The effect of ethanol on the environmental performance of a diesel engine

V A Likhanov, A N Chuvashev and A I Chuprakov

Federal State Budgetary Educational Institution of Higher Education «Vyatka state agricultural academy», Department of thermal engines, automobiles and tractors, October prospect, 133, 610017, Kirov, Russian Federation

E-mail: aleks_dvs@mail.ru

Abstract. The article is devoted to the use of ethanol-fuel emulsion as an alternative energy carrier in tractor diesel 4CH 11,0/12,5. In the Vyatka state agricultural Academy on the basis of the Department of heat engines, cars and tractors, a diesel engine was developed to work on ethanol-fuel emulsion. The article substantiates the possibility of establishing the maximum permissible concentration of ethanol in the emulsion for this diesel, it is 25% of the total fuel and provides sufficient conditions for the organization of a stable combustion process without skipping ignition. Experimental studies of the working process of diesel when working on ethanol-fuel emulsion determined the values of the main environmental indicators.

Currently, among many alternative fuels, natural gas and alcohol-containing fuels derived from natural gas, food and agricultural waste are the most likely to displace traditional gasoline and diesel. Recall that Russia has 40% of the proven reserves of natural gas. It is also important to note that alcohol fuel is renewable, unlike natural gas.

As can be seen from figure 1, alcohol is an environmentally friendly fuel, compared to gasoline and diesel fuel, and approaches the toxicity of combustion to natural gas. However, methanol and ethanol are not yet as widely used as natural gas. Countries that are not rich in oil and natural gas, such as South America (Brazil, Argentina) and Asia (Japan), are particularly active in developing the use of alcohol fuel.

High anti-knock qualities determine the predominant use of alcohols in internal combustion engines with forced (spark) ignition. But this does not exclude the use of alcohols in diesel fuel as additives to diesel fuel in the form of ethanol-fuel emulsions and when working on ethanol or methanol with a dual fuel supply system.

An analysis of the work carried out in Russia and abroad to investigate the possibility of using ethanol and methanol as motor fuel for diesels has shown that they are being carried out in various directions, from the creation of new models of diesels designed specifically for ethanol or methanol, to the modernization of diesels produced in series and equipped for ethanol (methanol) without significant design changes.

Indicator indicators of diesel when working on ethanol-fuel emulsion are shown in figure 2. Environmental indicators of diesel 4CH 11,0/12,5, taken when working on diesel fuel (DT) and ethanol fuel emulsion (ETE), depending on the load change at the optimal installation angle at the nominal speed of the crankshaft at n = 2200 min⁻¹, are shown in figure 3 [1-10].
When analyzing the schedules of operation on diesel fuel in nominal mode, the following conclusions can be drawn: the content of nitrogen oxides NO\textsubscript{x} in exhaust gases (OG) increases with the load from the minimum at $p_e = 0.13$ MPa to the maximum at $p_e = 0.69$ MPa, increases from 593 ppm to 945 ppm, respectively, i.e. the increase is 59.4 \% \[11-15\].

As the load increases, the CO\textsubscript{2} content in the exhaust gas increases. Thus, when the load is $p_e = 0.13$ MPa, the CO\textsubscript{2} value is 3.2 \%, and when the load is increased to the maximum, the CO\textsubscript{2} value increases to 7.5 \%. An increase of 2.3 times.

When the load increases, the content of CH\textsubscript{x} hydrocarbons in the exhaust gas decreases from the minimum to the corresponding value of 0.43 MPa from 0.033 to 0.029\%, respectively, the decrease is 0.004 \%. With a further increase in the load to the maximum, the content of CH\textsubscript{x} hydrocarbons in the exhaust gases increases to 0.067 \%, i.e. 2.3 times [16-25].

The CO content in exhaust gases has a minimum value at an average load of $p_e = 0.40$ MPa and reaches a value of 0.08 \%. The maximum CO content in exhaust gases is observed at maximum load and is 0.27 \%, i.e. an increase of 3.4 times [26-30].

The smoke content in the exhaust gases (C) increases with increasing load. At a minimum load of $p_e = 0.13$ MPa, the smoke content is 0.4 units on the Bosch scale, and at a maximum load of $p_e = 0.69$ MPa, it increases to 3.9 units on the Bosch scale. An increase in smoke content by 9.8 times [31-40].

The following conclusions can be drawn from the analysis of diesel operation schedules on ete in nominal mode: with increasing load, the content of nitrogen oxides NO\textsubscript{x} in exhaust gases increases from 432 ppm at $p_e = 0.13$ MPa to 715 ppm at $p_e = 0.69$ MPa. Increase in NO\textsubscript{x} content by 65.5 \%.

As the load increases, the CO\textsubscript{2} content of the exhaust gas also increases. This is when the load of $p_e = 0.13$ MPa of CO\textsubscript{2} is 3.9\%, and when the load increases to the maximum, the value of CO\textsubscript{2} increases to 9.2 \% [41-45].

As the load increased, the exhaust gas content decreased from the minimum value to $p_e = 0.52$ MPa, which is equal to 0.42\% and 0.18\%, respectively. At maximum load, the CH\textsubscript{x} content increases to 0.23
Figure 2. Indicator indicators of a diesel engine 4CH 11.0/12.5 at work ETE: at n = 2200 min\(^{-1}\), ------ DT; - - - - - - ETE.

The CO content in exhaust gases is reduced from 0.45 % at \(p_e = 0.13\) MPa to 0.10 % at \(p_e = 0.55\) MPa. If the road increases further to the maximum, the CO increases to 0.21 %.

As the load increases, the smoke content in the exhaust gas increases. Thus, at \(p_e = 0.13\) MPa, the smoke content is 0.10 units on the Bosch scale, the maximum load increases to 1.9 units on the Bosch scale. An increase of 19.0 times.

When comparing the graphs corresponding to the operation of a 4CH 11.0 / 12.5 diesel engine on DT and on ETE, at the optimal installation angle, at a speed of 2200 \(\text{min}^{-1}\), it can be noted that environmental indicators and patterns of curve changes differ slightly.

The NO\(_x\) content at \(p_e = 0.13\) MPa decreases from 593 ppm when working with diesel on DT to 432 ppm when working with diesel on ETE, a decrease of 27.2 %. At maximum load, the difference in NO\(_x\) values increases to 945 ppm for DT and 715 for ETE. The decrease was 24.3 %.

The CO\(_2\) content in exhaust gases when working on ETE is higher and is: when \(p_e = 0.13\) MPa, 3.2 %, when working on DT, and when working on ETE increases to 3.94 %. When the load increases to the maximum CO\(_2\) content in the exhaust gases when the diesel is running on ETE, it increases compared to working on DT. Thus, at \(p_e = 0.69\) MPa, the CO\(_2\) content in exhaust gases increases from 7.5 to 9.2 %, i.e. by 22.7 %.

The CH\(_x\) content in the exhaust gases when operating on ETE is greater over the entire load range. The greatest difference in content is observed at low loads. Thus, at \(p_e = 0.13\) MPa, CH\(_x\) increases from 0.033 to 0.42 %. When the load increases to \(p_e = 0.69\) MPa, the CH\(_x\) content in the exhaust gases when running a diesel engine on ETE increases from 0.067 to 0.230 %, increasing by 3.4 times.

The CO content in exhaust gases at \(p_e = 0.13\) MPa when working on DT is 0.11 %, and when working
on diesel, this increases to 0.45 %. When the load increases to $p_e = 0.55$ MPa, the CO content in

![Figure 3](image-url)

**Figure 3.** Environmental performance of diesel when running on ethanol, depending on the load change at $n = 2200$ min$^{-1}$; —— DT; —— ETE.

the exhaust gases when working on DT and ETE is equalized to 0.1 %. When the load increases to $p_e = 0.69$ MPa, the CO content in the exhaust gases when working on DT increases in comparison with work on ETE, i.e. by 0.27 and 0.21%, respectively.

The smoke content in exhaust gases when running a diesel engine on an ETE is lower over the entire load range. Thus, when $p_e = 0.13$ MPa, the smoke value decreases from 0.4 to 0.1 units on the Bosch scale, that is, by 4.0 times. When the load is increased to the maximum, the smoke value when working on ETE decreases from 3.9 to 1.9 units on the Bosch scale, that is, by 2.1 times [46-51].

Based on the data obtained, it can be concluded that the use of ethanol as an ethanol-fuel emulsion can significantly reduce the content of the main toxic components of the engine when operating at all load and speed modes.

**References**

[1] Luksho V A, Kozlov A V, Terenchenko A S and Grinev V N 2018 *International Journal of Mechanical Engineering and Technology* **9** 1385-95

[2] Kozlov A N, Anfilitov A A and Chuvash A N 2019 *Journal of Physics: Conf. Series* **1399** 055051

[3] Lopatin O P 2020 *IOP Conf. Series: Earth and Environmental Science* **421** 072019

[4] Sivakumar M, Ramesh kumar R, Syed Thasthagir M H and Shanmuga Sundaram N 2018 *Renewable Energy* **116** 518-26

[5] Chuvash A N and Chuprakov A I 2019 *Journal of Physics: Conf. Series* **1399** 055085
[6] Lopatin O P 2020 IOP Conf. Series: Materials Science and Engineering 734 012199
[7] Yadava S and Maitra S S 2017 Global Nest Journal 19 533-9
[8] Ahmad I 2016 Journal of Pure and Applied Microbiology 10 95-102
[9] Chuvashev A N, Chuprakov A I and Anfilatov A A 2020 IOP Conf. Series: Materials Science and Engineering 734 012184
[10] Anfilatov A A and Chuvashev A N 2020 Journal of Physics: Conf. Series 1515 042048
[11] Skryabin M L 2020 IOP Conf. Series: Earth and Environmental Science 421 072012
[12] Lopatin O P 2020 Journal of Physics: Conf. Series 1515 052004
[13] Shatrov M G, Sinyavski V V, Dunin A Y, Shishlov I G, Vakulenko A V and Yakovenko A L 2018 International Journal of Engineering and Technology 7 288-295
[14] Zhilenkov A A and Efremov A A 2017 IOP Conference Series: Materials Science and Engineering 10 012043
[15] Anfilatov A A and Chuvashev A N 2020 Journal of Physics: Conf. Series 1515 042052
[16] Devetyarov R R and Chuvashev A N 2020 Journal of Physics: Conf. Series 1515 042080
[17] Anfilatov A A and Chuvashev A N 2020 Journal of Physics: Conf. Series 1515 022035
[18] Lopatin O P 2020 Journal of Physics: Conf. Series 1515 042009
[19] Anfilatov A A and Chuvashev A N 2020 Journal of Physics: Conf. Series 1515 042077
[20] Sinyavski V V, Alekseev I V, Ivanov I Y, Bogdanov S N and Trofimenko Y V 2017 Pollution Research 36 686-92
[21] Lopatin O P 2020 Journal of Physics: Conf. Series 1515 042021
[22] Chuvashev A N and Chuprakov A I 2020 Journal of Physics: Conf. Series 1515 042094
[23] Gonzalez-Salazar M A, Venturini M, Poganietz W-R, Finkenrath M and Leal M R 2017 Renewable and Sustainable Energy Reviews 73 159-77
[24] Anfilatov A A and Chuvashev A N 2020 IOP Conf. Series: Materials Science and Engineering 862 032052
[25] Chuvashev A N and Chuprakov A I 2020 IOP Conf. Series: Materials Science and Engineering 862 062089
[26] Anfilatov A A 2020 Journal of Physics: Conf. Series 1515 042049
[27] Kopchikov V N and Fominykh A V 2020 Journal of Physics: Conf. Series 1515 042028
[28] Melbert A A, Shaposhnikov Y A, Mashensky A V and Voinash S.A. 2019 Journal of Physics: Conference Series 012011
[29] Anfilatov A A and Chuvashev A N 2020 IOP Conf. Series: Materials Science and Engineering 862 032055
[30] Chuvashev A N and Chuprakov A I 2020 IOP Conf. Series: Materials Science and Engineering 862 062083
[31] Anfilatov A A 2020 Journal of Physics: Conf. Series 1515 042098
[32] Chen W, Pan J, Liu Y, Fan B, Liu H and Otchere P 2019 Applied Energy 176 453-67
[33] Anfilatov A A and Chuvashev A N 2020 IOP Conf. Series: Materials Science and Engineering 862 062064
[34] Semprini S, Sánchez D and De Pascale A 2016 Solar Energy 132 279-93
[35] Anfilatov A A and Chuvashev A N 2020 IOP Conf. Series: Materials Science and Engineering 862 062069
[36] Osorio-Tejada J L, Llera-Sastresa E and Scarpellini S 2017 Renewable and Sustainable Energy Reviews 71 785-95
[37] Skryabin M L and Grebnev A V 2020 Journal of Physics: Conf. Series 1515 052052
[38] Starik A M, Savel’ev A M, Favorshkii O N and Titova N S 2018 International Journal of Green Energy 15 161-8
[39] Skryabin M L 2020 Journal of Physics: Conf. Series 1515 04283
[40] Presser C, Nazarian A and Millo A 2018 Fuel 214 656-66
[41] Skryabin M L 2020 Journal of Physics: Conf. Series 1515 042107
[42] Jeevahan J, Mageshwaran G, Joseph G B, Raj R B D and Kannan R T 2017 Chemical Engineering Communications 204 1202-23
[43] Lopatin O P 2020 IOP Conf. Series: Materials Science and Engineering 862 062025
[44] Frances C 2009 Sustainability 1 43-54
[45] Devetyarov R R 2020 IOP Conf. Series: Materials Science and Engineering 862 062072
[46] Sinyavski V V, Shatrov M G, Dunin A Y, Shishlov I G and Vakulenko A V 2019 Periodicals of Engineering and Natural Sciences 7 281-6
[47] Rajesh Kumar B and Saravanan S 2016 Renewable and Sustainable Energy Reviews 60 84-115
[48] Lopatin O P 2020 IOP Conf. Series: Materials Science and Engineering 862 062087
[49] Gough R V and Bruno T J 2012 Energy and Fuels 26 6905-13
[50] Mikulski M and Wierzbicki S 2016 Journal of Natural Gas Science and Engineering 31 525-37
[51] Chai X, Mahajan D and Tonjes D J 2016 Progress in Energy and Combustion Science 56 33-70