The economic performance of diesel engine when operating on methanol with a dual fuel supply system

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Abstract. Limited reserves of fuel of oil origin and a significant increase in the price of oil and its products have made the work aimed at finding and justifying the use of alternative fuels relevant. Among the latter, methanol occupies an important place, for the production of which raw materials are available on a large scale. Methanol can be obtained from natural gas, coal, biomass, or urban waste. Methanol can be attributed to renewable energy sources. It should be noted that the development of a fundamentally new engine model that meets modern environmental and economic requirements requires long-term research and high material costs, so our research is aimed at upgrading commercially available engines. The article presents the results of implementing a method for using methanol by feeding it directly into the combustion chamber and igniting it from the igniting part of diesel fuel. The economic indicators of the developed diesel engine when working on methanol under different load conditions are analyzed.

For several years, the Vyatka state agricultural Academy conducted research on converting internal combustion engines to methanol. The purpose of our research is to improve the efficiency and environmental performance of diesels when working on methanol using a dual-fuel supply system (DST) and using a multi-jet nozzle for supplying a portion of diesel fuel (DT) by improving the processes of mixing, combustion and heat generation. The implementation of a method for using methanol by feeding it directly into the combustion chamber and igniting it from a part of the DT provided for the installation of two fuel systems, including two high-pressure fuel pumps of the 2UTNM type and two injectors for each cylinder. At the same time, an additional hole was drilled in the head, in the same vertical plane as the standard hole, to install an additional nozzle [1-3].

Studies have shown that the best results in fuel consumption are obtained when the incendiary part of DT and methanol are simultaneously supplied. The value of the incendiary part of the DT when working on methanol with DST was determined by reducing the supply of DT to the unstable operation of the diesel, after which it increased slightly until the stable operation of the diesel was achieved. In the future, the volume of incendiary fuel supply was fixed and remained constant, and the loading mode was changed only by changing the supply of methanol. Figure 1 shows graphs of changes in the economic indicators of the engine at different angles of the fuel injection installation in the nominal operating mode [4-8].

Considering the efficiency of the diesel engine when working on methanol with DST at a given angle of injection of methanol 34°, we can note the following. The minimum value of the total fuel consumption when feeding methanol at the setting angle of injection of methanol 34° is observed when
feeding DT at the setting angle of injection of DT 34° ($g_{e\Sigma} = 502$ g/(kW·h)). When changing the angle of injection of diesel fuel in one side or the other performance indicators deteriorated. For example, if the DT installation angle is 38° and the methanol injection angle is 34°, then the value $g_{e\Sigma} = 510$ g/(kW·h). With a further increase in the DT injection angle to 42° and the methanol injection angle to 34°, the $g_{e\Sigma}$ value = 532 g/(kW·h), that is, the increase in fuel consumption at optimal angle values is 30 g/(kW·h), or 5.6%. When the DT injection angle is reduced by 30° and the methanol injection angle is 34°, the value $g_{e\Sigma} = 506$ g/(kW·h). If the DT injection angle is further reduced to 26° and the methanol injection angle is reduced to 34°, then the fuel consumption increases to $g_{e\Sigma} = 520$ g/(kW·h), i.e. the increase in $g_{e\Sigma}$ from the fuel injection angle obtained at optimal values is already 18 g/(kW·h), or 3.5% [9-15].

Considering the efficiency of the diesel engine when working on methanol with DST at the installation angle of injection of methanol 38°, we can note the following. The minimum value of fuel consumption when feeding methanol at a methanol injection angle of 38° is observed at a DT injection angle of 38° and has the value $g_{e\Sigma} = 505$ g/(kW·h). When you change the angle of injection of DT in one direction or another, the efficiency indicators deteriorate. When the DT feed angle is increased to a value of 42° and the methanol injection angle is 38°, the value of $g_{e\Sigma} = 515$ g/(kW·h), i.e. the increase in $g_{e\Sigma}$ from the value obtained at optimal values of angles is 10 g/(kW·h). With a decrease in the DT feed angle of 34° and a methanol injection angle of 38°, the $g_{e\Sigma}$ value = 506 g/(kW·h), i.e. the $g_{e\Sigma}$ increase from the one obtained at optimal values of the angles is only 1 g/(kW·h).

![Figure 1. Changes in economic indicators of diesel 2CH 10.5/12.0 at different installation angles of injection of DT and methanol at n = 1800 min⁻¹ and p_c = 0.585 MPa.](image-url)

Considering the efficiency of the diesel engine when working on methanol with DST at a given angle of injection of methanol 30°, we can note the following. The minimum fuel consumption for supplying methanol at a given methanol injection angle of 30° is observed at an injection angle of DT 34° and is $g_{e\Sigma} = 508$ g/(kW·h). When changing the angle of diesel fuel injection in one direction or another, the performance indicators deteriorated. For example, when the injection angle is set to DT 38° and methanol 30°, the value $g_{e\Sigma} = 511$ g/(kW·h). With a further increase in the injection angle of DT to 42° and methanol to 30°, the value of $g_{e\Sigma} = 528$ g/(kW·h), i.e. the increase in fuel consumption from angles obtained at optimal values is 20 g/(kW·h), or 3.8%. When the injection angle of DT is reduced to 30° and methanol is reduced to 30°, the flow rate is $g_{e\Sigma} = 513$ g/(kW·h). If the injection angle DT is further reduced to 26°, and methanol is reduced to 30°, then the flow rate increases to $g_{e\Sigma} = 532$ g/(kW·h), that is, the increase in fuel consumption from the angle obtained at optimal values is already 24 g/(kW·h),
Considering the efficiency of the diesel engine when working on methanol with DST at a given angle of injection of methanol 22º, we can note the following. The minimum fuel consumption for methanol injection at an installation angle of 26º is observed for DT injection at an installation angle of 34º and has the value $g_{\Sigma} = 524 \text{g/(kW\cdoth)}$. When changing the angle of injection of diesel fuel in one side or the other performance indicators deteriorated. For example, for a given DT 38º injection angle and a 26º methanol injection angle, the flow rate is $g_{\Sigma} = 528 \text{g/(kW\cdoth)}$. If the dt injection angle is further increased to 42º, and the methanol injection angle is increased to 26º, then the value $g_{\Sigma} = 557 \text{g/(kW\cdoth)}$, i.e. the increase in fuel consumption from $p$ obtained at optimal angle values, is 33 g/(kW-h), or 5.9 %. When the DT injection angle is reduced to 30º and the methanol injection angle is 26º, the fuel consumption value is $g_{\Sigma} = 533 \text{g/(kW\cdoth)}$. If the dt injection angle is further reduced to 26º and the methanol injection angle is reduced to 26º, the flow rate increases to $g_{\Sigma} = 550 \text{g/(kW\cdoth)}$, i.e. the increase in fuel consumption from fuel obtained at optimal angles is already 26 g/(kW-h) or 4.7 % [16-20].

When analyzing the changes in the efficiency indicators depending on the change in the installation angle of injection of DT and methanol when the diesel engine is running on methanol with DST, we can draw the following conclusions. The following setting angles are optimal for the total specific effective fuel consumption: for DT 34º and for methanol 34º. At these angle values, the flow rate is $g_{\Sigma} = 502 \text{g/(kW\cdoth)}$. When you change the angle of injection of methanol in one direction or another, the efficiency indicators deteriorate. Comparing the minimum fuel consumption values at different methanol injection angles, it turns out that at a methanol injection angle of 38º, the minimum fuel consumption value is $g_{\Sigma} = 505 \text{g/(kW\cdoth)}$ and is achieved when DT is injected at 38º. The increase in fuel consumption compared to that obtained at optimal angles is 3 g/(kW-h). At a set methanol injection angle of 30º, the minimum fuel consumption value is $g_{\Sigma} = 508 \text{g/(kW\cdoth)}$ and is achieved when DT is injected at an angle of 34º. The increase in fuel consumption is obtained at optimal values of the angles is 6 g/(kW-h). At the set methanol injection angle of 26º, the minimum value $g_{\Sigma} = 524 \text{g/(kW\cdoth)}$ and is achieved with DT injection of 34º. The increase in fuel consumption compared to that obtained at optimal angles is 22 g/(kW-h), or 4.2 %. With a set methanol injection angle of 22º, the minimum value $g_{\Sigma} = 551 \text{g/(kW\cdoth)}$ and is achieved when DT is injected at an angle of 38º. The increase in fuel consumption compared to that obtained at optimal angles is 49 g/(kW-h), or 8.9 %.

Thus, at a later injection of methanol (with a decrease in the injection angle of methanol) and at an earlier injection of methanol, the efficiency indicators deteriorate. The cause is a violation of the combustion process.

Analyzing the data obtained, we can draw the following conclusions. At an early setting angle of advance of fuel injection, the first phase of the combustion process - the period of ignition delay-increases, since the pressure and temperature of the air in the cylinder at the time of injection is less than optimal. It will take longer to warm up the fuel droplets, vaporize them, and form zones with a sufficient number of active radicals that can ignite the injected fuel. More time will be spent on the development of pre-flame reactions occurring in the fuel, but the homogeneity of the mixture will im-
prove somewhat [21-25].

By the time of ignition in the combustion chamber will accumulate a large amount of fuel, with which there are complex physical and chemical processes leading to the formation of a sufficient amount of active radicals that initiate the formation of foci of spontaneous combustion, so the ignition of the fuel gas pressure and rate of pressure increase in the cylinder will increase. The combustion of most of the fuel (the second phase) will occur up to the upper dead point, in a decreasing volume, with limited values of the maximum rate of increase in pressure, increasing the negative work of the cycle (compression work). The maximum pressure of the gases is shifted closer to the upper dead point, which indicates a decrease in the useful work of the cycle. This causes an increase in the temperature and pressure of the gases in the combustion process, which can lead to "hard" operation of the diesel engine. The increased rate of heat release and the rapid increase in gas pressure in the cylinder determine the dynamics of the action of gas forces on the parts of the crank mechanism. All this leads to a decrease in the values of effective efficiency, effective power, as well as an increase in the specific effective fuel consumption.

At optimal fuel injection advance angles, the workflow is organized in the best possible way. The fuel is injected into the air that has the optimal pressure and temperature value. Fuel evaporation, the development of pre-flame reactions, and fuel accumulation during the first phase are carried out in optimal quantities and at optimal speeds. The value of the «stiffness» of the combustion process at optimal fuel injection angles when operating a diesel engine on methanol with DST has a smaller value compared to an experienced diesel engine running on DT. At optimal angles, the value of the total specific effective fuel consumption is minimal. Therefore, the values of the injection angles of diesel fuel equal to 34° and methanol equal to 34° were taken as optimal, and all further studies were carried out at these values of angles.

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