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ИСПОЛЬЗОВАНИЕ ЭТАНОЛА И БУТАНОЛА В КАЧЕСТВЕ ДОБАВКИ К БЕНЗИНОВОМУ ТОПЛИВУ ДЛЯ СНИЖЕНИЯ ВЫБРОСОВ В АТМОСФЕРУ

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USE OF ETHANOL AND BUTANOL AS AN ADDITIVE TO GASOLINE FUEL TO REDUCE EMISSIONS INTO THE ATMOSPHERE

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Аннотация. В настоящее время проблема автомобильного транспорта рассматривается как одна из составляющих всей экологической безопасности. Экологические проблемы, связанные с использованием традиционного автомобильного топлива в двигателях различных конструкций, актуальны не только для Азербайджанской Республики, но и для широкого круга стран. Автомобильный транспорт, который создает шум и загрязняет окружающую среду, считается одним из наиболее значимых источников загрязнения окружающей среды в мегаполисах и населенных пунктах. более того, он негативно влияет на здоровье людей. Влияние моторного топлива на окружающую среду колоссально, так как автотранспорт является одним из основных потребителей энергии и сжигает огромное количество продуктов, получаемых в результате переработки нефти. Выхлопные газы автотранспорта являются источниками негативных процессов: загрязнения атмосферы вредными и токсичными газами, образования кислотных дождей, фотохимического смога и, конечно же, глобального потепления, в результате которого образуются газы, формирующие парниковый эффект. С другой стороны, выхлопные газы являются негативными для организма человека, которые при вдыхании в больших концентрациях могут вызывать неблагоприятные последствия для людей. В настоящее время основными компонентами автомобильного топлива, снижающими количество выхлопных газов, являются оксигенаты. Оксигенаты – это добавки, обога-

Annotation. Currently, the problem of motor transport is considered as one of the components of all environmental safety. Eco-problems related to the use of traditional automobile fuel in engines of various designs are relevant not only for the Republic of Azerbaijan, but also for a wide range of countries. Motor transport, which reproduces noise and pollutes the natural atmosphere, is considered as one of the most influential sources of environmental pollution in mega cities and populated areas. moreover, it negatively affects people's health. The impact of motor fuel on the environment is colossally significant, because motor transport is one of the main consumers of energy and burns a massive amount of products obtained as a result of oil refining. Exhaust gases from motor vehicles are sources of negative processes: atmospheric pollution with harmful and toxic gases, the formation of acid rain, photochemical smog, and of course global warming, which results in gases that form the greenhouse effect. On the other hand, exhaust gases are negative for the human body, which, when inhaled in large concentrations, can cause adverse consequences for people. In modern times, the main components of auto fuel that reduce the amount of exhaust gases are oxygenates. Oxygenates are additives enriched with oxygen in their molecular structures. These include: alcoщенные кислородом в своей молекулярной структуре. К ним относятся: спирты (этанол, бутанол, метанол); эфиры. Использование оксигенатов в качестве добавок на современном этапе развития нефтяной промышленности находится на начальном этапе изучения и применения. Эти добавки являются одним из важнейших компонентов традиционной автомобильной топливной смеси, повышая не только эксплуатационные свойства, но и экологические характеристики автомобильного топлива. Таким образом, с экологической точки зрения в качестве жидкого топлива нами было выбрано традиционное автомобильное топливо, а точнее бензин и дизельное топливо.

Ключевые слова: этанол, бутанол, моторное топливо, оксигенаты, н-бутанол, алкилат, изомеризация.

hols (ethanol, butanol, methanol); ethers. The use of oxygenates as additives at the present stage of development of the oil industry is at the initial stage of study and application. These additives are one of the most important components of the traditional automobile fuel mixturincreasing not only the performance properties, but also the environmental characteristics of the automobile fuel. Thus, from an environmental point of view, we have chosen traditional automobile fuel, or rather gasoline and diesel fuel, as a liquid fuel.

Keywords: ethanol, butanol, motor fuel, oxygenates, n-butanol, alkylate, isomerization.

Introduction

The impact of motor fuel on the environment is of colossal significance because automotive transportation is one of the primary consumers of energy and burns a massive amount of products derived from oil processing. [1] The exhaust emissions of automotive transport are sources of negative processes: air pollution with harmful and toxic gases, the formation of acid rain, photochemical smog, and, of course, global warming, the result of which is greenhouse gases [2]. On the other hand, exhaust emissions are harmful to the human body and can have adverse effects on people when inhaled in high concentrations [3].

During the operation of vehicles with internal combustion engines (ICE) of various categories, harmful sources that pollute the biosphere include exhaust motor gases, gases from the Crankcase Ventilation System (CVS), and the evaporation of the working mixture from the fuel systems [4]. Exhaust gases of automotive transport contain some amount of toxic lead, which, in combination with various salts of a wide range of metals, penetrates into the soil, surface waters, and groundwater. Later, it is absorbed by vegetation, which people consume daily [5]. Water bodies are contaminated as a result of the deposition of acid rain, which is caused by the reaction of nitrogen oxides and carbon dioxide with water. It is also worth noting that the main threat from toxic exhaust gases is the depletion of the ozone layer, which protects our planet from the penetration of ultraviolet rays [6]. These rays have the ability to cause a variety of diseases. Hydrocarbons, when reacting with nitrogen oxides, form the so-called near-ground or tropospheric ozone, which also has a negative impact on human health in minor concentrations [7].

Problem statement

Therefore, due to the tightening of the environmental characteristics of traditional automotive fuels, various projects are being implemented in Azerbaijan and the CIS countries, the main goal of which is to reduce the content of harmful substances in gasoline and diesel fuel and transition to a quality that complies with Euro standards. The real goal is to reduce various heterogeneous impurities in fuel: the content of polycyclic aromatic hydrocarbons, benzene, which are carcinogenic substances; the content of sulfur, mercaptan compounds; the replacement of aromatic hydrocarbons with some oxygen-containing additives, alkylates, isomerates. In 2011, new regulations on the benzene content were introduced in the United States, reducing it to 0.95–0.97 % by weight, and as of 2016, new restrictions on benzene content in automotive gasoline to 0.63 % by weight came into effect.

In modern times, the main components of automotive fuel that reduce the amount of exhaust emissions are oxygenates. Oxygenates are additives enriched with oxygen in their molecular structures. These include alcohols (ethanol, butanol, methanol) and ethers (MTBE, ETBE). When oxygen-containing additives are added to the fuel-air mixture at a concentration of 9–15 %, the content of carbon monoxide (CO) and hydrocarbons decreases due to complete combustion, thanks to the presence of oxygen in the fuel mixture. The carbon dioxide content increases because this gas is a product of complete combustion. When using MTBE, the concentration of nitrogen oxides also increases to a negligible extent, and their concentrations do not have negative consequences [8].

The use of oxygenates as additives in the modern stage of the oil industry's development is still in the early stages of study and application. These additives are among the most important components of traditional automotive fuel blends, improving not only operational properties but also the environmental characteristics of automotive fuels.

Problem solution

For example, in the chemical industry, catalysts are used in the form of various powder fillers, which increase the contact surface between the interacting substances, and other bulk substances, inside the pores of which liquids and gases are filtered [9–11]. During the filtration process, an electric potential of the flow arises, which is not taken into account when designing and implementing a chemical reaction. However, failure to take into account the process of electrification can lead to distortion of the results, and sometimes to equipment accident. The primary research and experiments were conducted in the environmental monitoring department of the «SOCAR» company. Two mixtures were used as raw materials: the composition of the first mixture consisted of 300 mg of A-92 gasoline and 6 mg (2 % by mass) of ethanol (96.4 %), and the composition of the second mixture was determined by 300 mg of pure gasoline of the same brand and 6 mg (2 % by mass) of n-butanol (99 %). The main measurements were carried out on a 2004 Mitsubishi Airtrek automobile. The vehicle belongs to Euro-2 class according to European environmental standards (table 1).

Table 1 – The production of vehicles that comply with the environmental standards of the Euro class

Countries that manufacture vehicles	The year of manufacture of the vehicles and their classification according to Euro emission standards				
	1 and lower	2	3	4	5
Countries of the European Union	until 1996	1997–2000	2001–2004	2005	2010
USA	until 1995	1996–2000	2001–2003	2004	---------
Japan	until 1997	1998–2004	2005–2010	2011	----------
Canada	until 2000	2001–2003	2004	---------	----------
India	until 2004	2005–2009	2010	---------	---------
China	until 2003	2004–2007	2008	---------	--------
South Korea	until 2000	2001–2002	2003–2005	2006	---------

The main real study was conducted to compare the composition of exaust gases from an internal combustion engine when using pure gasoline and a mixture of traditional fuel containing 2 % by mass of ethanol and butanol as additives. The experiments were conducted on a four-cylinder, four-stroke engine with water cooling in a 2004 Mitsubishi Airtrek car. The composition of the exhaust gases was determined using a Stargas/898 gas analyzer [12–13]

The mixture, consisting of gasoline and biofuel additives at a specified concentration, was prepared by centrifugation at room temperature for 8 hours of a laboratory working day, with short mixing intervals of 10–15 minutes every 2 hours. The mixture containing a 2 % biofuel additive was tested for stability and resistance to phase separation. The study was conducted under the following conditions: fuel temperature – 60 °C, sample volume of gasoline – 300 ml, relative humidity – 50/55 %, and the average laboratory ambient temperature was 22 °C.

The research was conducted in two stages: The sample was prepared as follows: ethanol was added to pure gasoline at a concentration of 2 % by mass, and the stability of the mixture was examined for phase separation at temperatures ranging from 25 °C to 30 °C. The condition of the mixture was visually checked every 2 hours over a period of 10 days. The mixture of gasoline and butanol was studied using the same methodology. The composition of the exhaust gases was monitored for the content of CO, hydrocarbon, CO_2. Mechanical mixing of the mixture took place directly in the fuel pump, and the condition of the injector was visually inspected, with no significant soot deposits observed.

To measure the quantity of exhaust gases using the Stargas/898 gas analyzer, the following methods are employed: When measuring the chemical components of exhaust gases, the environmental conditions should be within the following limits:

Ambient temperature: from –10 °C to 35 °C. Atmospheric pressure: from 91.5 kPa to 102.4 kPa (650–790 mmHg). Preparation for measurements: The visual inspection of the system that reduces toxic emissions from the vehicle is carried out. If the actual equipment provided by the manufacturer is not present, measurements are not performed. Prior to measurement, the engine temperature should not be below 60 °C, and it should be heated to the specified temperature if the working temperature of the oil and coolant does not meet the requirements specified in the vehicle's repair manual [14]. After the engine has been heated, the vehicle is prepared for measurements in the following order: The transmission is set to neutral mode. The vehicle is immobilized using the parking brake and the engine is turned off. Tachometer and engine oil temperature sensor are installed. The gas analyzer probe is inserted into the vehicle's exhaust pipe to a depth of at least 300 mm from the deepest point of the pipe section. To determine the quantity of carbon monoxide and hydrocarbons from vehicles operating with the engine in neutral position, measurements are conducted at minimum (n_min) and increased (n_up) crankshaft rotation speeds as specified by the manufacturer [15].

In the absence of manufacturer-specified data, the following parameters apply:

1-n_min should not exceed the following values:

– For M_1 and N_1 category vehicles: 1100 rpm.
– For other vehicle categories: 900 rpm.

2-n_up is set based on the following criteria:

– For M_1 and N_1 category vehicles without emission control systems: 2500–3500 rpm.
– For M_1 and N_1 category vehicles with emission control systems: 2000–3500 rpm.
– For other vehicle categories, regardless of equipment: 2000–2800 rpm.

Measurement of exhaust gases from gasoline-powered vehicles:

1. The vehicle's transmission is set to neutral.
2. The vehicle is brought to a stop using the brakes.
3. The engine is turned off.
4. The hood of the engine is opened.
5. A tachometer is installed.
6. The gas analyzer probe, for sampling, is inserted into the cross-section of the exhaust pipe up to a depth of 300 mm (or a shorter length for a damaged muffler).
7. The air filter cover is fully opened.
8. Special cables are attached to the battery terminals to measure the engine's revolutions.
9. Probes for temperature and the quantity of exhaust gases are installed on the exhaust pipe.
10. The engine is started, and the crankshaft rotation speed is increased by n revolutions, and the engine continues to operate in this mode for at least 15 seconds.
11. The minimum crankshaft rotation speed is determined, and the quantity of carbon monoxide and hydrocarbons is measured a minimum of 20 seconds.
12. At n number of engine revolutions, the crankshaft rotation speed is determined, and a minimum of 30 seconds is used to measure the quantity of carbon monoxide and hydrocarbons.
13. At the minimum number of engine revolutions, the results obtained are displayed on the instrument screen and printed on paper.

Procedure for measuring the exhaust gases of vehicles equipped with emission control systems: Before commencing measurements, a visual inspection is performed, and the readings of CO, hydrocarbon, and CO_2 are reset on the gas detector. The measurements are carried out in the following order: Start the engine by pressing the control pedal, increase the crankshaft rotation speed to n_up, and let the engine run in this mode for 2–3 minutes. It is worth noting that at an ambient temperature below 0 °C, this should be extended to 4–5 minutes. After the parameters stabilize, the quantity of CO and hydrocarbon is determined. Then, reduce the crankshaft rotation speed to the minimum, n_min, and measure the quantity of carbon monoxide and hydrocarbons again. Measurements at n_min should be conducted no later than 30 seconds after the n_up mode. Before measuring the exhaust gases of vehicles with a built-in three-component emission control system, it is necessary to check this system using the diagnostic indicator installed on the instrument panel.

The exhaust gas measurements were carried out using the Stargas/898 gas analyzer. The technical condition of the vehicles and their engine systems should comply with the requirements of Section 3 of the 4th Addendum to GOST R 41.83, as listed in table 2.

Table 2 – Requirements for the technical condition of vehicles and engine systems

Car systems	Requirements for the technical condition
Exhaust gas system	Completeness (absence of system components is not allowed); tightness (absence of mechanical punctures and through corrosion; there should be no leaks in the connections and elements of the exhaust gas system when the engine is idling, and for vehicles equipped with exhaust gas aftertreatment systems, no leaks are allowed into the atmosphere bypassing the aftertreatment system)
Exhaust gas aftertreatment system and other devices for reducing harmful emissions	Completeness (the absence or non-compliance of elements of the aftertreatment system, fuel vapor recovery system, exhaust gas recirculation system, forced idle speed controller, etc., with the operational documents is not allowed)
Crankcase ventilation system	Completeness; tightness (disconnection of hoses in the engine crankcase ventilation system and leakage of crankcase gases through various imperfections into the atmosphere are not allowed)
Built-in engine diagnostics system	The operation of the diagnostic indicator corresponds to the proper functioning of the engine and its systems (the diagnostic indicator is off when the engine is running)
Fuel system	Completeness (the absence or non-compliance of fuel system components with the operational documents is not allowed); tightness (fuel leakage is not allowed)

The measurements were conducted in the following sequence: 1 – Using pure gasoline with the brand AI-92 without any additives as fuel. 2 – Fuel mixture of gasoline and ethanol. 3 – Fuel mixture of gasoline and butanol.

Problem solution method

The measurement results are recorded in the same order in the table mentioned in table 3 below.

Table 3 – Results of experimental measurements of exhaust gases

Indicators of the results when using pure gasoline without the use of additives				
CO (%)	CO_2 (%)	hydrocarbon (ppm)	O_2 (%)	NO_x (ppm)
0,030	14,14	26	1,49	0,1
Indicators of the results of exhaust gases when using a mixture of gasoline and ethanol				
0,0276	16,2	22,8	1,61	0,094
Indicators of the results of exhaust gases when using a mixture of gasoline and n-butanol				
0,029	15,9	23,5	1,68	0,095

The indicators of the results when comparing oxidant-containing additives are presented in the following table 4.

Table 4 – Result indicators when comparing oxidant-containing additives

Comparison of indicators using pure gasoline and a mixture of gasoline and ethanol				
CO	CO_2	hydrocarbon	O_2	NO
decreased by 8 %	increased by 14,4 %	decreased by 13,2 %	increased by 8,1 %	decreased by 6 %
Comparison of indicators using pure gasoline and a mixture of gasoline and n-butanol				
CO	CO_2	hydrocarbon	O_2	NO
decreased by 3,5 %	increased by 12,4 %	decreased by 9,6 %	increased by 12,8%	decreased by 5 %

After the measurements conducted, it can be concluded that the vehicle on which the measurements were performed complies with the technical and regulatory standards (table 5).

Table 5 – Permissible emission limits for toxic gases into the atmosphere from vehicles running on gasoline

Vehicle emission standard	Categories	Carbon monoxide (CO), volume fraction, %	Hydrocarbons, volume fraction, (ppm)	Nitrogen oxides (NO_x), volume fraction, (ppm)
		Emission limit	Emission limit	Emission limit
Euro-1	M_1 и N_1	3,5	1200	-------------
	M_2, M_3, N_2, N_3	4,5	2500	-------------
Euro-2	M_1 и N_1	1,0	400	-------------
	M_2, M_3, N_2, N_3	1,5	600	-------------
Euro-3	M_1 и N1	0,5	100	70
	M_2, M_3, N_2, N_3	0,7	200	150
Euro-4	M_1 и N_1	0,3	50	40
	M_2, M_3, N_2, N_3	0,5	100	70
Euro-5	M_1 и N_1	0,3	50	30
	M_2, M_3, N_2, N_3	0,5	100	50

*Note:
M_1 – passenger cars with no more than 1+8 seats;
M_2 – passenger cars with more than 1+8 seats, maximum weight up to 5 tons;
M_3 – passenger cars with more than 1+8 seats, maximum weight over 5 tons;
N_1 – goods vehicles, maximum weight up to 3.5 tons;
N_2 – goods vehicles, maximum weight from 3.5 to 12 tons;
N_3 – goods vehicles, maximum weight over 12 tons.

The reduction in CO, HC, and NO emissions can be attributed to the higher oxygen content in the fuel mixture due to oxygen-containing additives such as ethanol and butanol, which promote more complete combustion. This, in turn, leads to an increase in CO_2 emissions due to the complete combustion of carbon monoxide (CO).

It's also worth noting that a range of technical malfunctions in the vehicles themselves can influence the exhaust gases of the vehicles (table 6).

Table 6 – Main Reasons for Non-Compliance with Regulatory Limits for Toxic Exhaust Gas Emissions CO, hydrocarbon, CO_2, O_2

CO	Incorrect carburetor calibration. Dirty or clogged air filter. Defective combustion phase enrichment. Defective acceleration concentration. Ignition spark plug deficiencies. Pressure regulator inadequacy
Hydrocarbon	Ignition leaks. Defects in the reduction valve connections. Defects in spark plugs. Deficiencies in ignition spark plug electrical wires. Incomplete combustion. Lean fuel mixture. Air leaks required for complete combustion during intake. Mechanical defects. Lack of pressure. Leaky valves
CO_2	Exhaust Gas Leaks and Defects
O_2	Exhaust Gas Leaks and Defects. Rich Mixture

Conclusion

1. The article provides an analysis of the use of fuel methanol and ethanol in internal combustion engines of automobiles that meet modern toxicity standards. Based on the conducted research, it has been established that the use of ethanol and butanol as an additive to gasoline fuel in internal combustion engines of cars allows, on the one hand, to significantly reduce emissions of harmful substances, and on the other hand, to reduce the consumption of petroleum fuel:

– when ethanol is added to gasoline, the content of harmful substances in exhaust gases is reduced by 27.2 %.

– when butanol is added to gasoline, the content of harmful substances in exhaust gases is reduced by 18.1 %.

2. Consequently, the use of ethanol and butanol as a hydrocarbon component will make it possible to successfully use cheap low-octane gasoline fractions in internal combustion engines of cars.

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