Application of ethanol fuel emulsion in diesel engines

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, 610017, Kirov, October prospect, 133, Russian Federation

E-mail: aleks_dvs@mail.ru

Abstract. The article analyzes experimental data obtained during bench tests of tractor diesel 4CH 11.0/12.5 using alternative fuel - ethanol. Ethanol was supplied to the diesel cylinder as part of an emulsion, this method allows for minor modifications of the diesel fuel system to use alternative fuel with a sufficiently high efficiency. 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. The article presents experimental studies of the working process of diesel when working on ethanol-fuel emulsion, which were brought to the maximum.

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, were taken at the nominal speed of the crankshaft (n = 2200 min⁻¹) and at the frequency corresponding to the maximum torque (n = 1700 min⁻¹) [1-10].

The main properties of alcohols and diesel fuel are shown in table 1. Indicator indicators of diesel when working on ethanol-fuel emulsion are shown in figure 1. When analyzing the schedules of diesel engine operation on DT in the mode corresponding to the maximum torque (figure 2), the following conclusions can be drawn: the content of nitrogen oxides NOx in exhaust gases when the load increases from the minimum at pₑ = 0.13 MPa to the maximum at pₑ = 0.76 MPa increases from 976 ppm to 1135 ppm, respectively, i.e. the increase is 16.3 %. The minimum value of NOx emissions is observed at pₑ = 0.29 MPa, which is 887 ppm [11-18]. As the load increases, the CO2 content in the exhaust gas increases. Thus, when the load is pₑ = 0.13 MPa, the CO2 value is 3.0 %, and when the load is increased to the maximum, the CO2 value increases to 7.8 %. An increase of 2.6 times.

When the load increases, the content of CHx hydrocarbons in the exhaust gas decreases from the minimum to the corresponding value of 0.40 MPa from 0.026 to 0.023%, respectively, the decrease is 0.003 %. With a further increase in the load to the maximum, the content of CHx hydrocarbons in the exhaust gases increases to 0.060 %, i.e. 2.6 times [19-26].

The CO content in exhaust gases has a minimum value at an average load of pₑ = 0.40 MPa and reaches a value of 0.08 %. The maximum CO content in exhaust gases is observed at a minimum load and is 0.49 %.

The smoke content in the exhaust gases (C) increases with increasing load. At a minimum load of pₑ = 0.13 MPa, the smoke content is 0.3 units on the Bosch scale, and at a maximum load of pₑ = 0.76 MPa,
it increases to 4.6 units on the Bosch scale. Increase in smokiness by 15.3 times [27-35].

**Table 1.** Comparative characteristics of motor fuels.

| Properties                                                                 | Ethanol | Methanol | Diesel fuel |
|----------------------------------------------------------------------------|---------|----------|-------------|
| Elementary composition, kg / kg:                                          |         |          |             |
| carbon                                                                    | 0.520   | 0.375    | 0.870       |
| hydrogen                                                                  | 0.130   | 0.125    | 0.130       |
| oxygen                                                                    | 0.360   | 0.5      | -           |
| Molecular weight                                                          | 46      | 32       | 180…200    |
| Density at 20° C, kg / m³                                                 | 789     | 795      | 820         |
| The theoretical amount of air required for complete combustion of the fuel | 9.074   | 6.52     | 14.35       |
| 1 kg of fuel, kg of air/kg of fuel                                         |         |          |             |
| Boiling point, °C                                                         | 79      | 64.7     | 170…380    |
| Ignition temperature, °C                                                  | 420     | 470      | 200…220    |
| Flash point, °C                                                           | 21      | 11       | 35…80      |
| Viscosity at 20 ° C, mm²/s, (sSt)                                        | 0.5     | 0.55     | 3.0…6.0    |
| Heat of combustion, kJ/kg                                                  | 25500   | 19665    | 42530       |
| Heat of combustion of the working mixture, MJ/kg                          | 2.8     | 2.76     | 2.77        |
| Evaporation heat, kJ/kg                                                   | 841     | 1104     | 250         |
| Calorific value of stoichiometric mixture at 20 ° C                       | 3514    | 3638     | 3461        |
| and P=105 Pa, kJ/m³ in relation to the internal mixing                    |         |          |             |
| The limits of flammability, % volume                                      | 4.3…19 | 6.7…36  | 1.58…8.2   |
| Octane number:                                                            |         |          |             |
| according to the method of the study                                      | 100     | 110      | -           |
| according to the motor method                                             | 89      | 92       | -           |
| Cetane number                                                             | 8       | 3        | 45…55      |
| Miscibility with water                                                    | good    | good     | bad         |
| Compatibility with hydrocarbons                                           | bad     | bad      | good        |
| Theoretical coefficient molecular changes in the human body gorenje       | 1.14    | 1.21     | 1.06        |
| stoichiometric mixture (internal mixing)                                  |         |          |             |

When analyzing the schedules of diesel operation on ETE in the mode corresponding to the maximum torque, the following conclusions can be drawn: with increasing load, the content of nitrogen oxides NOx in exhaust gases increases from 698 ppm at $p_e = 0.13$ MPa to 763 ppm at $p_e = 0.76$ MPa. Increase in NOx content by 9.3 %. As the load increases, the CO2 content of the exhaust gas also increases. Thus, with a load of $p_e = 0.13$ MPa, CO2 is 3.5%, and when the load is increased to the maximum, the CO2 value increases to 9.4 % [36-40].

As the load increases, the CHx content in the exhaust gas decreases from a minimum to $p_e = 0.55$ MPa, which is equal to 0.34% and 0.17%, respectively. At maximum load, the CHx content increases to 0.21 %.

The CO content in exhaust gases is reduced from 0.49 % at $p_e = 0.13$ MPa to 0.10 % at $p_e = 0.53$ MPa. With a further increase in the load to the maximum, the co increases to 0.30 %. In addition, as the load increases, the exhaust smoke also increases. Thus, at $p_e = 0.13$ MPa, the smoke content is 0.10 units. On the Bosch scale, the maximum load increases to 1.4 units on the Bosch scale. An increase of 14.0 times.

When comparing the graphs corresponding to the operation of the diesel 4CH 11.0/12.5 in DT and ETE under the optimum installation of UOFT, at speed of 1700 min⁻¹, which corresponds to the maximum torque, it can be noted that environmental performance and change patterns of the curves are somewhat different. The NOx content at $p_e = 0.13$ MPa decreases from 976 ppm when working with
diesel on DT to 698 ppm when working with diesel on ETE, a decrease of 28.5 %. At maximum load, the difference in NOx values increases to 1135 ppm for DT and 763 for ETE. The decrease was 32.8 %.

Figure 1. Indicator indicators of a diesel engine 4CH 11.0/12.5 at work ETE: at n = 1700 min⁻¹, ------ DT; - - - - - ETE.

The CO2 content in the exhaust gases when working on ete is higher and is: at pe = 0.13 MPa 3.0 %, when working on DT, and when working on ETE increases to 3.5 %. When the load increases to the maximum CO2 content in the exhaust gases when working on diesel ete, it increases compared to working on DT. Thus, at pe = 0.76 MPa, the CO2 content in exhaust gases increases from 7.8 to 9.4%, i.e. by 20.5 %, [41-45].

The CHx content in exhaust gases when working on ETE is greater over the entire load range. The greatest difference in content is observed at low loads. Thus, at pe = 0.13 MPa, CHx increases from 0.026 to 0.34 %. When the load increases to pe = 0.76 MPa, the CHx content in the exhaust gases when running a diesel engine on ETE increases from 0.060 to 0.210%, increasing by 3.5 times.

The CO content in exhaust gases at pe = 0.13 MPa when working on DT is 0.11 %, and when working on diesel ETE increases to 0.49 %. When the load increases to pe = 0.55 MPa, the CO content in the exhaust gases when working on DT and ETE is equalized to 0.1 %. When the load increases to pe = 0.76 MPa, the CO content in the exhaust gases when working on DT increases in comparison with work on ETE, i.e. by 0.38 and 0.30%, respectively.

The smoke content in exhaust gases when running a diesel engine on an ETE is lower over the entire load range. Thus, when pe = 0.13 MPa, the smoke value decreases from 0.3 to 0.1 units on the Bosch scale, that is, by 3.0 times. When the load is increased to the maximum, the amount of smoke when working on ETE decreases from 4.6 to 1.4 units on the Bosch scale, i.e. by 3.3 times [46-53].
Based on the obtained graphs, the operation of diesel on ETE, in comparison with the operation of diesel on DT, allows reducing the content of nitrogen oxides in exhaust gases to 32.8%, reducing the content of soot particles by 3.3 times, also significantly increases the emission of total hydrocarbons and slightly increases the content of CO₂.

References
[1] Mohammadi Khoshkar Vandani A and Joda F 2016 Energy Conversion and Management 109 103-12
[2] Chuvash A N and Chuprakov A I 2019 Journal of Physics: Conf. Series 1399 055085
[3] Likhanov V A and Rossokhin A V 2020 IOP Conf. Series: Materials Science and Engineering 862 062046
[4] Dincer I and Zamfirescu C 2016 Journal of Natural Gas Science and Engineering 28 461-78
[5] Anisimov I, Ivanov A, Chikishev E, Chainikov D, Reznik L and Gavaev A. 2017 International Journal of Sustainable Development and Planning 12 1006-17
[6] Anfilatov A A and Chuvashev A N 2020 Journal of Physics: Conf. Series 1515 042048
[7] Anfilatov A A and Chuvashev A N 2020 IOP Conf. Series: Materials Science and Engineering 862 062069
[8] Datta A and Mandal B K 2016 Applied Thermal Engineering 98 670-82
[9] Arent D J, Wise A and Gelman R 2011 Energy Economics 33 584-93
[10] Anfilatov A A 2020 Journal of Physics: Conf. Series 1515 042049
[11] Lopatin O P 2020 IOP Conf. Series: Earth and Environmental Science 421 072019
[12] Chang W R, Hwang J J and Wu W 2017 Renewable and Sustainable Energy Reviews 67 277-88
[13] Aydin F and Ogut H 2017 Renewable Energy 103 688-94
[14] Lif A and Holmberg K 2006 *Advances in Colloid and Interface Science* **123** 231-39
[15] Likhanov V A, Kozlov A N and Araslanov M I 2020 *IOP Conf. Series: Materials Science and Engineering* **734** 012211
[16] Likhanov V A and Rossokhin A V 2020 *IOP Conf. Series: Materials Science and Engineering* **862** 062047
[17] Skryabin M L 2020 *IOP Conf. Series: Earth and Environmental Science* **421** 072012
[18] Chuvashev A N and Chuprakov A I 2020 *IOP Conf. Series: Materials Science and Engineering* **862** 062089
[19] Luksho V A, Kozlov A V, Terenchenko A S and Grinev V N 2018 *International Journal of Mechanical Engineering and Technology* **9** 1385-95
[20] Sivakumar M, Ramesh kumar R, Syed Thasthagir M H and Shanmuga Sundaram N 2018 *Renewable Energy* **116** 518-26

[21] Yadava S and Maitra S S 2017 *Global Nest Journal* **19** 533-39
[22] Ahmad I 2016 *Journal of Pure and Applied Microbiology* **10** 95-102
[23] Likhanov V A and Lopatin O P 2020 *IOP Conf. Series: Materials Science and Engineering* **862** 062014
[24] Kopchikov V N and Fominykh A V 2020 *Journal of Physics: Conf. Series* **1515** 042028
[25] Anfilatov A A and Chuvashev A N 2020 *Journal of Physics: Conf. Series* **1515** 042052
[26] Lopatin O P 2020 *Journal of Physics: Conf. Series* **1515** 042009
[27] Devetyarov R R and Chuvashev A N 2020 *Journal of Physics: Conf. Series* **1515** 042080

[28] 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
[29] Zhilenkov A A and Efremov A A 2017 *IOP Conference Series: Materials Science and Engineering* **10** 012043
[30] Sinyavski V V, Alekseev I V, Ivanov I Y, Bogdanov S N and Trofimenko Y V 2017 *Pollution Research* **36** 686-92
[31] Gonzalez-Salazar M A, Venturini M, Poganietz W-R, Finkenrath M and Leal M R 2017 *Renewable and Sustainable Energy Reviews* **73** 159-77
[32] Melbert A A, Shaposhnikov Y A, Mashensky A V and Voinash S.A. 2019 *Journal of Physics: Conference Series* **102011**

[33] Likhanov V A and Lopatin O P 2019 *Ecology and Industry of Russia* **23(9)** 60-5
[34] Chuvashev A N, Chuprakov A I and Anfilatov A A 2020 *IOP Conf. Series: Materials Science and Engineering* **734** 012184
[35] Lopatin O P 2020 *Journal of Physics: Conf. Series* **1515** 052004
[36] Chuvashev A N and Chuprakov A I 2020 *IOP Conf. Series: Materials Science and Engineering* **862** 062083

[37] Skryabin M L 2020 *Journal of Physics: Conf. Series* **1515** 042107
[38] Likhanov V A and Anfilatov A A 2020 *IOP Conf. Series: Materials Science and Engineering* **862** 032044
[39] Lopatin O P 2020 *IOP Conf. Series: Materials Science and Engineering* **734** 012199
[40] Kozlov A N, Anfilatov A A and Chuvashev A N 2019 *Journal of Physics: Conf. Series* **1399** 055051
[41] Chen W, Pan J, Liu Y, Fan B, Liu H and Othere P 2019 *Applied Energy* **176** 453-467
[42] Semprini S, Sánchez D and De Pascale A 2016 *Solar Energy* **132** 279-93
[43] Osorio-Tejada J L, Llera-Sastresa E and Scarpellini S 2017 *Renewable and Sustainable Energy Reviews* **71** 785-95

[44] Starik A M, Savel'ev A M, Favorskii O N and Titova N S 2018 *International Journal of Green Energy* **15** 161-8
[45] Presser C, Nazarian A and Millo A 2018 *Fuel* **214** 656-66
[46] Jeevahan J, Mageshwaran G, Joseph G B, Raj R B D and Kannan R T 2017 *Chemical Engineering Communications* **204** 1202-23
[47] Frances C 2009 Sustainability 1 43-54
[48] 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
[49] Rajesh Kumar B and Saravanan S 2016 Renewable and Sustainable Energy Reviews 60 84-115
[50] Gough R V and Bruno T J 2012 Energy and Fuels 26 6905-13
[51] Mikulski M and Wierzbicki S 2016 Journal of Natural Gas Science and Engineering 31 525-37
[52] Chai X, Mahajan D and Tonjes D J 2016 Progress in Energy and Combustion Science 56 33-70
[53] Rossokhin A V and Anfilatov A A 2020 IOP Conf. Series: Materials Science and Engineering 862 062065