Power and fuel efficiency of a diesel engine with separate feed

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Abstract. The paper presents the power and economic indicators of tractor diesel in the first place, which depends on the characteristics of the working process and, in particular, on the type of combustion chamber, fuel injection system. In the study of the working process of a diesel engine running on diesel fuel and on methanol with a separate feed, the necessary condition was the preservation of the same values of Ne for each studied load mode. Therefore, the primary goals of the research were to assess changes in the power and economic indicators of a diesel engine when operating on diesel fuel and methanol with a separate feed depending on the change in load.

It is well known that the full and timely satisfaction of the needs of the economic complex and the country’s population in transportation by improving the efficiency and quality of the transport system remains one of the most important tasks. Its solution is provided by the transport industry through the release of equipment with great technology and the possibility of using non-traditional types of fuels. Essential for solving the most important problem contributes to the expansion of the use of diesel engines in transport. Moreover, according to forecasts, the reciprocating internal combustion engine will remain as the main energy installation of transport, and preference will be given to the most economical engine - a diesel engine [1-4].

Power and efficiency are the main generalized parameters that characterize the performance of a diesel engine. Productivity and efficiency of machine-tractor units depend on their values.

Power is the ratio of the amount of work to the time during which it is completed. The fuel efficiency of a diesel engine is estimated by the specific fuel consumption denoting the mass flow rate per unit of power. Indicator power is the work of gases performed in engine cylinders per unit time. When the engine is fully loaded, the largest part of the indicator power is spent on useful work done using the crankshaft. The rest (20 ... 30%) is spent on overcoming friction in the movable interface of the engine and the drive of its auxiliary mechanisms. This part of the power is called the power of mechanical losses. The difference between the indicator power and the power of mechanical losses is called the effective power that is spent on useful work. Effective power depends on the amount of fuel supplied to the cylinders, the completeness of its combustion and the speed of the crankshaft. With the deterioration of these indicators, power decreases [5-9].

The fuel efficiency of the engine is significantly affected by the process of fuel combustion in the cylinders. If the combustion process deteriorates due to malfunctions, part of the unburned fuel in the form of smoke leaves the exhaust gas into the atmosphere. As a result, engine efficiency drops sharply.
The power and efficiency of the engine, as a rule, is estimated when working at maximum speed and load conditions.

The power and economic indicators of the diesel engine 2H 10.5 / 12.0, depending on the load change when operating on diesel and methanol with separate feed at the nominal speed of rotation (n = 1800 min⁻¹), are presented in Figure 1a. It follows from Figure 1a that when a diesel engine is running on diesel fuel, as the load increases, fuel consumption increases from 1.85 kg / h at p_e = 0.127 MPa to 7.15 kg / h at p_e = 0.65 MPa. The increase is 5.3 kg / h, or 74.1%. The minimum value of the specific effective fuel consumption is reached at p_e = 0.50 MPa and is g_e = 265 g / kW h. At rated load (p_e = 0.585 MPa) g_e = 273 g / kW h. The value of the effective efficiency with increasing load increases with η_e = 0.185 at p_e = 0.127 MPa to η_e = 0.266 at p_e = 0.65 MPa, while the maximum value is reached at p_e = 0.50 MPa and is η_e = 0.315. As the load increases, the exhaust gas temperature also increases.

Thus, in a diesel engine, when operating on diesel fuel at p_e = 0.127 MPa t_g = 235 °C and with an increase in the load to the maximum at p_e = 0.65 MPa, t_g = 645 °C. The increase is 410 °C, or 63.6%. Air consumption at p_e = 0.127 MPa is 116.6 kg / h and decreases to 112 kg / h at p_e = 0.65 MPa. The decrease is 3.9 %. The coefficient of excess air when operating on diesel fuel decreases with increasing load from α = 4.45 at p_e = 0.127 MPa to a value α = 1.15 at p_e = 0.65 MPa. The decrease is 74.2 %. The filling ratio at low loads (p_e = 0.127 MPa) is 0.90, and at maximum load (p_e = 0.65 MPa) it is 0.865. The decrease is 3.9 % [10-15].

Power and economic indicators vary over the entire range of load changes. When a diesel engine runs on methanol with separate feed, as the load increases, the total fuel consumption increases from 3.95 kg at p_e = 0.127 MPa to 10.6 kg at p_e = 0.65 MPa. The increase is 6.65 kg/h, or 62.7 %. The minimum value of the total specific fuel consumption is reached at p_e = 0.54 MPa and is g_{e∑} = 490 g / kW h. At rated load (p_e = 0.585 MPa), the value of g_e = 502 g / kW h. The magnitude of the effective efficiency with increasing load increases with η_e = 0.16 at p_e = 0.127 MPa to η_e = 0.320 at p_e = 0.65 MPa, with the maximum value being reached at p_e = 0.54 MPa and is η_e = 0.34. As the load increases, the exhaust gas temperature also increases.

Thus, when a diesel engine runs on methanol with separate feed at p_e = 0.127 MPa, the value of t_g = 220 °C, and with an increase in the load to the maximum at p_e = 0.65 MPa, it increases to t_g = 535 °C. The increase is 315 °C, or 58.9 per cent. Air consumption at p_e = 0.127 MPa is 116 kg / h and decreases to 115 kg / h at p_e = 0.65 MPa.

![Figure 1](image1.jpg)

**Figure 1.** Power and economic indicators of a diesel engine 2H 10.5 / 12.0 when operating on diesel fuel and on methanol with a separate supply depending on the load change: a - with n = 1800 min⁻¹; b - with n = 1400 min⁻¹: ——— diesel fuel, ———- methanol with separate feed
The coefficient of excess air when the diesel engine runs on separate methanol decreases with increasing load with $\alpha = 3.6$ and $p_e = 0.127$ MPa to a value $\alpha = 1.5$ at $p_e = 0.65$ MPa. The decrease is 58.3 %. The filling factor at low loads ($p_e = 0.127$ MPa) is equal to 0.86 and at maximum load ($p_e = 0.65$ MPa) does not change and is also equal to 0.86.

Assessing the changes in power and economic performance of a diesel engine depending on the load change at rotational speed ($n = 1800$ min$^{-1}$), the following can be noted. Fuel consumption when running a diesel engine on methanol with separate supply is much higher than when running on diesel fuel. So, at $p_e = 0.127$ MPa, fuel consumption when operating on diesel fuel is 1.85 kg / h, and when operating on separate supply of methanol - 3.95 kg / h. The increase is 53.2 %. At $p_e = 0.65$ MPa, the consumption of methanol is also higher than when operating on diesel fuel [16-21].

When working on diesel fuel, fuel consumption is equal to 7.15 kg / h, then at the same load, but when operating on separate feed methanol is equal to 10.6 kg / h. The increase is 32.5 %. The increase in fuel consumption is due to the fact that methanol has a lower calorific value, and to maintain power performance at the level of a commercial diesel engine, methanol must be supplied in large quantities. Specific fuel consumption when working on methanol with a separate supply, respectively, is also higher than when working on diesel fuel. In nominal mode, the value of $g_e = 273$ g / kW h when the diesel engine is running on diesel fuel, when operating on separate methanol with the same load is $g_{eC} = 502$ g / kW h. The increase is 45.6 %. The value of the effective efficiency at $p_e = 0.127$ MPa and diesel engine operation on diesel fuel is 0.185, and when operating on separate feed methanol - 0.16. The decrease is 13.5 %. With an increase in the load to $p_e = 0.65$ MPa, the value of $\eta_e$ for a serial diesel engine is 0.266, and when operating on separate methanol, it is 0.320. The increase is 16.8 %.

The temperature of the exhaust gases when working on methanol with a separate supply in the entire range of load changes is less than that of a serial diesel engine. So, at $p_e = 0.127$ MPa $t_g = 235^\circ$C when the diesel engine is running on diesel fuel, and when the diesel engine is running on methanol with separate feed, $t_g = 220^\circ$C. The decrease is 6.4 %. With an increase in the load to $p_e = 0.65$ MPa, the value of $t_g = 645^\circ$C when the diesel engine runs on diesel fuel and $t_g = 535^\circ$C when working on methanol with separate feed. The decrease is 110 $^\circ$C, or 17 %. Air consumption at low loads when the diesel engine is running on different fuels has the same value. With an increase in load ($p_e = 0.65$ MPa), the air consumption for a serial diesel engine is 112 kg/h, and when working on methanol with a separate supply – 115 kg/h, the increase is 2.6 %. The excess air ratio at $p_e = 0.127$ MPa and the diesel engine on diesel fuel is 4.45, and when working on methanol with a separate supply $\alpha = 3.6$. The decrease is 19.1 %. When $p_e = 0.65$ MPa, the $\alpha$ value when the diesel engine is running on diesel fuel is 1.15, and when running on separate methanol $\alpha = 1.5$. The increase is 23.3 %. The filling ratio at $p_e = 0.127$ MPa and the diesel engine operating on diesel fuel is 0.90, and when operating on methanol with separate feed $\eta_e = 0.86$. The decrease is 4.4 %. At $p_e = 0.65$ MPa, the value of $\eta_e$ for a syrian diesel engine is 0.865, and when operating on methanol with separate feed $\eta_e = 0.86$ [22-25].

The power and economic indicators of a diesel engine depending on the load change when operating on diesel fuel and on methanol with separate feed at the maximum torque mode at ($n = 1400$ min$^{-1}$) are presented in figure 1b. It follows from Figure 1b that when a diesel engine runs on diesel fuel, as the load increases, fuel consumption increases from 1.4 kg / h at $p_e = 0.127$ MPa to 4.75 kg / h at $p_e = 0.635$ MPa. The increase is 3.35 kg/h, or 70.5 %. The minimum value of the specific effective fuel consumption is reached at $p_e = 0.51$ MPa and is $g_e = 266$ g / kW h. With a load of $p_e = 0.594$ MPa, the value of $g_e = 282$ g / kW h. The value of the effective efficiency with increasing load increases with $\eta_e = 0.19$ at $p_e = 0.127$ MPa to $\eta_e = 0.285$ at $p_e = 0.635$ MPa. The maximum value is reached at $p_e = 0.51$ MPa and is $\eta_e = 0.32$. As the load increases, the exhaust gas temperature also increases. So, in a serial diesel engine with $p_e = 0.127$ MPa, the value of $t_g = 215^\circ$C and with an increase in the load to the maximum at $p_e = 0.635$ MPa is $t_g = 560^\circ$C. The increase is 345$^\circ$C, or 61.6 per cent. Air consumption at $p_e = 0.127$ MPa is 87.5 kg / h and decreases to 83.5 kg / h at $p_e = 0.635$ MPa. The decrease is 4.6 %. The coefficient of excess air when the diesel engine runs on diesel fuel decreases with increasing load, $\alpha = 4.35$ at $p_e = 0.127$ MPa to a value $\alpha = 1.25$ at $p_e = 0.635$ MPa. The decrease
is 71.3 %. The filling ratio at low loads ($p_e = 0.127 \text{ MPa}$) is equal to 0.855 and at maximum load ($p_e = 0.635 \text{ MPa}$) is 0.830. The decrease is 2.9 % [26-29].

Power and economic indicators vary over the entire range of load changes. When a diesel engine runs on methanol with separate feed, as the load increases, the total fuel consumption increases from 3.1 kg at $p_e = 0.127 \text{ MPa}$ to 8.0 kg at $p_e = 0.635 \text{ MPa}$. The increase is 4.9 kg/h, or 61.2 %. The minimum value of the total specific fuel consumption is reached at $p_e = 0.55 \text{ MPa}$ and is $g_{sc} = 488 \text{ g / kW h}$. With a load of $p_e = 0.594 \text{ MPa}$, the value of $g_e = 490 \text{ g / kW h}$. The magnitude of the effective efficiency with increasing load increases with $\eta_e = 0.16$ at $p_e = 0.127 \text{ MPa}$ to $\eta_e = 0.34$ at $p_e = 0.635 \text{ MPa}$, with the maximum value being reached at $p_e = 0.55 \text{ MPa}$ and $\eta_e = 0.352$. As the load increases, the exhaust gas temperature also increases. Thus, when a diesel engine runs on methanol with separate feed at $p_e = 0.127 \text{ MPa}$, the value of $t_g = 190 \degree \text{C}$, and with increasing load to the maximum at $p_e = 0.635 \text{ MPa}$ is $t_g = 425 \degree \text{C}$. The increase is 235 \degree \text{C}, or 55.3 %. Air consumption at $p_e = 0.127 \text{ MPa}$ is 90 kg / h and decreases to 86.5 kg / h at $p_e = 0.635 \text{ MPa}$. The coefficient of excess air when the diesel engine runs on separate methanol decreases with increasing load from $\alpha = 3.5$ at $p_e = 0.127 \text{ MPa}$ to a value $\alpha = 1.6$ at $p_e = 0.635 \text{ MPa}$. The decrease is 54.3 %. The filling ratio at low loads ($p_e = 0.127 \text{ MPa}$) is equal to 0.87, and at maximum load ($p_e = 0.635 \text{ MPa}$) it drops to a value of 0.85.

Assessing changes in power and economic performance of a diesel engine depending on the load at rotational speed ($n = 1400 \text{ min}^{-1}$), the following can be noted. Fuel consumption when running a diesel engine on methanol with separate supply is much higher than when running on diesel fuel. So, at $p_e = 0.127 \text{ MPa}$, the consumption of methanol is also higher than when a diesel engine is running on diesel fuel. If the fuel consumption is 4.75 kg/h when the diesel engine is running on diesel fuel, then at the same load, but when working on methanol with a separate supply, the consumption is 8.0 kg/h. The increase is 40.6 %. Specific fuel consumption when working on methanol with separate feed is also higher than when working on diesel fuel. At $p_e = 0.594 \text{ MPa}$ $g_e = 282 \text{ g/kW·h}$ when the diesel engine is running on diesel fuel, when working on methanol with a separate supply and the same load $g_{sc} = 490 \text{ g/kW·h}$. The increase is 42.5 %. The value of the effective efficiency with $p_e = 0.127 \text{ MPa}$ and diesel engine operation on diesel fuel is 0.19, and when operating on separate feed methanol - 0.16. The decrease is 15.8 %. With an increase in the load to $p_e = 0.635 \text{ MPa}$, the value of $\eta_e$ for a syrian diesel engine is 0.285, and when operating on separate methanol, it is 0.34. The increase is 16.2 %. The temperature of the exhaust gases during the operation of a diesel engine on methanol with a separate supply in the entire range of load changes is less than when working on diesel fuel. Thus, when $p_e = 0.127 \text{ MPa}$, the value of $t_g = 215\degree \text{C}$ when operating the diesel engine on diesel fuel and when operating on methanol, with separate supply $t_g = 190\degree \text{C}$. The decrease is 11.6 %. With an increase in the load to $p_e = 0.635 \text{ MPa}$, the value of $t_g = 560 \degree \text{C}$ when the diesel engine runs on diesel fuel and $t_g = 425 \degree \text{C}$ when working on methanol with separate feed. The decrease is 135\degree \text{C}, or 24 %. Air consumption at low loads, when running a diesel engine on diesel fuel is 87.5 kg / h, and when running on methanol with a separate feed $G_A = 90 \text{ kg / h}$. The increase is 2.8 %. With an increase in load ($p_e = 0.635 \text{ MPa}$), the air consumption for a serial diesel engine is 83.5 kg / h, and when operating on separate supply of methanol - 86.5 kg / h. The increase is 3.5 %. The coefficient of excess air at $p_e = 0.127 \text{ MPa}$ and diesel engine operation on diesel fuel is 4.35, and when operating on separate methanol $\alpha = 3.5$. The decrease is 19.5 %. At $p_e = 0.635 \text{ MPa}$, the value $\alpha$ for a serial diesel engine is 1.25, and when operating on separate methanol $\alpha = 1.6$. The increase is 21.9 %. The filling ratio at $p_e = 0.127 \text{ MPa}$ and the diesel engine operating on diesel fuel is 0.855, and when operating on separate feed methanol, $\eta_e = 0.87$. The increase is 1.7 %. At $p_e = 0.635 \text{ MPa}$, the value of $\eta_e$ for a serial diesel engine is 0.83, and when operating on methanol with separate feed $\eta_e = 0.85$. The increase is 2.3 %.

References
[1] Likhanov V A and Lopatin O P 2018 *IOP Conf. Series: Materials Science and Engineering* **457** 012011
Likhanov V A and Lopatin O P 2019 Journal of Physics: Conf. Series 1399 055016
Likhanov V A and Lopatin O P 2019 Journal of Physics: Conf. Series 1399 055020
Likhanov V A, Lopatin O P and Yurlov A S 2019 Journal of Physics: Conf. Series 1399 055026
Likhanov V A and Lopatin O P 2020 IOP Conf. Series: Earth and Environmental Science 421 072018
Likhanov V A and Lopatin O P 2019 Journal of Physics: Conf. Series 1399 055016
Likhanov V A and Lopatin O P 2019 Journal of Physics: Conf. Series 1399 055020
Likhanov V A, Lopatin O P and Yurlov A S 2019 Journal of Physics: Conf. Series 1399 055026
Likhanov V A and Lopatin O P 2020 IOP Conf. Series: Earth and Environmental Science 421 072018
Aydin F and Ogut H 2017 Renewable Energy 103 688-94
Yadava S and Maitra S S 2017 Global Nest Journal 19 533-39
Lopatin O P 2020 IOP Conf. Series: Earth and Environmental Science 421 072019
Likhanov V A and Lopatin O P 2017 Thermal Engineering 64(12) 935-44
Likhanov V A and Lopatin O P 2019 Ecology and Industry of Russia 23(9) 60-5
Likhanov V A and Lopatin O P 2018 Ecology and Industry of Russia 22(10) 54-9
Marchuk A, Likhanov V A and Lopatin O P 2019 Theoretical and Applied Ecology 3 080-6
Romanyuk V, Likhanov V A and Lopatin O P 2018 Theoretical and Applied Ecology 3 27-32
Likhanov V A and Rossokhin A V 2018 IOP Conf. Series: Materials Science and Engineering 457 012007
Likhanov V A and Skryabin M L 2019 IOP Conf. Series: Earth and Environmental Science 315 032045
Likhanov V A and Rossokhin A V 2019 Journal of Physics: Conf. Series 1399 044038
Likhanov V A and Lopatin O P 2020 IOP Conf. Series: Materials Science and Engineering 734 012202
Likhanov V A, Lopatin O P and Yurlov A S 2020 IOP Conf. Series: Materials Science and Engineering 734 012208
Likhanov V A and Rossokhin A V 2020 IOP Conf. Series: Materials Science and Engineering 734 012207
Likhanov V A, Kozlov A N and Araslanov M I 2020 IOP Conf. Series: Materials Science and Engineering 734 012211
Skryabin M L and Likhanov V A 2020 IOP Conf. Series: Materials Science and Engineering 734 012075
Lopatin O P 2020 IOP Conf. Series: Materials Science and Engineering 734 012199
Kozlov A N, Anfilatov A A and Chuvashov A N 2019 Journal of Physics: Conf. Series 1399 055051
Chuvashov A N and Chuprakov A I 2019 Journal of Physics: Conf. Series 1399 055085
Skryabin M L 2020 IOP Conf. Series: Earth and Environmental Science 421 072012
Chuvashov A N, Chuprakov A I and Anfilatov A A 2020 IOP Conf. Series: Materials Science and Engineering 734 012184
Skryabin M L and Likhanov V A 2019 Journal of Physics: Conference Series 1399 044063
Sempri S, Sánchez D and De Pascale A 2016 Solar Energy 132 279-93
Gough R V and Bruno T J 2012 Energy and Fuels 26 6905-13