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DEVELOPMENT OF AUTOMOBILE GASOLINES WITH OXYGEN-CONTAINING FUEL ADDITIVES

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Abstract. The use of oxygenates or oxygen-containing compounds as high-octane components of motor gasoline or as additives to obtain gasoline with other, higher environmental classes is one of the most affordable and modern solutions to the energy and environmental problems of land vehicles.

It is known that the use of one or another type or mixture of oxygen-containing compounds as additives to motor gasoline largely depends on their actual resources in a given economic region or a particular state.

This article presents the results of scientific research on the use of various oxygen-containing compounds as additives to motor gasoline.

This article presents the results of scientific research on the use of various oxygen-containing compounds as additives to motor gasoline. The results obtained allow the use of oxygen-containing compounds, a complex mixture of lower and higher alcohols, as well as ethers, as additives to motor gasoline or base commercial gasoline.

Key words: motor gasolines, oxygen-containing compounds, properties of fuel mixtures.

1. Introduction

Currently, the world's annual demand for various motor gasolines is about 1.2 billion tons, which must meet modern requirements for operational, environmental and economic properties [3].

Oxygenates or oxygen-containing compounds that provide sufficient detonation resistance of motor gasoline and reduce emissions of carbon monoxide and carbon dioxide (carbon dioxide) into the environment are an environmental additive to motor fuels, and they are also significant substances that extend the life of produced motor gasoline [1-4].

An assessment of the use of oxygenates (various alcohols and ethers) as an environmentally friendly component of motor gasoline in general should be characterized by the content of their volume fraction in the composition of gasoline with limited concentrations of sulfur, benzene, olefinic and aromatic hydrocarbons, monomethylaniline, methanol, oxygen and the absence of lead, manganese and gland [5-8].

Carrying out the necessary studies of oxygen-containing fuel additives to motor gasoline under real operating conditions makes it possible to obtain the necessary data for their comparative assessment, and the results obtained are the basis for recommendations for their use.

2. Goal and problem statement

It is known that the establishment of the most important operational and environmental properties of motor gasoline with oxygen-containing fuel additives and their impact on the operation of vehicles are important scientific and practical directions in the energy supply of vehicles.

Modern vehicles are equipped with various modern systems to ensure their environmental friendliness and fuel efficiency. For example, the performance of a catalyst largely depends on the composition of the fuel and the fuel additives or additives used. The gasoline injection fuel supply system is sensitive to the cleaning properties of the fuel, and at low ambient temperatures, the stability of the fuel mixture is of great importance.

Typically, those vehicles that run on petroleum gasoline are switched to be powered by gasoline with oxygen-containing high-octane components, and, therefore, more attention is paid to the difference in the energy and environmental performance of engines running on one type of fuel or another. In this regard, the calculated values of the studied indicators are first preliminarily determined and then compared with the obtained experimental values.

It should be noted that for type approval of a vehicle running on any alternative fuel such as liquefied petroleum gas (LPG) or compressed natural gas (CNG), its rated power output must be between 0.7 and 1 .15 base vehicle engine power output [9-11].

However, many consumers of vehicles running on alternative fuels are interested in maintaining the basic performance of vehicles, regardless of the type of motor fuel used.

In this regard, when using any type of motor fuel, a preliminary assessment of the main indicators of the vehicle is carried out by calculation and, upon obtaining satisfactory results, experimental studies are carried out and further studies are carried out under real operating conditions.

In this regard, the purpose of this research is to establish the maximum possible concentration of oxygen-containing components of motor gasoline with improved properties, subject to constant basic control parameters of the internal combustion engine power and ignition systems.

3. Analysis of publications

Modern motor gasolines are multicomponent energy sources. The quality of produced motor gasoline is ensured by innovative technological processes and compounding with various additives and additives, and oxygen-containing additives are mainly used as anti-knock agents [12-15].

In accordance with the requirements of modern regulatory documents, additives based on metal-containing additives (containing manganese, lead and iron), including lithium isoalkylcarboxylates (lithium-containing compounds), which do not satisfy the environmental safety and reliability of exhaust gas aftertreatment and ignition systems, are excluded from the composition of motor gasoline. increase the tendency of gasoline to form deposits on the intake valves, combustion chamber and exhaust system components [16].

All advanced countries of the world are leaning towards the production of motor gasoline of high environmental class - K5, which should contain benzene - no more than 1.0% vol., sulfur - no more than 10 ppm, aromatic hydrocarbons - no more than 35% vol., olefin hydrocarbons – no more than 14% by mass, oxygen – 2.7% by mass, and no less than 46% by volume is distilled up to 100˚C, and no more than 75% by volume is distilled up to 150°C. Moreover, the requirement for octane number for gasoline of eco-classes K3-K5 has now been removed from the technical regulations [4].

It is known that additives for fuels or other operating materials are chemicals (a mixture of chemicals) added to fuel to improve its operational, environmental and other consumer properties. Some technical literature notes the conventional differences between the concepts of additives (introduced up to 0.5%) and additives (introduced from 0.5% and above) to fuels [18].

Many domestic and foreign standards establish the mass and volume fraction of oxygen for oxygenates (alcohols and ethers) in gasoline, depending on their environmental class. Typically, the recommended concentration of oxygenates in gasoline is 3-15% by volume and is selected so that the oxygen content in the fuel does not exceed 2.7% by weight. However, in Europe, during the transition from Euro-5 to Euro-6 emissions standards, the quality requirements for motor gasoline are somewhat softened; the permissible content of oxygenates increases to 3.7% by weight of oxygen (22% methyl tert-butyl ether or up to 10% ethanol) , the American standard for E85 gasoline allows oxygen content up to 29.5% [17-22].

Many studies have established that the use of oxygenates as an environmentally friendly component of motor gasoline leads to phase instability during watering. This problem can be solved in various ways (using higher stabilizer alcohols or on-board small-sized cavitators or special additives, etc.) or using multifunctional (improving combustion characteristics, detergent and low-temperature properties) oxygen-containing additives of complex composition [19].

Analysis of the results of previously completed research works, including research by the authors of this article, has established that improving the operational, including environmental, properties of motor gasoline through the scientifically based selection of oxygen-containing additives to them is an important scientific direction.

4. Research methods

The main physicochemical and performance indicators of gasolines with and without oxygen-containing additives were determined on the basis of current regulatory and other guidance documents. Motor gasolines with rational concentrations of oxygen-containing additives were also subjected to studies to improve the physical stability (low-temperature properties, tendency to evaporation losses, time of separation and precipitation of the second phase, hygroscopicity, mixing compatibility) of fuel mixtures in accordance with regulatory requirements [20].

During the research, butanol, fusel oil, ethers (methyl acetate, ethyl acetate), etheraldehyde fraction and furfuryl alcohol, which are products of the local petrochemical industry, were used as a stabilizer for gasoline-alcohol mixtures.

5. Research results and discussion

5.1. Calculated results of fuel indicators

It is known that many oxygenates (methanol, ethanol, butanol, etc.) have lower volumetric and mass energy intensity (heat of combustion) than gasoline, however, their thermal performance (heat of combustion of the combustible mixture) and gasoline air-fuel mixtures during combustion differ slightly in that reason, that the distinctive values of the theoretically required amount of air for complete combustion of fuel, the high value of their heat of evaporation helps to improve the filling of the engine cylinders and reduce the thermal stress of parts, which leads to an increase in the completeness of combustion, but at the main load conditions due to a significant depletion of the mixture composition, a decrease in engine power occurs [20].

Motor gasolines of petroleum origin and oxygen-containing additives (alcohols and ethers) have different physical, chemical and thermophysical properties (Table 1), the main values of which were calculated on the basis of guidelines and reference documents [21].

Table 1.

Comparative physico-chemical and thermophysical properties of various fuels

Name	Unit change.	Fuel						
		Gasoline (AI-92)	Methanol	Ethanol	Butanol	MTBE	DME	MMA
Chemical formula	–	C_8H_{17}	CH_3OH	C_2H_5OH	C_4H_9OH	$C_5H_{12}O$	C_2H_6O	CH_3NH_2
Elemental composition: Carbon Hydrogen Oxygen	%	 0,855 0,145 -	 0,375 0,125 0,500	 0,522 0,130 0,348	 0,649 0,135 0,216	 0,682 0,136 0,182	 0,522 0,130 0,348	 0,387 0,161 -

Nitrogen		-	-	-	-	-		0,452
Ratio H/C	-	0,17	0.33	0.25	0,21	0,20	0.25	0.42
Lower heat of combustion	MDj/kg	44,21	19,9	22,2	36	35,2	28,4	35,4
Lower heat of combustion of a combustible mixture at α=1	MDj/kg	2,9	3,1	3,0	3,2	-	-	-
Molecular mass	kg/ kmol	112	32,04	46,08	74,121	88,15	46,07	100,121
Heat of vaporization	kDj/kg	295	1100	840	677	332	410	256
Specific heat capacity	kDj/kg·K	1,4	2,488	2,39	2,34	2,1	2,35	
The theoretically required amount of air for complete combustion of fuel	kg/kg kmol/kg	14,96 0,512	6,52 0,238	9,06 0,31	11,2 0,385	11,85 0,405	9,06 0,31	4,306 0,189
Octane number	RON EON	92 83,5	115 91	118 95	96 78	125 100	- -	280 -
Required concentration to increase the RON by 1 unit.	% mass	-	2,5-2,6	2,9-3,0	-	3,6-3,8	-	0,3

Calculation of the octane number of fuel oxygen-containing mixtures (FOM) consisting of gasoline, alcohols and ethers was carried out according to the formul:

$$\Sigma ОЧ_{ткс} = \Sigma \upsilon_i \cdot ОЧ_i \qquad (1)$$

где υ_i - volume fraction i – component FOM;

$ОЧ_i$ – octane number i – component FOM.

Calculated values of octane numbers FOM -1 (gasoline AI-92 74%, butanol 20%, ethanol 5%, MMA 1%) and FOM -2 (gasoline AI-92 74.5%, butanol 20%, ethanol 5%, MMA 0.5%) respectively, RON of 96.5 and 95.4 were obtained, which were then subjected to motor tests.

5.2. Experimental results of fuel indicators

Experimental studies of base gasoline AI-92 and fuel oxygen-containing mixtures (FOM) consisting of gasoline, alcohols and ethers were carried out to determine their octane numbers and other indicators (Table 2).

Table 2

Main indicators of fuel performance properties

Indicator name	Unit change	Fuel		
		Petrol AI-92	FOM – 1	FOM – 2

Octane number (RON) Calculation Experiment	-	– 92	96,5 97,4	95,4 95,1
Factional composition Distillation start temperature Distillation temperature of 10% fuel Distillation temperature 50% fuel Distillation temperature 90% fuel End of boil	ºC	not less 35 not higher 75 not higher 120 not higher 190 not higher 215	39 51 100 162 192	39 59 103 159 205
Volume fraction of residue in flask	%	not higher 2	1,1	1,1
Remainder and losses	%	not higher 4	4	4
Mass concentration of resins	mg/100 sm^3	not higher 10	5,2	4

As the results of the work performed show, when using lower and higher alcohols together with ethers as additives to gasoline, its motor and other properties are significantly improved.

5.2. Discussion of the results of computational and experimental studies

The use of several lower or lower and higher alcohols together with ethers as additives to motor gasoline makes it possible to improve a number of their performance properties.

At the same time, based on motor gasoline of classes K2 and K3, it is possible to obtain gasoline of eco-classes K4 and K5, using additional production capacities to obtain oxygen-containing additives.

Conclusion

According to the results of the research, it was established that the joint use of various oxygen-containing fuel additives (alcohols, ethers) to motor gasoline will simultaneously improve its detonation, environmental, low-temperature, and detergent properties, and also expand the service life of the products and new production capacities.

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