeness of combustion of the mixture, which means that there will be less soot particles in the
combustion products. The higher rigidity of the combustion process when operating on gas engine fuel also favorably affects effective performance [50-56].

When analyzing heat release indicators, it should be noted that at a rotation speed of 2400 min⁻¹, the relative heat release rate when working on gas fuel will be higher than when working on diesel fuel by about 40%. If the mixture entering the engine cylinder is homogeneous, then its burning rate, and hence the dynamics of heat generation, will be higher.

Of course, this will increase the maximum temperature of the gases in the cylinder and the fraction of heat released by the time the maximum pressure of the gases is reached, that is, during the second phase of the combustion process: 0.82 versus 0.74 when working on diesel fuel.

This tendency persists when the value of the angle of advance of fuel injection is changed both up and down with respect to the optimal value. So, at 11° p.k.v. it will increase by 23% [57-61].

When switching to a gas-diesel process, such an important indicator as the ignition delay period also changes. If we are talking about replacing petroleum fuel with gas-engine fuel, then we can not ignore that natural gas is much less prone to self-ignition compared to diesel fuel. Accordingly, the ignition delay period will also change, although the ignition portion of the diesel fuel remains to ignite the fuel [62-65].

Considering the results of studies during the operation of a diesel engine with a rotational speed of 1900 min⁻¹, which is a basic modification, that of a modernized version, we see the same dependence as with a rotational speed of 2400 min⁻¹. That is, when working on gas engine fuel, active heat generation increases, the proportion of heat released during the fast burning phase increases, accordingly, the amount of heat released in the last phases of the combustion process decreases. It is important that the completeness of combustion of fuel increases, this leads to a decrease in the share of harmful substances in exhaust gases, since most of them are just products of incomplete combustion of fuel.

3. Conclusion
Summarizing the results obtained, we can conclude that the use of gas motor fuel as the main one on the D-245.12C diesel engine allows one to save, and in some cases even improve, the parameters of the combustion process. The studies conducted made it possible to formulate specific recommendations in relation to the engine model being studied, namely, when switching a diesel engine to a gas engine fuel by a gas-diesel process, it is necessary to maintain the installation angle of fuel injection advance equal to 11° p.k.v.

With this angle, the considered parameters of the combustion and heat generation process are within acceptable limits, the engine retains its power characteristics, but at the same time it will provide less toxicity of exhaust gases. The foregoing refers to the rated mode of operation of the engine and the maximum torque mode.

Maintaining the factory value of the installation UOVT will allow the transition from one fuel to another without making additional adjustments. Further research should already be carried out at this value of the UOVT to confirm the improvement of the environmental performance of the engine during the transition to the gas-diesel process.

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