Analysis of indicators of the working process of diesel engine when operating on methanol

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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 running on methanol at maximum torque are analyzed.

Figure 1 shows a graph of changes in the economic indicators of diesel 2CH 10.5/12.0 at various installation UOVТ DT and methanol at n = 1400 min\(^{-1}\). The characteristics were taken at different setting angles of injection advance for both DT and methanol [1-5].

Considering the efficiency of the diesel engine when working on methanol with DST at the setting angle of injection of methanol 34º, we can note the following. The minimum value of \(g_{es}\) when feeding methanol at the setting angle of injection of methanol 34º is observed when injecting DT at the setting angle of injection of DT 34º and has a value of \(g_{es} = 490\text{ g/(kW\cdot h)}\). When you change the angle of injection of DT in one direction or another, the efficiency indicators deteriorate. For example, when the setting angles of DT injection are 38º and methanol is 34º, the fuel consumption value is \(g_{es} = 506\text{ g/(kW\cdot h)}\). With a further increase in the injection angle of DT to 42º and methanol to 34º, the value \(g_{es} = 528\text{ g/(kW\cdot h)}\), i.e. the increase in fuel consumption from that obtained at optimal angles is 38 g/(kW·h), or 7.2 %. When the injection angle of DT is reduced to 30º and methanol to 34º, the value is \(g_{es} = 493\text{ g/(kW·h)}\). When the injection angle of DT is further reduced to 26º and methanol to 34º, the value increases to \(g_{es} = 510\text{ g/(kW·h)}\), i.e. the increase in \(g_{es}\) from the fuel injection angle obtained at optimal values is already 20 g/(kW·h), or 3.9 % [6-10].

Considering the efficiency of the diesel engine when working on methanol with DST at the installation angle of injection of methanol, equal to 38º, we can note the following. The minimum value of specific fuel consumption when feeding methanol at an angle equal to 38º is observed when injecting DT at an angle equal to 38º and has the value \(g_{es} = 511\text{ g/(kW\cdot h)}\). When you change the angle of in-
jection of DT in one direction or another, the efficiency indicators deteriorate [12-15].

When increasing the DT feed angle to a value equal to 42°, and methanol to 38°, the value of $g_{eΣ} = 536$ g/(kW·h), i.e., the increase in the total fuel consumption from the angles obtained at optimal values is 25 g/(kW·h), or 4.7 %. When the DT feed angle is reduced to 34° and the methanol feed angle is reduced to 38°, the $g_{eΣ} = 512$ g/(kW·h), i.e. the increase in specific fuel consumption from the angle obtained at optimal values is only 1 g/(kW·h).

![Figure 1](image.png)

**Figure 1.** Changes in economic indicators of diesel 2CH 10.5/12.0 at different installation angles of injection of DT and methanol at $n = 1400$ min$^{-1}$ and $p_e = 0.594$ MPa.

Considering the efficiency of the diesel engine when working on methanol with DST at the installation angle of injection of methanol, equal to 30°, we can note the following. The minimum value of the specific fuel consumption when feeding methanol at the installation angle of injection of methanol equal to 30° is observed at the injection angle of DT equal to 30° and is the value $g_{eΣ} = 494$. When you change the setting angle of the DT injection in one direction or another, the efficiency indicators deteriorate. For example, when the setting angles of injection of DT equal to 34° and methanol equal to 30°, the value is $g_{eΣ} = 502$ g/(kW·h). For DT injection angles of 38° and methanol injection angles of 30°, the value is $g_{eΣ} = 516$ g/(kW·h). With a further increase in the injection angle of DT to 42° and methanol to 30°, the value of $g_{eΣ} = 536$ g/(kW·h), i.e. the increase in fuel consumption from the obtained at optimal values of angles is 42 g/(kW·h), or 7.8 %. When the injection angle of DT is reduced to 26° and methanol is reduced to 30°, the value increases to $g_{eΣ} = 502$ g/(kW·h), i.e. the increase in $g_{eΣ}$ from the value obtained at optimal angle values is 8 g/(kW·h) [16-20].

Considering the efficiency of the diesel engine when working on methanol with DST at the installation angle of injection of methanol, equal to 26°, we can note the following. The minimum value of the specific fuel consumption when feeding methanol at the installation angle of injection of methanol equal to 26° is observed when injecting DT at the installation angle of 30° and has the value $g_{eΣ} = 522$ g/(kW·h). When you change the angle of injection of DT in one direction or another, the efficiency indicators deteriorate. For example, when the setting angles of injection of DT equal to 34° and methanol equal to 26°, the value is $g_{eΣ} = 524$ g/(kW·h). At the set injection angles of DT equal to 38° and methanol equal to 26°, the value is $g_{eΣ} = 534$ g/(kW·h). With a further increase in the injection angle of DT to 42° and methanol to 26°, the value of $g_{eΣ} = 544$ g/(kW·h), i.e., the increase in the specific fuel consumption from the fuel obtained at optimal values of the angles is 22 g/(kW·h), or 4 %. When the injection angle of DT is reduced to 26° and methanol to 26°, the value increases to $g_{eΣ} = 533$ g/(kW·h), i.e. the increase in specific fuel consumption from the fuel obtained at optimal values at injection angles of DT equal to 30° and methanol equal to 26° is 11 g/(kW·h), or 2 % [21].
Considering the efficiency of the diesel engine when working on methanol with DST at the installation angle of injection of methanol, equal to 22°, we can note the following. The minimum value of the specific fuel consumption when feeding methanol at the installation angle of injection of methanol, equal to 22°, is observed when injecting DT at the installation angle of injection of DT, equal to 34° and has the value \( g_{e \Sigma} = 532 \text{ g/(kW\cdot h)} \). When you change the angle of injection of DT in one direction or another, the efficiency indicators deteriorate. For example, when the setting angles of injection of DT equal to 38° i methanol, equal to 22°, the fuel consumption value is \( g_{e \Sigma} = 540 \text{ g/(kW\cdot h)} \). At the set injection angles of DT equal to 42° and methanol equal to 22°, the value of the specific fuel consumption is \( g_{e \Sigma} = 550 \text{ g/(kW\cdot h)} \), i.e. the increase in the specific fuel consumption from the one obtained at the optimal values of the angles is 18 g/(kW\cdot h), or 3.3 %. When the injection angle of DT is reduced to 30° and methanol to 22°, the value increases to \( g_{e \Sigma} = 533 \text{ g/(kW\cdot h)} \). When the injection angle of DT is further reduced to 26° and methanol to 22°, the specific flow rate increases to \( g_{e \Sigma} = 546 \text{ g/(kW\cdot h)} \), i.e. the \( g_{e \Sigma} \) increase from the value obtained at optimal angles is already 14 g/(kW\cdot h), or 2.6 %.

Analyzing the change in efficiency indicators depending on the change in the setting angles of fuel injection when operating a diesel engine on methanol with DST, the following conclusions can be drawn. Optimal for the total specific effective fuel consumption are the following values of the fuel injection setting angles: for DT - 34° and for methanol - 34°. For these angle values, the specific fuel consumption value is \( g_{e \Sigma} = 490 \text{ g/(kW\cdot h)} \). When you change the angle of injection of methanol in one direction or another, the efficiency indicators deteriorate. Comparing the minimum values of \( g_{e \Sigma} \) at different angles of injection of methanol, it turns out that at an injection angle of methanol equal to 38°, the minimum value of the specific fuel consumption is \( g_{e \Sigma} = 511 \text{ g/(kW\cdot h)} \) and is achieved when injecting DT at an angle equal to 38°. The increase in \( g_{e \Sigma} \) compared to that obtained at optimal angle values (for DT - 34° and for methanol - 34°) is 21 g/(kW\cdot h), or 4.1 %.

With a set methanol injection angle of 30°, the minimum specific fuel consumption is \( g_{e \Sigma} = 494 \text{ g/(kW\cdot h)} \) and is achieved when DT is injected at an angle of 30°. The increase in \( g_{e \Sigma} \) obtained at optimal angle values (for DT - 34° and for methanol - 34°) is 4 g/(kW\cdot h). With a set methanol injection angle of 26°, the minimum value \( g_{e \Sigma} = 522 \text{ g/(kW\cdot h)} \) is achieved when DT is injected at an angle of 30°. The increase in \( g_{e \Sigma} \) compared to that obtained at optimal angle values (for DT - 34° and for methanol - 34°) is 32 g/(kW\cdot h), or 6.1 %. At the set angle of injection of methanol, equal to 22°, the minimum value \( g_{e \Sigma} = 532 \text{ g/(kW\cdot h)} \) and is achieved when injecting DT = 34°. The increase in \( g_{e \Sigma} \) compared to that obtained at optimal angle values is 42 g/(kW\cdot h), or 7.9 %.

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 improve somewhat [23-25].

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 deter-
mine 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 34º and methanol equal to 34º were taken as optimal, and all further studies were carried out at these values of angles.

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