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CETANE NUMBER ANALYSIS OF SYNTHETIC DIESEL FUEL

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Abstract
Currently, the use of synthetic diesel fuel in road transport, synthesized from various sources (coal, oil shale, natural gas, biomass) is an important direction in meeting the energy and environmental requirements for the operation of modern vehicles. In the process of performing various searches, research and other works to obtain synthetic diesel fuel, it becomes necessary to determine their various properties, for example, cetane number. Experimental determination of this property of diesel fuel is costly, and in this regard, a preliminary calculation of the cetane number of synthesized diesel fuels through the cetane index is important. This article presents the results of scientific research on the calculated determination of the cetane number of synthesized diesel fuels using various technologies.

Keywords: synthetic motor fuel, synthetic diesel fuel, cetane number, cetane index.

Introduction
At present, the use of various alternative environmentally friendly energy sources, including synthetic motor fuels, is the most affordable and expedient solution to the energy and environmental problems of road transport.

In the world, technologies for producing synthetic diesel fuel (SDF) from various raw materials (coal, oil shale, natural gas, biomass) have found the greatest distribution. At present, several high-performance GTL plants operate in the global industry: Mossel Bay (South Africa), Bintulu (Malaysia), Oryx (Qatar), Pearl (Qatar), and Eskravos (Nigeria). A plant for the production of synthetic liquid fuels from natural gas (Gas to Liquids-GTL) was put into operation in Uzbekistan for the production of diesel fuel, aviation kerosene, naphtha and liquefied petroleum gas.

It is known that one of the main performance properties of diesel fuel (DF), which determines the high power, economic and environmental performance of the engine, is the cetane number - the main indicator of the flammability of diesel fuel. It determines the starting of the engine, the rigidity of the working process, fuel consumption and exhaust smoke.

Usually, the determination of the cetane number (CN) of diesel fuel is carried out experimentally - by directly measuring the cetane number by the motor method.

However, due to the fact that this method requires significant costs, in many cases (research work, evaluation of additives to improve the cetane number), a calculation method is used to determine the cetane index (CI) of diesel fuel.

The properties of diesel fuel obtained from oil are somewhat different from the properties of synthetic diesel fuel synthesized from other raw materials. In this regard, the calculation of CI synthetic diesel fuel has its own characteristics.

Purpose and Problem Statement

At present, synthetic diesel fuel from natural gas is produced in the world based on the Fischer-Tropsch technology. At the same time, due to the high-quality requirements of DF, a wide range of research and practical work is being carried out to increase their CN and improve other performance properties of DF. In this case, it always becomes necessary to evaluate the CN or CI of motor fuel.

It is known that the calculation of the cetane index according to existing standards applies to diesel fuel that does not contain additives and establishes a method for determining the cetane index of no more than 60 units.

Since the CN or CI of synthetic diesel fuel is more than 60 units, it is of great scientific and practical interest to be able to calculate the CI of this motor fuel using or improving existing calculation methods.

In this regard, when using synthetic diesel fuel from natural gas, the possibility of applying existing methods for calculating CI and approaches to improve them to obtain more reliable data is being studied.

In the future, by comparing the results of calculated and experimental studies, it is possible to establish the relationship between CI and CN for diesel fuels of various origins.

Literature Revive

Currently, modern energy and environmental problems of vehicles with an internal combustion engine are being solved using various types of environmentally friendly alternative sources, such as natural gas in compressed or liquefied form, liquefied petroleum gas, alcohols, ethers, hydrogen, biofuels, including synthetic motor fuels from various raw materials (coal, oil shale, natural gas, biomass) [1-3].

Moreover, in recent years, the technology for the production of synthetic diesel fuel from natural gas has been dynamically developing in those countries that have sufficient natural resources, including Uzbekistan. A significant amount of work on the determination of the CN of diesel fuels has been carried out by experimental methods, where CN is determined by comparing its combustion characteristics in a test single-cylinder engine of classical design (standard crankcase with pump assembly, cylinder block, heat exchange cooling system, fuel system, injector assembly, electrical control system and exhaust pipe) with the characteristics of mixtures of control fuels with a known cetane number under standard operating conditions. Moreover, the numerical values of the properties of DF obtained from oil and SDF differ significantly from each other [4-8].

It is known that the cetane index is an analytical way to evaluate the CN of diesel fuel and is not an alternative way to express CN. It is an additional tool that is properly applied to limits and is used to estimate the cetane number of diesel fuel when the engine test is not available to directly determine this value or when a sample is available that does not meet the requirements of the engine method or when a large amount of ongoing research work.

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If the cetane number of the fuel has been established earlier, the cetane index can be used to confirm the cetane number of other samples of this fuel, provided that the source of fuel and the method of its production remain unchanged [9-17].

Several methods are currently used to calculate the CI of diesel fuels, for example, using a four-variable equation (density at a temperature of 15℃ and temperatures of 10%, 50% and 90% of the distillation volume), and in accordance with another method using an equation with two variables (density at a temperature of 15 ℃ and a temperature of 50% of the distillation volume) [18-26].

The cetane index of diesel fuel (DF) can also be approximated by a formula that takes into account two parameters - the viscosity of the fuel and the density of the fuel. In addition, there is an equation for calculating the cetane index of oil fractions, which takes into account the relative specific gravity of oil fractions and the average fuel distillation temperature [25–29].

Methods

Today, diesel fuel is the most consumed motor fuel produced by global oil refineries. The volumes of production and consumption of diesel fuel are growing every year. The cetane index DF, along with its other main quality indicators, is regulated by certain requirements and is interconnected with many other properties [30–37].

At the same time, as was noted, most methods for experimental determination of CN or CI of diesel fuels are lengthy and laborious. Considering this, when determining the CN or CI of synthetic DF, it is relevant to use and improve known calculation methods for determining these parameters. Using the method of calculating the CI of diesel fuels using a two-variable equation (density at a temperature of 15 ℃ and a temperature of 50% distillation volume) is the simplest and least time-consuming, allowing you to obtain the most reliable data on the CI of synthetic DF. However, taking into account the fact that this method determines the cetane index no higher than 60 units, the CI nomogram should be improved. At the same time, the data properties of synthetic DF entered for calculating CI should be compared with similar data on DF of petroleum origin [38-44].

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In the process of computational studies, distinctive values of the properties of petroleum diesel fuel will be observed (minimum values of density at 15 °C - 0.835 kg/l and temperature, the fractional composition of 50% vol. - 245 °C) and other properties (Table 1).

Table 1. Comparative performance of various diesel fuels

Indicators	*Unit*	*Standards*		
		O'zDSt 1134-2018	GOST 32511-2013 (EN 590:2009)	EN 15940:2016(GTL)
cetane number	CFR	≥50	≥51	≥70
cetane index	-	-	≥46	≥70
Carbon content	% wt.	-	86.3	85.2
Hydrogen content	% wt.	-	13.6	14.7
Net calorific value	MJ/kg	-	42.9	44.0
Density at 15°C	kg/m³	≤840	820-845	≥765
Viscosity at 40°C	mm²/s	3.0–6.0	2.9	2.0-4.5
Sulfur content	mg/kg	<0.01	<10	ots.
Start boiling point	°C	170	170	200
End boiling point	°C	368	360	310
Boiling temperature				
95% volume	°C	≤360	≤360	≤360
50% volume	°C	≤280	≤280	≤280
Content of polyaromatic hydrocarbons				
Aromatic content	% wt.	≤8.0	<11.0	<0.1
Olefin content	% about.	-	≤1.0	-
Limiting filterability temperature	% about.	-	≤0.1	-
	°C	≤ - 5	– 37	-27
Filterability coefficient	-	-	≤2	-
Conductivity	pS/m	≥100	≥100	≥100
Lubricity (wear scar)	µm	460	460	460

Results

The calculation of cetane index (CI) is calculated according to the equation

$$CI = 454,74 - 1\,641,416\rho + 774,74 - 0,554t + 97,803\,(lgt)^2, \qquad (1)$$

where ρ is the density at 15 °C, g/cm³;

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t - the boiling point of 50% (by volume) of the fraction, taking into account the correction for normal barometric pressure, ℃; *lg* - the decimal logarithm. Determination of cetane index (CI) by nomogram. The calculated CI value from Equation (1) can be checked against a nomogram that has been modified to take into account the CI of synthetic diesel fuel (Figure 1).

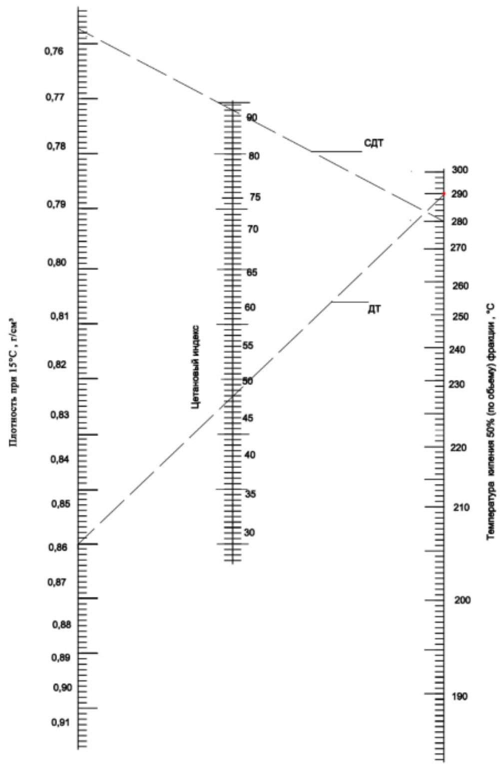

Fig.1. Upgraded nomogram for determining cetane index DF and SDF

Establishing the relationship between cetane number and index of petroleum diesel fuel and synthetic diesel fuel from natural gas. In the course of experimental studies, SDF samples with different
properties obtained by displacement with diesel fuel with a low cetane number.
As a result of the experimental studies, the dependences between the cetane number and the index of petroleum diesel fuel and synthetic diesel fuel from natural gas were obtained (Fig. 2).

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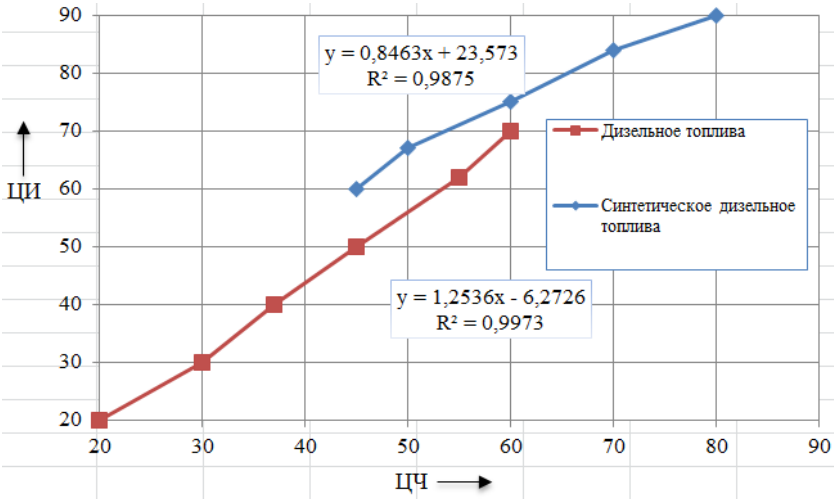

Fig.2. Relationship between cetane number and index of petroleum diesel fuel and synthetic diesel fuel from natural gas

Discussion of the results of computational and experimental studies. Computational and experimental studies to determine the flammability (cetane index) of synthetic diesel fuel have revealed the distinctive features of the relationship between the cetane number and the index of petroleum diesel fuel and synthetic diesel fuel from natural gas. The recommended method for calculating the cetane index of synthetic diesel fuels can be used also when evaluating the flammability of diesel fuels derived from other technologies.

Conclusion

It is advisable to evaluate the flammability of synthetic diesel fuels obtained on the basis of various technologies by calculating their cetane indices. This approach makes it possible to obtain reliable data on the flammability of the studied diesel fuels obtained by various technologies at the lowest cost.

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