Development of environmentally friendly alcohol-fuel emulsions for diesel engines

V A Likhanov and O P Lopatin

Department of thermal engines, automobiles and tractors, Vyatka State Agricultural Academy, 610017, Kirov, October prospect, 133, Russian Federation

E-mail: nirs_vsaa@mail.ru

Abstract. In this work, the ecological mixture of alcohol with petroleum motor fuel was studied. Since one of the main qualities of an alcohol emulsion that determines its applicability in diesels is stability, the emulsion must have sufficient stability to operate the diesel for a long time. The results of microscopy of newly prepared samples of alcohol emulsions and samples with already started flocculation process are presented. The stability of alcohol emulsions with different amounts of alcohol and additives was studied. The optimal values of methyl and ethyl alcohol, water and additives in the emulsion intended for use in diesel engines were determined.

Probably everyone knows about the use of various alcohols in diesels. Alcohol in diesels can be served both in pure form and in various mixtures to increase the cetane number. The preferred method of using alcohols in diesels from the point of view of the economic effect and preservation of the cetane number can be an alcohol emulsion [1-8].

An emulsion is a structure consisting of insoluble liquids, in this case, one is uniformly dispersed (crushed) in the form of tiny droplets in the other (figure 1).

![Figure 1. Microscopy of emulsions: a - globules of water-fuel emulsion (1mkm) at an increase of 25000 times; b - globules of emulsion at the price of division of the microscope 5 mkm.](image-url)
Emulsion fuel, created on the basis of hydrocarbon fuels are multicomponent chemical systems, combustion characteristics which are currently not sufficiently systematized [9-14]. Alcohol-fuel emulsions are similar to water-fuel emulsions, since both are reverse-type emulsions, so it is fair to consider the mechanisms of crushing water droplets in oil (figure 2) to study alcohol-fuel emulsions.

![Figure 2. Schemes of micro-explosions of water drops in oil.](image)

In scheme 1 (figure 2), the drop was first divided into two fragments, and then each of them was divided into even smaller ones in several stages. In some cases, small drops exploded, completely passing into a vaporous state, and sometimes when they were further lowered into the area of higher temperatures. According to scheme 2 (figure 2), some of the drops began to boil, so that chains of tiny vapor cavities were generated from their surface. As the drop descended into the area of higher oil temperatures, the intensity of vapor release increased, and sometimes several more bubble generations occurred. The structure of the bubble chains resembled the beginning of boiling on a heated solid surface on which a vapor-gas cavity located in a crack "works". As the drop dropped, the frequency of bubble formation and their volume increased. Drops of the third type (scheme 3), the number of which in the total mass depended on what water (distilled, water settled or water not settled) was used in the experiments, exploded, immediately passing into steam. This usually occurred at temperatures 170°C [15-19].

![Figure 3. Microscopy of ethanol-fuel emulsion: a - immediately after preparation; b - at the beginning of the flocculation process.](image)
Thus, the scheme of formation of the competitive phase in water droplets when they are heated in the fuel medium is determined mainly by the gas content, i.e. the number and size distribution of the competitive phase nuclei (steam-water). The results obtained show that when considering the features of micro-explosion of emulsified fuel droplets, one of the main positive effects is the formation of a competitive vapor phase during overheating. It is also believed that the lower the vaporability of the fuel, the better the beneficial effects of emulsification are manifested, since micro-explosions will cause a secondary grinding effect only if they appear before a large mass of the original drops evaporates or pyrolyzes [20-25].

Figure 4. Results of stability studies of alcohol-fuel emulsions with succinimide C-5A additive: \( k_{at} \) - concentration of succinimide C-5A additive; 10, 20, 30, 40, 50% - alcohol concentration; a - absolute methanol; b - methanol with a water content of 7%; c - absolute ethanol; d - ethanol with a water content of 7%.
To improve the stability of alcohol emulsions, water is added to them. Adding water in the amount of 10% by weight, for example, to methanol allows you to get an emulsion that is stable for several days. Stability can also be improved by simultaneously introducing equivalent amounts (relative to methanol) of low-molecular-weight aromatic hydrocarbons that boil below the boiling point of diesel fuel, or using higher alcohols, in particular butanol, or effective surfactants as a stabilizer [26-31].

The introduction of low-molecular-weight aromatic compounds can increase the physical stability of the mixture up to 3-5 days. Optimal emulsion stabilizers are additives: succinimide in combination with a water-soluble wetting agent, as well as a composite fuel-soluble stabilizer consisting of a special additive to engine oils and a coolant additive.

Preparation of a stable alcohol-containing fuels can be carried out by mechanical or chemical emulsifiers. It is most preferable to prepare alcohol-containing fuels immediately before injecting them into the diesel cylinders. Emulsions were prepared using the MPW-302 homogenizer at a shaft speed of 2000 min⁻¹, and their stability was determined according to the scientific production program of the NGO "Synthesis PAV". The alcohol concentration varied from 10% to 50% by weight in increments of 10.0%, and the additive concentration from 0.5% to 2.0% in increments of 0.5%.

Samples of the newly prepared emulsion and samples with already begun flocculation were examined under a microscope. In figure 3a, the sample has a uniform composition in terms of particle size, and over time, the particles merge into larger "aggregates", which determines the flocculation process (figure 3b).

The stability criterion was taken to be the time before the appearance of visually observed changes in the emulsion samples. The stability of emulsions, as shown in the diagrams in figure 4, depends on both the amount of alcohol and the additive (k<sub>ad</sub>).

Thus, the resulting alcohol-fuel emulsions are characterized by a sufficient "time reserve" to maintain stability, which allows them to be used in diesels. During this time, the emulsion sample easily returns to its original state by shaking or by vibration of the operating diesel [32-37].

According to research results, the concentration of 50% methanol (CH₃OH) or ethanol (C₂H₅OH) in the emulsion is optimal under conditions of resistance to destructive processes. However, eco-friendly fuel is recommended, consisting of alcohol (25%), succinimide C-5A additive (0.5%), water (7%) and diesel fuel (67.5%) due to a significant increase in the rigidity of the working process during primary diesel tests.

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