Study of toxicity of diesel engine on alcohol fuel

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Abstract. The paper substantiates the necessity of using alcohol fuels in diesel engines. It is shown that to obtain alcohol fuel for a diesel engine, it is advisable to use an emulsion of the following composition: ethanol-25%, detergent-dispersing additive succinimide C-5A - 0.5%, water - 7%, diesel fuel - 67.5%. The results of experimental studies of the effect of ethanol-fuel emulsion as an alternative fuel on the environmental characteristics of a diesel engine are presented. As a result of the transfer of the diesel engine to work on ethanol-fuel emulsion, there is a decrease in the exhaust gases of soot by 4.8 times, nitrogen oxides by 40.3%, carbon dioxide by 26.6%, carbon monoxide by 28.6%.

The current scientific, technical and technological state of the domestic engine industry in terms of environmental and fuel and economic indicators in the conditions of market relations and restrictions of harmful effects of components of combustion products of diesel engines on the environment makes engine-building plants radically restructure their technical policy taking into account regulatory requirements for the environment. Therefore, it is necessary to think seriously about alternative energy sources of non oil origin [1-3].

The use of alternative mixed fuels based on ethyl alcohol in transport provides a solution to these problems, namely, allows replacing petroleum fuels, significantly expands the raw material base for obtaining motor fuels, facilitates the solution of issues of modernization of fuel systems of vehicles and stationary installations. The possibility of obtaining fuels with the required physical and chemical properties allows purposefully improve the working processes of diesel engines and, thereby, improve fuel efficiency and toxicity of exhaust gases (EG) [4-6].

In Vyatka state agricultural Academy on the basis of the Department of heat engines, cars and tractors conducted research on the transfer of diesel engine to work on ethanol-fuel emulsion (EFE) [7-9].

In order to obtain the greatest effect from emulsions as an alternative motor fuel, it is necessary to study the physical and chemical properties of the alcohol emulsion, their influence on the working processes of the diesel engine. EFE is a dispersed system formed by two mutually insoluble liquids, which are on the one hand ethyl alcohol and water, on the other hand diesel fuel and additives. The emulsion is an unstable system that constantly tends to go to the initial (divided by phases) state, which, in turn, is already determined by stability. Stability, i.e. the time from the moment of preparation of the emulsion to the appearance of layers with different concentrations depends primarily on the physical properties of the components of the emulsion [10-12].

To improve the physical and of course operational properties of ETE, it is necessary to use relatively inexpensive additives, which must meet the following requirements: completely burn in the engine without the formation of deposits, do not degrade the properties of the fuel, increase the stability of the emulsion, dissolve well in the fuel and its components, be stable, not too volatile and
persist in the fuel in various operating conditions. Succinimide C-5A can be attributed to the additives that meet these requirements. Succinimide C-5A belongs to the class of detergent-dispersing additives. It is a concentrate of high molecular weight succinic acid alkenylamide in oil [13, 14].

For the tests on the engine, the emulsion of the following composition was chosen as optimal for the 4F 11.0/12.5 diesel engine: 25% - absolute ethanol, 0.5% - succinimide additive C-5A, 7% - water and 67.5% - diesel fuel. The quantitative content of the additive was selected from the conditions of economic feasibility. All subsequent tests of the diesel engine were carried out on this emulsion composition.

MPW-302 homogenizer was used for preparation of EFE in laboratory conditions (figure 1).

![MPW-302 homogenizer](image1.png)

**Figure 1.** General view of the homogenizer MPW-302 (a) and manufactured them EFE (b).

An electric brake stand SAK-N670 with a balancing pendulum machine was used as a loading device for testing the diesel engine. The installation was equipped with the necessary measuring complex:

- the rotational speed of the crankshaft of the diesel engine was measured using an electronic digital tachometer TC-1;
- fuel consumption was determined using an electronic flowmeter AIR-50;
- the flow rate of air consumed by the diesel engine was determined using the gas meter RG-400, installed in front of the intake receiver and pulse counter MES-66.

To indicate the combustion process in the cylinder of a diesel engine, an electropneumatic indicator MAI-5A was used. EG sampling was carried out by gas intakes of the ASGA-T system installed on the exhaust pipeline of the engine. The smoke content of the EG was measured using a smoke meter «BOSCH-EFAW-68A» [15-17].

The content of toxic components in the EG of the diesel engine depending on the change in the setting angle of the fuel injection advance (AFIA) for the speed of 2200 min\(^{-1}\) is shown in figure 2, a.

Comparing the curves corresponding to the operation of a diesel engine on diesel fuel and on EFE on different installation AFIA at a nominal speed of 2200 min\(^{-1}\), it can be noted that environmental indicators differ, and there are some differences in the laws of change. The content of nitrogen oxides NO\(_x\) in the EG of a diesel engine when working on EFE at all installation AFIA is less than when working on diesel fuel. At \(\Theta_{inj}=23^\circ\) the NO\(_x\) value decreases from 1100 to 657 ppm, or 40.3%. At \(\Theta_{inj}=26^\circ\), the NO\(_x\) value decreases from 1320 to 730 ppm, or 44.7%. The content of hydrocarbons CH\(_x\) in the EG of a diesel engine when working on EFE is greater than when working on diesel fuel on all
installation AFIA. At Θ_{inj}=23º when switching to EFE, the value of CH\textsubscript{x} increases from 0.108 to 0.22%, or 2.0 times. At Θ_{inj}=26º when switching to EFE, the value of CH\textsubscript{x} increases from 0.110 to 0.20%, or 1.8 times. The CO\textsubscript{2} content in the EG of a diesel engine when operating on EFE is less than when operating on diesel fuel. At Θ_{inj}=23º the CO\textsubscript{2} value during the transition to EFE decreases from 10.9 to 8.0%, or 26.6%. At Θ_{inj}=26º, the CO\textsubscript{2} value during the transition to EFE decreases from 10.5 to 7.6%, or 27.6%. The curve of the CO content in the EG of a diesel engine when operating on EFE has a distinctive character of change in comparison with the diesel process. Thus, at the installation AFIA 29º CO is greater than when working on diesel fuel, and at all other studied angles there is a decrease. At Θ_{inj}=23 and 26º, the CO content when working on EFE is reduced compared to work on diesel fuel from 0.21 to 0.15%, i.e. by 28.6%, and from 0.20 to 0.17%, i.e. by 15.0%, respectively. The values of EG smoke during the transition to EFE are reduced. Thus, at Θ_{inj}=23º, the smoke content of the EG decreases from 5.8 to 1.2 units on the Bosch scale, i.e. 4.8 times. At Θ_{inj}=26º the smokiness value decreases from 6.2 to 1.5 units on the Bosch scale, or 4.1 times [18-20].

![Graph with data points showing changes in NO\textsubscript{x}, CO, and CO\textsubscript{2} values for different installation angles with and without EFE.]

**Figure 2.** Influence of EFE on the content of toxic components in the EG of diesel engine 4F 11.0/12.5 depending on the change of the installation AFIA: a – n=2200 min\textsuperscript{-1}; b - 1700 min\textsuperscript{-1}.

Thus, at the nominal operating mode and the optimal setting AFIA Θ_{inj}=23º the use of EFE while maintaining the power indicators leads to the following values of the toxicity and smokiness of the EG (table 1).

**Table 1.** Indicators of toxicity and smokiness EG of diesel engine 4F 11.0/12.5 at the setting AFIA Θ_{inj}=23º and nominal mode (n=2200 min\textsuperscript{-1}, p_{e}=0.64 MPa).

| Fuel | Indicators | NO\textsubscript{x}, % | C, Bosch | CO\textsubscript{2}, % | CO\textsubscript{2}, % | CH\textsubscript{x}, % |
|------|------------|------------------------|----------|------------------------|------------------------|------------------------|
| Diesel | 1100 | 5.8 | 10.9 | 0.21 | 0.11 |
| EFE | 657 (decrease of 40.3%) | 1.2 (decrease by 4.8 times) | 8.0 (decrease of 26.6%) | 0.15 (decrease of 26.6%) | 0.22 (increase in 2 times) |
The content of toxic components in the EG of a diesel engine depending on the change in the installation AFIA for the speed corresponding to the maximum torque n=1700 min\(^{-1}\) is shown in figure 2, b. The regularities of the change in the content of toxic components in the EG depending on the change in the installation AFIA at n=2200 min\(^{-1}\) are preserved for the speed of 1700 min\(^{-1}\). The content of nitrogen oxides NO\(_x\), soot C and carbon dioxide CO\(_2\) in the EG of a diesel engine when working on EFE at all installation AFIA is less than when working on diesel fuel. The content of carbon monoxide CO in the EG of a diesel engine when working on the EFE on the installation AFIA from 20 to 26\(^\circ\) is lower than the diesel process and at 29\(^\circ\) there is already an increase in relation to the diesel process [21, 22].

Thus, at the maximum torque mode and the optimal setting AFIA \(\Theta_{mj}=23^\circ\), the use of EFE while maintaining the power indicators leads to the following values of the toxicity and smokiness of the EG (table 2).

**Table 2.** Indicators of toxicity and smoke EG of diesel engine 4F 11.0/12.5 at the setting AFIA \(\Theta_{mj}=23^\circ\) and the maximum torque (n=1700 min\(^{-1}\), \(p_e=0.69\) MPa).

| Fuel   | Indicators | \(\text{NO}_x\), % | C, Bosch | \(\text{CO}_2\), % | CO, % | CH\(_x\), % |
|--------|------------|---------------------|----------|-------------------|-------|------------|
| Diesel |            | 1300                | 5.1      | 9.6               | 0.16  | 0.09       |
| EFE    |            | 730 (decrease of 43.9%) | 0.9 (decrease by 5.7 times) | 7.8 (decrease of 18.8%) | 0.10 (decrease of 37.5%) | 0.18 (increase in 2 times) |

The content of toxic components in the EG of the diesel engine depending on the load changes at a speed of 2200 min\(^{-1}\) and the setting AFIA 23 degrees (optimal for operation on EFE) is presented in figure 3, a.

![Figure 3](image-url)

**Figure 3.** Influence of EFE on the content of toxic components in the EG of diesel engine 4F 11.0/12.5 depending on the load change at \(\Theta_{mj}=23^\circ\): a - n=2200 min\(^{-1}\); b - 1700 min\(^{-1}\).

Analyzing the curves of the content of toxic components in the EG of the diesel engine when working on diesel fuel and EFE, it is necessary to note the following. The NO\(_x\) content when working
on EFE is lower than the diesel process in the entire load range. Thus, at \( p_1 = 0.13 \) MPa, the value of the NO\(_x\) content in the EG when the transition to EFE is reduced from 260 to 250 ppm, or 3.8%. At \( p_1 = 0.69 \) MPa, the value of the NO\(_x\) content in the EG decreases from 1100 to 715 ppm, or by 35.0%, when switching to EFE. The CO\(_2\) content in the EG when working on ETE is lower in the entire range of load changes in relation to the diesel process. Thus, when working on diesel fuel at \( p_1 = 0.13 \) MPa, the CO\(_2\) content in the EG is 3.5%, and when working on EFE is reduced to 2.8%, or 20.0%. At \( p_1 = 0.69 \) MPa, this decrease is 26.4%. The application of EFE increases the content of CH\(_x\) in the EG. Thus, at \( p_1 = 0.13 \) MPa, the content of CH\(_x\) when working on EFE is 4.9 times greater than the diesel process, and at \( p_1 = 0.69 \) MPa, the content of CH\(_x\) is 2.1 times higher. The use of EFE leads to a decrease in the CO content in the EG at loads above \( p_1 = 0.57 \) MPa and to an increase at loads less than this value. Thus, at \( p_1 = 0.13 \) MPa, the use of EFE leads to an increase in CO from 0.08 to 0.20%, or 2.5 times. At \( p_1 = 0.69 \) MPa, the use of EFE leads to a decrease in CO from 0.29 to 0.18%, or 37.9%. Smoke (C) EG when the diesel engine on EFE is reduced throughout the load range. Thus, at \( p_1 = 0.13 \) MPa, the smokiness value decreases from 1.4 to 0.1 units on the Bosch scale, i.e. 14.0 times. When the load increases to \( p_1 = 0.69 \) MPa, the smokiness value during the transition to EFE decreases from 7.7 to 1.9 units on the Bosch scale, i.e. 4.1 times [23-25].

The content of toxic components in the EG of a diesel engine depending on the load change at the speed of 1700 min\(^{-1}\) and the setting angle of fuel injection advance 23\(^\circ\) is shown in figure 3, b. The regularities of the change in the content of toxic components in the EG depending on the load change at \( n = 2200 \) min\(^{-1}\) are preserved for the speed of 1700 min\(^{-1}\).

On the basis of the experimental bench studies of the working process of the diesel engine when working on the EFE, the values of the optimal setting AFIA - 23 degrees to the correct dead point on the meniscus were determined. Since the engine does not have any device for quickly changing the setting AFIA, the same value is recommended for the diesel process. At the same time, the possibility of preserving the power indicators at the level of a serial diesel engine at a concentration of ethanol in the composition of EFE - 25% was established. This saves diesel fuel up to 32.5% by replacing it with other components and reduces the toxicity EG of diesel engine (at nominal operation): soot 4.8 times, nitrogen oxides 40.3%, carbon dioxide 26.6%, carbon monoxide 28.6%.

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