Study of the effective performance of the diesel engine when working on methanol and methyl ether rapeseed oil

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Abstract. The experience of solving the world's environmental problems from the use of diesel engines allowed us to develop numerous ways to solve them, including the transfer to work on alternative fuels. The article presents the classification of alternative fuels. The article discusses the use of biofuel for the diesel engine. The use of alternative biofuels with different chemical composition and local conditions leads to the distinctive performance of the diesel engine. Therefore, for the scientific representation of the actual picture of the power and economic indicators of the diesel engine, experimental studies were conducted when it was operated on methanol and methyl ether of rapeseed oil. According to the results of laboratory and bench studies of load working processes of a diesel engine running on methanol and methyl ether of rapeseed oil, important information about hourly and specific fuel consumption, filling coefficients and excess air, effective efficiency and exhaust gas temperature were obtained. At the same time dependences of influence of modes of operation of the diesel engine on characteristics of power and economic indicators are established and their numerical values are defined. The presented research performance and economic performance of diesel engine demonstrate the applicability of methanol and methyl ester of rapeseed oil as an alternative bio-fuel is not only to improve the excellent service standard and performance indicators, but also to reduce the toxicity and smoke opacity of the exhaust gases, since alcohol, with its more simple structure and small size of molecules is one of the determining factors for a more "clean burning" fuel.

The production of diesel engines is one of the priorities in mechanical engineering, as it provides a solution to a number of problems: scientific, technical, economic, environmental, defense and others. Since the characteristics of the diesel engine are the defining indicators of the operational, energy, economic, environmental and weight and size properties of the operated equipment, the diesel engine will remain an uncontested power plant for a long time.

It should be noted that the emerging trend in recent years to strengthen the country's defense is not only of strategic importance for the Russian Federation, but also directly affects the development and production of power plants for the entire fleet of vehicles in the country, quite a large proportion of which is equipped with power plants – diesel engines. With the modern perspective development of diesel engines, it is assumed not only their fuel efficiency, but also the minimization of emissions of harmful substances with exhaust gases. World experience in solving environmental problems associated with the use of diesel engines, allowed to develop numerous ways to do this, including the transfer to alternative fuels. Currently, many research institutes and centers around the world are conducting research aimed at finding alternative fuels and designed to replace traditional liquid hydrocarbon fuels of oil origin [1].

Existing alternative fuels are classified according to the following criteria:
• By its composition (esters, alcohols, oils, gas fuels, hydrogen fuels, etc.).
• By aggregate state: liquid, solid and gaseous.
• According to the method of use, they are used both as additives and in natural form.
• According to the method of obtaining from various raw materials - peat, coal, shale, combustible gas, biomass, etc.

Of all existing alternative fuels, the most promising are biofuels and their mixtures with diesel fuel in different proportions (vegetable and mineral mixtures). Biodiesel fuels based on vegetable oils are different in composition and methods of application:

• Natural technical vegetable oil. Its basis is oilseeds, it is obtained by pressing or pressing. This oil is not chemically modified, unrefined or refined, has a lower calorific value in the range of 35-37 MJ/kg due to the dependence of the fatty acid composition, is used as a biofuel for the appropriate types of engines, meets the established emission standards of harmful substances.
• Biodiesel. The resulting methyl (or ethyl) ether, which is based on vegetable oil. Possesses the lowest calorific value in the range of 37,1-37,4 MJ/kg. The physico-chemical properties are close to properties of mineral diesel fuel. This fuel is used as a motor fuel in diesel engines.
• Mixed diesel fuel. It is made by mixing vegetable oil with mineral diesel fuel. The lowest calorific value lies within 37-39 MJ/kg. Physical, chemical and calorific properties are quite close to the properties of mineral diesel fuel. This allows the use of these components in the diesel engine without making significant design changes.

At the moment, alternative fuels from vegetable oil are quite common. So canola oil is used both in natural form and in the form of a methyl ester of rapeseed oil (MERO) and dimethyl ether of rapeseed oil. Such fuels are used in highly developed countries, despite the fact that they do not have serious problems with oil fuel [2].

MERO can be characterized by a lower level of coking of engine parts than the ethyl ester of rapeseed oil due to the lower viscosity and molecular weight. In addition, methyl esters are better preserved. The advantages of ethyl esters include reduced smoke and exhaust gas temperature and less aggressiveness to engine parts. In the further production process, ethyl esters are less harmful, but when cleaning biodiesel to remove excess alcohol, there are small difficulties, because ethanol forms a stable aqueous emulsion. In this regard, due to the lower cost of methyl alcohol, the production of MERO is more cost-effective. Therefore, MERO, as an alternative fuel, is becoming the most popular in Europe. Thus, the most suitable for the production of biodiesel is rapeseed oil. Based on the physical and chemical characteristics, availability, as well as the cost it can be used as a base or component of the fuel. Due to its physical and chemical properties, MERO is close to diesel fuel and is a renewable energy source, which opens up new opportunities for us to study this type of fuel in diesel engines [3]. No less important place among the promising alternative fuels for diesel engines is occupied by alcohols. These include primarily methyl alcohol (methanol). The production of which is possible from almost any raw material that contains carbon. Among the positive properties of methyl alcohol for use in a diesel engine can be noted the presence of oxygen atoms in its molecules, which makes it possible to use methanol as oxygenates (oxygen-containing components), contributing to the reduction of soot and carbon monoxide emissions in diesel engines [4].

When methyl alcohol is burned in a diesel engine, there is a problem of ignition, since alcohol fuels have low cetane numbers. Therefore, the ignition of methanol in the combustion chamber of a diesel engine is possible with the help of additionally installed spark plugs, the supply of methanol at the inlet or the use of various catalysts that reduce the ignition temperature of methyl alcohol, as well as accelerate the combustion reaction process. Another effective method of ignition of methanol in the cylinder of a diesel engine, can be attributed to the supply of the ignition portion of another fuel, such as MERO [5], [6].
In Vyatka state agricultural Academy on the basis of the Department of heat engines, cars and tractors conducted research on the effective performance of a diesel engine running on methanol and MERO [7], [8].

Figures 1-6 show the change in the effective performance of the diesel engine 2F 10.5/12.0 depending on the load at the rated speed (n=1800 min⁻¹).

**Figure 1.** Filling ratio: — diesel fuel; — methanol and MERO.

**Figure 2.** Efficiency: — diesel fuel; — methanol and MERO.

**Figure 3.** Air excess factor: — diesel fuel; — methanol and MERO.

**Figure 4.** Exhaust gas temperature: — diesel fuel; — methanol and MERO.
The filling factor at the minimum load \( p_e = 0.115 \text{ MPa} \) when using methanol and MERO is 0.904, which corresponds to diesel fuel. When working at nominal load, \( p_e = 0.588 \text{ MPa} \) when used as fuel of methanol and MERO is 0.872, and when working on diesel fuel equal 0.860.

Effective efficiency at minimum load \( p_e = 0.115 \text{ MPa} \) with methanol and MERO is 0.109, diesel fuel equal 0.187. When working at nominal load, \( p_e = 0.588 \text{ MPa} \) when used as fuel of methanol and MERO is 0.333, and when working on diesel fuel equal to 0.320. The coefficient of excess air at minimum load \( p_e = 0,115 \text{ MPa} \) with methanol and MERO is of 2.31 for diesel fuel equal to 5.20. When working at nominal load, \( p_e = 0.588 \text{ MPa} \) when used as fuel of methanol and MERO is 1.38, and when working on diesel fuel is equal to 1.69. The exhaust gas temperature at minimum load \( p_e = 0,115 \text{ MPa} \) with methanol and MERO is 240°C, diesel fuel equal to 200°C. When operating at rated load \( p_e = 0.588 \text{ MPa} \) when used as fuel of methanol and MERO is 480°C, and when working on diesel fuel is equal to 520°C.

Hourly fuel consumption at minimum load \( p_e = 0.115 \text{ MPa} \) for methanol is 4.02 kg/h and MERO 1.05 kg/h, diesel fuel is equal to 1.61 kg/h. When operating at rated load \( p_e = 0.588 \text{ MPa} \) when used as fuel of methanol and MERO is 8.14 kg/h and 1.05, respectively, and when working on diesel fuel equal to 4.83 kg/h. Effective specific fuel consumption at minimum load \( p_e = 0,115 \text{ MPa} \) with methanol and MERO is 773.7 g/kWh, diesel fuel equal 447.1 g/kWh. When operating at rated load \( p_e = 0.588 \text{ MPa} \) when used as fuel of methanol and MERO is 253.4 g/kWh, and when working on diesel fuel equal 260.6 g/kWh. The presented studies of power and economic indicators of the diesel engine clearly demonstrate the possibility of using methanol and MERO as an alternative biofuel not only to improve the effective indicators, but also to reduce the toxicity and smokiness of exhaust gases, since alcohol with its simpler structure and small molecule sizes is one of the determining factors of a “clean combustion” of fuel.

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