Alcohol biofuels for internal combustion engine

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Abstract. The use of alcohol biofuel (BF) for internal combustion engines (ICE) is justified. Possible ways of using methanol (CH₃OH), ethanol (C₂H₅OH), butanol (C₄H₉OH) and methyl ether are analyzed. Experimental characteristics on these alcohols and esters are presented and their ecological advantage in relation to diesel fuel (DF) is proved.

The increasingly deteriorating environmental situation in the world, especially in large localities, forces developed countries to impose regulatory restrictions on emissions of toxicity and smoke from vehicles. For example, in Russia, motor transport accounts for 90% of the total volume of harmful substances coming from all types of transport. Therefore, the problems of environmental safety of road transport are an integral part of the country’s environmental security. The significance and severity of this problem is growing every year. In the infrastructure of the transport industry in Russia, there are about 5 thousand large and medium-sized road transport companies engaged in passenger and cargo transportation. Changes in ownership and activities do not significantly affect the environment. Vehicle emissions increase by an average of 5% per year. In large metropolitan areas, this value reaches 10% [1-9].

Each car emits more than 200 different components into the atmosphere with EG. Harmful substances contained in EG are distributed and transformed in the atmosphere according to certain patterns. Solid particles settle on the underlying surfaces due to the action of gravitational forces. Small particles and impurities in the form of total hydrocarbons (СₓНᵧ) are distributed in the atmosphere by diffusion and participate in physical and chemical interaction on local territories within certain regions. Therefore, the norms are constantly updated not only in the country, but also in the framework of the UN economic Commission for Europe. Environmental requirements for motor transport are currently the highest priority. At the same time, manufacturers are already putting ecofriendliness into the design of vehicles at the design stage, and it should not deteriorate during their operation [10-17].

Diesel ICE are indispensable in public transport, heavy machinery, power generation, agricultural and industrial equipment due to their high efficiency, power output, torque, durability and reliability compared to gasoline engines. However, diesel ICE produces significant amounts of gaseous air pollutants and particulates. These emissions are factors that cause disease and can lead to a decrease in human immunity [18-23].

Primary alcohols CH₃OH, C₂H₅OH and C₄H₉OH have hydroxyl radical associated with the primary carbon. There are many advantages of alcohols replacing fossil fuels, they are obtained from many sources (biomass, coal, etc.). In addition, the oxygen and hydroxyl group (OH) of primary alcohol fuels increase the oxidation of soot during controlled mixing. This results in reduced smokiness, especially at...
high ICE workloads. Primary alcohols have a high octane number and can be used in spark-ignited ICE. However, direct use of primary alcohol fuels in ICE without ignition is difficult because they have low cetane numbers. Consequently, alcohol fuel is mainly used in diesel ICE with an alcohol - DF mixing mode and a dual-fuel mode. In recent years, the rapid depletion of fossil fuel reserves and higher levels of pollution have forced intensive research into alternative and clean energy at ICE [24-31].

Alternative BF are becoming increasingly common. Intensive work on converting vehicles to BF is underway even in highly developed countries that have the financial ability to purchase alternative fuels and in countries with large oil reserves [32-36].

The most studied and promising in motor transport are monatomic primary alcohols – methyl (CH$_3$OH), ethyl (C$_2$H$_5$OH), butyl (C$_4$H$_9$OH). Butanol has a weak hydrophilicity, its corrosion is small, it is convenient for transportation by pipeline. Biobutanol also has advantages in efficiency and cost-effectiveness to DF. First, C$_4$H$_9$OH is more compatible with gasoline and can provide a higher mixing ratio with gasoline. Without replacing ICE, ethanol can be mixed with gasoline no more than 10%, and the permitted butanol content in gasoline exceeds this value. Second, butanol has a higher energy density. Compared to CH$_3$OH and C$_2$H$_5$OH fuel the molecular structure of biobutanol contains more carbon atoms and can store enough energy per unit volume. Experiments have shown that the energy intensity (H) of butanol is similar to gasoline, and the density of ethanol is 35% lower than that of gasoline. Third, compared to many other alcohol fuels such as C$_2$H$_5$OH, biobutanol has a low vapor pressure, so it can flow through the pipeline and has a high resistance to water as an impurity when mixed with gasoline, making it more suitable for use in existing gasoline supply and distribution systems [37-44].

![Figure 1. The toxicity of diesel 4CH 11.0/12.5: - DF; - methanol-containing fuel.](image)

Compared with DF or other alcohol fuel, butanol has good miscibility, less hygroscopicity and corrosion activity. Compared to short-chain alcohols, butanol has many advantages, so it is considered to have good prospects for reducing soot content. The characteristics of butanol are summarized as follows. H$_b$ butanol is 31% higher than ethanol and 76% higher than methanol. Consequently, C$_4$H$_9$OH, when used in an engine, has better power. C$_4$H$_9$OH has a lower volatility, so the probability of cavitation and air resistance in the pipeline is less. The latent heat of butanol obviously reduces the charge temperature. Although this is useful for ICE air intake, it is easy to cause cold start difficulties in low temperature conditions [45-53].

Currently, the mixed combustion method is widely used in engines, because it can reduce the temperature of the mixture in the cylinder. A higher octane number of butanol can improve the anti-
knock properties of the mixed fuel, the compression ratio can be increased. Butanol has a wide range of ignition and is able to achieve depleted combustion. The speed of flame propagation in butanol is higher than in gasoline, which contributes to efficient combustion. Butanol is an oxygen-containing fuel and can reduce emissions of CO, CₓHᵧ and NOₓ [54-61].

When using alcohols, harmful substances in the EG are reduced (figure 1, 2). In addition, there are significantly fewer different sulfur compounds in EG when burning CH₃OH and C₂H₅OH. Alcohol with its simpler structure and small size of molecules is an indicator of a more «clean combustion».

Giving preference to CH₃OH, C₂H₅OH and C₄H₉OH, we should not forget about esters (figure 3). Thus, based on the availability and cost, CH₃OH, C₂H₅OH, C₄H₉OH and methyl ether can be used as the basis or component of eco-friendly BF for vehicles [62-69].

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