IOP Conference Series: Materials Science and Engineering

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To cite this article: V A Likhanov and O P Lopatin 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **734** 012202

Research of load modes of diesel engine at work on biofuel

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Abstract. The relevance of the article is due to the need to replace traditional petroleum motor fuels with alternative ones derived from non-oil raw materials. Quite a good prospect has a variety of alcohol fuels, allowing their physical and chemical properties to use them as additives in regular oil fuel, thereby replacing it and significantly reducing harmful emissions of exhaust gases into the atmosphere. The efficiency of using ethanol and methanol as an ecological additive to petroleum diesel fuel was confirmed and the possibility of a significant reduction in toxicity and smokiness of exhaust gases during diesel operation on biofuel was experimentally proved.

Global problems of modern civilization - energy and environmental - are directly related to the development of piston internal combustion engines as the main consumers of fuels of oil origin and sources of environmental pollution. Since internal combustion engines have found the widest distribution as a power unit of vehicles, it is natural that they should be characterized not only by high fuel efficiency, but also by the necessary environmental safety in accordance with applicable rules and regulations. It is obvious that the improvement of environmental parameters is one of the main tasks of modern diesel construction. Strict legislative requirements imposed at present, almost all developed countries, restrict concentrations in the combustion products of diesel engines of four harmful ingredients: nitrogen oxides (NO_x), particulates, carbon monoxide (CO) and hydrocarbons (CH_x). Of these, the first two represent the greatest danger to humans, flora and fauna. The total number of solid particles is dominated by particles of organic origin: carbon (soot) - about 70% and polycyclic aromatic hydrocarbons - about 25%. Inorganic particles (ash from engine oil additives, salt and rust particles, metal particles and ceramic fiber) make up the rest (~5%). The size of the soot particles formed in the combustion chambers of diesel engines varies between 0.01-10.0 microns, with a maximum size distribution of approximately 0.1 microns. In addition, they are the main generators of radiation and play a significant role in the radiation-convective heat exchange in the combustion chamber of diesel [1-4].

The environmental safety of a diesel engine largely depends on the type of energy carrier used in it, therefore, along with traditional oil energy carriers, alternative fuels are increasingly being used. Alternative energy can be divided into three categories. The first category includes mixed fuels containing petroleum fuels with additives of alcohols, vegetable oils, esters and other fuels of non-oil origin. The second category includes synthetic liquid fuels obtained by processing solid, liquid or gaseous hydrocarbon raw materials (natural gas and gas condensates, coal, oil shale, etc.). The third category consists of energy carriers of non-oil origin (alcohols, vegetable oils, esters, gaseous fuels, etc.). It should be noted that alternative energy carriers of the third category usually have physicochemical properties different from the properties of regular petroleum diesel fuel, which is the main fuel for diesels. Therefore, for their application, it is necessary to adapt these energy carriers to use in diesel engines, as well as to transport, storage and refueling at existing automobile filling stations [5-7].

It should be noted the prospects for the use of alternative mixed energy carriers in diesels that do not require major structural changes for their supply to the combustion chamber of the fuel supply equipment. The attractiveness of alcohol-based fuels is that they can be obtained from any hydrocarbon raw materials, both mineral (natural gas, coal, oil shale) and organic (potatoes, beets, other crops, plant waste, algae, etc.). Among the advantages of alcohol fuels should also be noted the presence of oxygen atoms in their molecules, which can significantly reduce the toxicity of exhaust gases of the internal combustion engine [8-11].

The simplest of alcohols - methanol (CH_3OH) is easily mixed with water in any ratio, mixed with alcohols, benzene, acetone and other organic solvents. It has a high octane number 112, so it is added to automobile gasoline. Another typical representative of the alcohols, ethanol (C_2H_5OH) is mixed with water in any proportions. Ethanol and methanol are attractive for use in internal combustion engines because they have good environmental qualities and the ability to obtain from a variety of raw materials. Their production is possible from biomass, various wastes, household and construction waste, paper. The main indicators characterizing ethanol and methanol as fuel for diesel engines are presented in table 1 [12-14].

Table 1. Main indicators of ethanol and methanol

Indicator	Ethanol	Methanol
Chemical formula	C_2H_5OH	CH_3OH
Density at 20^{o}C, kg/m^3	789,0	791,7
Cetane number	8	5
Lowest heat of combustion, kJ/kg	26800	19670
Amount of air required for combustion 1 kg of substance, kg	9,01	6,49
Octane number, determined by the motor method	99	98
Octane number, determined by the research method	111	112
The auto-ignition temperature, ^{o}C	Not less than 404	464
Flash temperature, ^{o}C	12,2	10,0
The concentration limits of ignition, %	3,2-19,0	6,7-36,5
Heat of evaporation, kJ/kg	870	1115

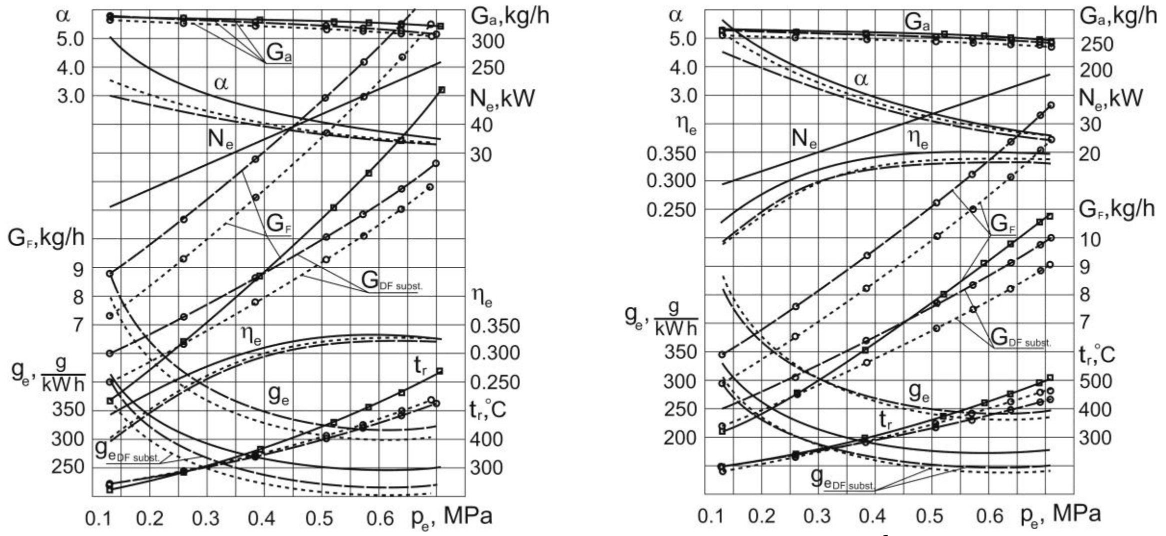
The Vyatka state agricultural Academy conducted research on diesel engine biofuels of the following composition: alcohol (methanol or ethanol) - 25%, detergent-dispersing additive succinimide C-5A - 0.5%, water - 7%, diesel fuel - 67.5% [15-17].

Table 2. Results of researches of power and economic indicators of work of the diesel engine 4F 11.0/12.5 on a nominal mode (n=2200 min^{-1}, p_e=0.64 MPa)

Fuel	Indicators		
	N_e, kW	Fuel consumption	
		g_e, g/(kW*h)	G_f, kg/h
Diesel	55.2	243	13.4
Methanol-fuel emulsion	55.4 (increase by 0,4%)	316 (increase by 30.0%)	17.5 (increase by 30.6%)
Ethanol-fuel emulsion	55.0 (decrease of 0.4%)	297 (increase by 22.2%)	16.3 (increase by 21.6%)

The characteristics of the power and economic parameters of the diesel engine, depending on its load, are shown in figure 1. Analyzing the effective parameters of diesel operation on biofuel (figure 1) it should be noted that there is a preservation of power indicators and their compliance with the values of the diesel process, while increasing the hourly fuel consumption G_f and the specific effective fuel consumption g_e. So, for example, at transition from diesel process to methanol-fuel emulsion at the minimum loading (p_e=0,13 MPa) G_f increases in 2,0 times, and at the loading equal to 0,70 MPa, on 21,2%. The use of biofuels leads to a decrease in the hourly air flow rate G_a, the excess air coefficient α, the effective efficiency coefficient p_e and the exhaust gas temperature t_r [18-21].

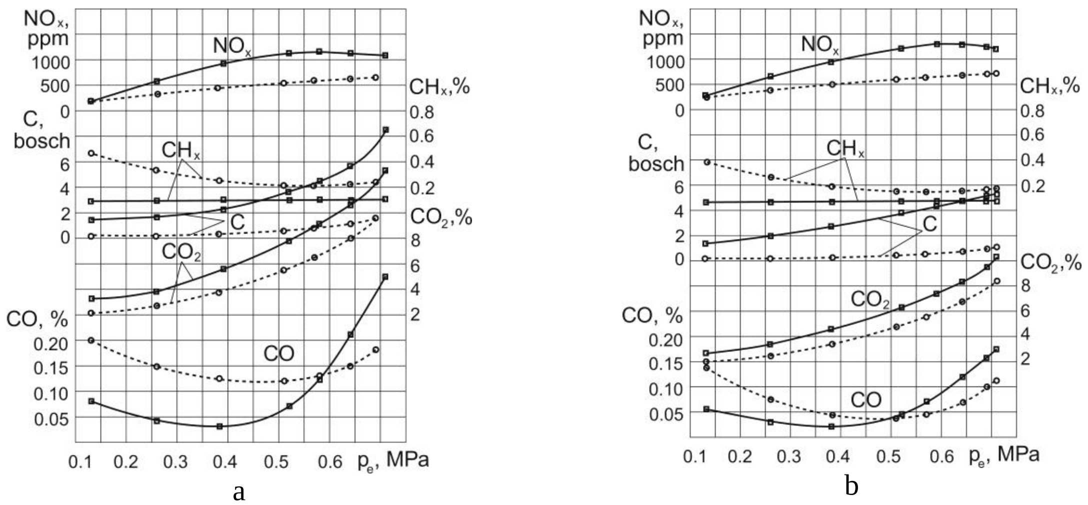
Thus, at the nominal operating mode, the use of biofuel leads to the following values of power and economic performance of the diesel engine, indicated in table 2.



a b

- diesel fuel; - ethanol-fuel emulsion; - methanol-fuel emulsion

Figure 1. The change of power and economic parameters of operation of the diesel engine 4F 11.0/12.5 depending on load: a - n=2200 min^{-1}; b - n=1700 min^{-1}.



a b

- diesel fuel; - ethanol-fuel emulsion; - methanol-fuel emulsion

Figure 2. A change in the content of toxic components in the exhaust gases of the diesel engine 4F 11.0/12.5 depending on load: a - n=2200 min^{-1}; b - n=1700 min^{-1}.

The content of toxic components in diesel exhaust gases depending on the load change is shown in figure 2. Analyzing the graphs of toxicity and smokiness of diesel exhaust gases when working on biofuel, it is seen that there is a decrease in the content of nitrogen oxides NO_x, soot C, carbon dioxide CO_2 and carbon monoxide CO in the entire range of the load study, while an increase in the total hydrocarbons of CH_x is noted [22-25].

The results of studies of toxicity and smokiness of diesel engine exhaust gases are presented in table 3.

Table 3. Results of researches of indicators of toxicity and smokiness of exhaust gases of the diesel engine 4F 11.0/12.5 on the nominal mode ($n=2200$ min^{-1}, $p_e=0.64$ MPa)

Fuel	Indicators			
	NO_x, %	C, Bosch	CO_2, %	CO, %
Diesel	1100	5.8	10.9	0.21
Methanol-fuel emulsion	775 (decrease of 29.6%)	0.9 (decrease by 6.4 times)	9.8 (decrease of 10.1%)	0.11 (decrease of 47.6%)
Ethanol-fuel emulsion	657 (decrease of 40.3%)	1.2 (decrease by 4.8 times)	8.0 (decrease of 26.6%)	0.15 (decrease of 28.6%)

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