Biofuel based on methanol and methyl ester of rapeseed oil for diesel engine

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Abstract. In order to improve the environmental performance of diesel engines, the use of renewable energy sources such as biofuels is justified. The factors influencing the processes of fuel combustion and issues allowing to properly provide the necessary conditions for the combustion of biofuels in the combustion chamber of diesel are considered. As a result of experimental studies developed biofuel for diesel engine consisting of methanol and methyl ester of rapeseed oil. Experimental studies of the efficiency and environmental performance of the diesel engine on this biofuel have been carried out.

For radically improving the environmental performance of diesel engines requires the use of new and renewable sources of energy, replacing traditional petroleum fuel with alternative biofuels, while ensuring that properly required conditions for combustion in the combustion chamber. Conversion of autotransport diesel engine from petroleum fuel to biofuel will significantly improve the environmental situation in cities and industrial agglomerations, reducing the environmental damage caused by the use of traditional petroleum fuels. In addition, the steady growth of consumption of exhausted oil energy resources by diesel engines, whose reserves are not limitless, also forces to look for alternative renewable energy sources. The increased environmental hazard of petroleum fuels and their combustion products in diesel engines is a problem, the solution of which can only be comprehensive, including the creation of new biofuels with environmentally improved characteristics. Therefore, along with petroleum fuels, in a mixture with them are increasingly trying to use alternative, extracted from gas, coal and various plants [1-4].

The development of diesel engines in the past and at the present time is stimulated by various standards and regulations providing for the production of fuels with an additive package to improve their properties. Additive packages are also being developed for complex improvement of individual properties of diesel fuel for diesel engines. The use of oxygen-containing additives in fuel for motor vehicles in many countries of the world is incorporated into government programs that provide for the improvement of the environmental situation and the use of renewable sources of raw materials in the production cycle. From this point of view, methanol and ethanol obtained from plant biomass and other ways are the best suited. For example, in Brazil, 90% of all produced internal combustion engines are designed for the use of alcohol fuels [5-8].

There are two directions of influence on fuel combustion processes in diesels: change of fuel composition and change of its combustion process. The first problem is solved by introducing the fuel composition additives that improve its environmental performance, the second is by the introduction
of additives - catalysts of fuel combustion. As additives or substitutes for diesel fuel, oxygen-containing compounds - oxygenates - simple aliphatic alcohols (methanol, ethanol) and their esters find a special place. The addition of oxygenate fuels to the main fuel can improve the combustion process, and therefore reduce emissions of exhaust gases into the atmosphere. With a less complex structure and smaller molecules of methanol and ethanol, during their combustion, the decay process reduces the number of intermediate chemical compounds that can be toxic. In addition, due to the reduction of carbon content in relation to hydrogen, during the combustion of alcohol biofuels in smaller quantities, compared with gasoline, carbon oxides are formed. For this reason, alcohols during their combustion do not pollute the environment to the same extent as diesel fuel and gasoline [9-11].

In this regard, it is necessary to study all aspects of the use of renewable energy sources at the stage of production, storage, distribution, as well as features of diesel engines on these fuels. Therefore, research aimed at improving the properties of alcohol biofuels for diesel engines is an important scientific task, causing the possibility of widespread use of unconventional biofuels in the future [12-14].

The Vyatka state agricultural Academy has developed an eco-friendly biofuel consisting of methanol (88%) and methyl ether of rapeseed oil (MERO) (12%). To optimize the working process at the first stage of bench testing of the engine, the optimal ratio of methanol and MERO was determined. At the same time, the supply of MERO was fixed and remained constant, and the change in the load mode was carried out only by changing the supply of methanol. The lower heat of combustion of MERO is significantly higher than that of methanol. In this regard, a decrease in the size of the ignition portion leads to an increase in the supply of methanol and an increase in the total fuel consumption, and vice versa. Therefore, it was decided to use the effective efficiency factor (\( \eta_e \)) as a criterion for choosing the optimal value of the ignition portion of the MERO [15-17].

To this end, the load characteristics were removed at different feed MERO. At the same time, the MERO supply varied from 0.8 to 2 kg/h at the nominal speed \((n=1800 \text{ min}^{-1})\), figure 1 and from 0.6 to 1.6 kg/h at the speed corresponding to the maximum torque \((n=1400 \text{ min}^{-1})\), figure 2), which is from 7 to 19 mg/cycle. From figure 1, 2 it can be seen that the value of the MERO feed has an ambiguous effect on the \( \eta_e \). Thus, an increase in the supply of MERO leads to a certain increase in the effective efficiency at low loads, which on the other hand leads to a decrease in \( \eta_e \) at maximum load modes of operation of the diesel engine [18-20].

The increase in the efficiency at maximum loads at low values of the ignition portion of the MERO is most likely due to the presence of a large amount of oxygen in methanol, which naturally
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contributes to a more complete combustion of the fuel in conditions of oxygen deficiency at high load modes. In order to obtain the maximum efficiency under load, a minimum ignition portion of the MERO was installed, ensuring stable operation of the diesel at low loads and idling. As a result of experimental studies, these conditions correspond to the value of the ignition portion MERO, equal to 1.05 kg/h (at nominal speed, figure 1) and 0.73 kg/h (at maximum torque, figure 2) [21-23].

Figure 2. The effect of the ignition portion MERO on the effective efficiency of the diesel engine 2F 10.5/12.0 when working on methanol and MERO at n = 1400 min⁻¹.

Figure 3 shows the load characteristics of the effective performance of diesel powered by methanol and MERO.

Figure 3. Power and economic indicators of the diesel engine 2F 10.5/12.0 depending on the load at n=1800 min⁻¹.

Figure 4. Indicators of toxicity and smoke of the diesel engine 2F 10.5/12.0 depending on change of loading at n=1400 min⁻¹.
Considering the values of power and economic indicators of diesel (figure 3), it is necessary to highlight the increase in the total consumption of methanol and methyl ether in comparison with the consumption of diesel fuel over the entire range of load changes. At the same time, at the load corresponding to the minimum average effective pressure (\( p_e = 0.12 \) MPa), the total flow rate is 5.1 kg/h, and the diesel fuel consumption is 1.6 kg/h. With an increase in the load to the nominal (\( p_e = 0.59 \) MPa), the total consumption of methyl alcohol and MERO is also higher and is 9.1 kg/h, and in the diesel process at the same load is 4.9 kg/h. It should be noted that the observed increase in the total flow rate when working on these alternative fuels is due to a lower lower heat of combustion of methyl alcohol and MERO compared to diesel fuel [24-27].

The total specific effective fuel consumption of ge when the engine is running on methanol and MERO is also higher than the consumption of diesel fuel. Thus, when working on methanol and MERO at \( p_e = 0.12 \) and 0.59 MPa, ge equals 1409 and 490 g/(kWh), respectively, and in the diesel process at the same load values, the ge value is 447 and 263 g/(kWh).

You can also notice differences when operating on methanol and MERO relative to diesel process, characterized by the shift of the maximum effective coefficient of performance of the \( \eta_e \) to the right in the direction of high loads, increasing the exhaust gas temperature at low loads and reducing at the maximum, the increase time of \( G_a \) fuel consumption and volumetric efficiency \( \eta_v \), the reduction of the excess air ratio at low and medium loads and a slight increase at maximum.

Figure 4 shows the toxicity load characteristics of a methanol and MERO diesel at a speed corresponding to the maximum torque.

As can be seen from figure 4, the diesel engine running on methyl alcohol and MERO has a decrease in emissions of soot and NO\(_x\) throughout the studied load range, and with increasing load, the decrease in emissions of soot becomes more significant, which is characterized by a more complete burnout. It is also necessary to note the reduction of carbon monoxide and dioxide at maximum loads.

On the basis of laboratory and bench studies of the working process of the diesel engine, the possibility of reducing its environmental performance, saving diesel fuel by using methanol and MERO was established. When the diesel engine is running on methanol and MERO, the content of soot in the exhaust gases is reduced from 3.7 to 6.7 times, nitrogen oxides NO\(_x\) to 46.1%, carbon monoxide CO to 6.5 times, carbon dioxide CO\(_2\) to 17.5%.

References

[1] Datta A and Mandal B K 2016 Applied Thermal Engineering 98 670-82
[2] Mikulski M and Wierzbicki S 2016 Journal of Natural Gas Science and Engineering 31 525-37
[3] Gough R V and Ryu T J 2012 Energy and Fuels 26 6905-13
[4] Luksho V A, Kozlov A V, Terenchenko A S and Grinev V N 2018 International Journal of Mechanical Engineering and Technology 9 1385-95
[5] Likhanov V A and Lopatin O P 2019 Ecology and Industry of Russia 23
[6] Yadava S and Maitra S S 2017 Global Nest Journal 19 533-39
[7] Yang W, Lang Y-H, Bai J and Li Z-Y 2015 Ecological Engineering 74 117-24
[8] Likhanov V A and Lopatin O P 2018 Ecology and Industry of Russia 22
[9] Starik A M, Savel’ev A M, Fuvorskii O N and Titova N S 2018 International Journal of Green Energy 15 161-8
[10] Aydin F and Ogtu H 2017 Renewable Energy 103 688-94
[11] Chai X, Mahajjan D and Tonjes D J 2016 Progress in Energy and Combustion Science 56 33-70
[12] Marchuk A, Likhanov V A and Lopatin O P 2019 Theoretical and Applied Ecology 3
[13] Arent D J, Wise A and Gelman R 2011 Energy Economics 33 584-93
[14] Lif A and Holmberg K 2006 Advances in Colloid and Interface Science 123 231-39
[15] Likhanov V A and Lopatin O P 2017 Thermal Engineering 64
[16] Gonzalez-Salazar M A, Venturini M, Poganietz W-R, Finkenrath M and Leal M R 2017 Renewable and Sustainable Energy Reviews 73 159-77
[17] Anisimov I, Ivanov A, Chikishev E, Chainikov D, Reznik L and Gavaev A. 2017 *International Journal of Sustainable Development and Planning* **12** 1006-17

[18] Likhanov V A and Skryabin M L 2019 *IOP Conference Series: Earth and Environmental Science* **315** 032045

[19] Presser C, Nazarian A and Millo A 2018 *Fuel* **214** 656-66

[20] Melbert A A, Shaposhnikov Y A, Mashensky A V and Voinash S.A. 2019 *Journal of Physics: Conference Series* 012011

[21] Romanyuk V, Likhanov V A and Lopatin O P 2018 *Theoretical and Applied Ecology* **3**

[22] Chen W, Pan J, Liu Y, Fan B, Liu H and Otchere P 2019 *Applied Energy* **176** 453-467

[23] Frances C 2009 *Sustainability* **1** 43-54

[24] Likhanov V A and Lopatin O P 2018 *IOP Conference Series: Materials Science and Engineering* **457** 012011

[25] Rajesh Kumar B and Saravanan S 2016 *Renewable and Sustainable Energy Reviews* **60** 84-115

[26] Likhanov V A and Rossokhin A V 2018 *IOP Conference Series: Materials Science and Engineering* **457** 012007

[27] Ahmad I 2016 *Journal of Pure and Applied Microbiology* **10** 95-102