MOTOR FUEL SUSTAINABILITY: COMPOSITIONAL STRATEGIES, TECHNOLOGIES, AND ENVIRONMENTAL CRITERIA

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ABSTRACT:

The article is devoted to the study of sustainability and environmental suitability of motor fuel compositions, taking into account aspects of their synthesis, production technology and operation. The main objective of the study is to develop and analyze innovative approaches to the creation of environmentally friendly and efficient types of fuel that help reduce the negative impact on the environment and ensure the sustainable operation of vehicles.

INTRODUCTION. The article is devoted to the study of sustainability and environmental suitability of motor fuel compositions, taking into account aspects of their synthesis, production technology and operation. The main objective of the study is to develop and analyze innovative approaches to the creation of environmentally friendly and efficient types of fuel that help reduce the negative impact on the environment and ensure the sustainable operation of vehicles.

The paper examines various alternative and renewable energy sources such as biodiesel, bioethanol, natural gas and synthetic fuels and their impact on the environmental situation. The study includes an analysis of the processes of synthesis of fuel compositions, an assessment of their technological characteristics and operational properties, as well as a study of sustainability and safety issues when using these fuels in automobile engines.

The research results provide recommendations for optimizing fuel compositions to minimize harmful emissions and improve vehicle efficiency. The results can be used in industry and academia to develop cleaner and more sustainable fuel technologies that help preserve the environment and ensure its sustainable development.

Keywords: motor fuel compositions, gas condensate, isomerate gasoline, alkylate, isoesters, sustainable fuels, environmental impact, synthesis technology, fuel efficiency, eco-friendly fuels, hydrocarbon processing, octane number, catalytic reforming, alternative fuels, low-emission fuel

Introduction. In the modern world, the problems of ecology and sustainable development are becoming increasingly important. The automobile industry plays a significant role in environmental pollution, and the development of environmentally friendly and efficient types of motor fuels is an important area of research. This article discusses aspects of the synthesis, technology and operation of motor fuel compositions in order to improve their environmental sustainability and efficiency.

The technology of obtaining more environmentally friendly and high-quality motor fuel compositions from various fractions of gas condensate and semi-finished products, as well as ashless additives, is a relevant area of research with high scientific and practical interest. The goal of our work is to develop a new motor fuel composition with improved quality characteristics and reduced environmental impact, based on local raw materials of gas condensate, semi-finished products (including reforming and isomerate) and ashless additives. In addition, we seek to determine the operational efficiencies of the developed fuel compositions in order to ensure their applicability and competitiveness in the market.

In order to achieve the stated objectives, a technology was developed for the process of obtaining straight-run gasoline fractions from gas condensate, including natural gasoline of the 45–1200°C grade, light gasoline in the range of 115–1450°C and heavy gasoline from 140 to 2000°C. A study was conducted of the group composition of hydrocarbons in the said gasolines, as well as a study of the isomerization and alkylation processes of butane-butylene fractions of cracking gases of the Republic's oil refineries in order to obtain gasoline alkylate. Gas condensates, which are mixtures of light and mobile hydrocarbons, are highly valuable as feedstock for the production of motor fuel composites and other semi-finished products. By means of precise rectification of the Shurtan gas condensate, it was possible to obtain straight-run gasolines, the study of which made it possible to determine their physicochemical parameters, including a low content of isohydrocarbons .

Table 1. Group composition and properties of Shurtan gas condensate

Fraction, °C	Fraction yield, %	Group composition of hydrocarbons, % by weight			Specific gravity, kg/m3 D_4^{20}	Refractive index n_4^{20}
		methane	naphthenic	aromatic		
65-90	9.3	58.4	21.8	19.8	637.1	1,3615
90-120	26.8	41.5	32.7	28.8	639.1	1,4314
120-	33.1	39.0	20.7	40.3	732.5	1,4327

150						
150-175	16.6	62.0	5.5	32.3	733.8	1,4454
175-200	12.8	52.0	20.0	27.0	758.4	1,4622
200-225	8.7	49.5	21.0	28.5	774,0	1,4525

improved catalysts under selected conditions was developed . Then, the composition and properties of the resulting isomerized gasoline were studied .

Table 2. Comparative characteristics of the composition of gasoline isomerizate

Hydrocarbons	Content, % by weight		
	Reform gasoline	Straight-run gasoline	Isomerisate Petrol
C_2-C_4	1.7-1.9	-	0.80
N-paraffins	7.6	34.5	21.0
Iso-paraffins	10.7	16.5	30.0
Naphthenic	8.2	19.2	12.0
Alkyl naphthenes	7.1	14.8	22.0
Aromatic	28.5	8.6	4.2
Alkylaromatic	18.4	6.4	10.0
Benzene content	11.5	8.6	4.2
Ratio of iso/- n hydrocarbons	32.7/67.3	47.7/52.3	62/38

From the comparative analysis it is evident that the content of isohydrocarbons in isomerate gasoline exceeds the similar indicator in straight-run gasoline.

To obtain alkylate gasoline, cracking gases accumulated at oil refineries were used. The composition of unsaturated hydrocarbons in the gases was propylene (37-40 %), butylene-isobutylene (40-50%) and amylene- isoamylene (10-15%). The resulting component for use in motor fuel compositions was obtained by alkylation on a solid phosphorus catalyst and had the following characteristics: specific gravity - 685 kg/m³, refractive index - 1.3465 at 200°C, initial boiling point - 400°C, final boiling point - 1050°C, saturated vapor pressure - 90600 Pa. When alkylating the butylene fraction with propane, isoheptanes are formed, when propane -propylene alkylation isohexane is formed, and when propane and propylene are trimerized, isonanane is formed . The conversion of gases into alkylate gasoline was estimated by the mass of alkylate gasoline obtained in terms of monoolefins .

Straight-run gasoline and reformate compositions were used as a basis for creating more complex composite gasolines, such as compounds, which have high quality and performance characteristics.

The experiments conducted made it possible to determine the composition of environmentally friendly motor fuel compositions with improved performance properties:

- 40–60% by weight of straight-run gasoline;
- 10–20% by weight of reformate;
- 15–18% by weight of isomerate ;
- 5–10% wt. isoesters (MTBE or ETBE).

Such complex fuel compositions demonstrated an octane number from 80 to 95, which meets the requirements of motor fuel standards.

Isomerate gasoline, which acts as a high-octane component in the compound, is formed in the process of catalytic reforming of the oil fraction or gas condensate. However, in this process the gasoline obtained contains no more than 15% isomerate gasoline, which is insufficient to ensure high performance characteristics of the fuel. In order to achieve optimal engine performance parameters, such as no detonation, sufficient thermal load, minimal carbon deposit formation and aggressive emissions into the atmosphere, it is necessary to develop softer, more environmentally friendly and high-octane fuel components. This includes an increase in the proportion of isomerate gasoline (content of about 60-65 % isohydrocarbons), alkylate gasoline (content of about 40-45% low-molecular unsaturated isohydrocarbons), as well as the use of antiknock additives (isoesters) and other components.

This paper examines the results of isomerization of the gasoline fraction of gas condensate. The isomerization process occurs by the ionic mechanism in the presence of bifunctional catalysts, which are metal oxides on an acid-type carrier. During the reaction, intermediate carbocations are formed . The initiating stage is the cracking of paraffins or their dehydrogenation, resulting in the formation of olefins. Then, interacting with the active centers of the catalyst, acting as proton donors, olefins are converted into carbocations , etc. ion-chain isomerization of normal hydrocarbons continues.

$$\text{I.}\quad RCH_2-CH_2R_1 \rightleftarrows RCH_2^+ + R_1CH_2^+ \overset{-H_2}{\rightleftarrows} R_2C=CH_2 + H^+;$$

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$$\text{II.}\quad RCH=CH_2 + HOMe \rightleftarrows R\overset{+}{C}H-CH_3 + M\overset{-}{O};$$

катализатор карбокатиониты

$$\text{III.}\quad RCH_2-CH_2R_1 \overset{R\overset{+}{C}H-CH_3}{\rightleftarrows} R\overset{+}{C}H-CH_2-R_1 + RCH_2-CH_3;$$

$$\text{IV.}\quad R\overset{+}{C}H-CH_2R_1 + 2R_{11}CH_3 \overset{H^+}{\rightleftarrows} \underset{\displaystyle CH_2R_{11}}{RCH}-CH_2R_1 + R_{11}CH_2^+ + H^+ \ldots$$

It follows from the presented data that carbocations have the ability to split off hydrogen atoms (in the form of hydride ions) from hydrocarbon molecules. Under such conditions, reactions of splitting, di- , tri- and tetramerization , as well as alkylation, occur, which leads to the formation of various isohydrocarbons in the isomerization products . The use of excess hydrogen in the isomerization reaction prevents the deep development of these reactions, which in turn inhibits the formation of resin and promotes the conversion of paraffins into isohydrocarbons .

Based on the above, in the presence of the initial components of domestically produced fuels, as well as borrowing isomerate and obtaining the corresponding additives (alkylate and MTBE) in laboratory conditions, we obtained gasolines, the indicators of which are given in Table 3.

Table 3. Qualitative indicators of gasolines obtained from gas condensate

Indicators	Straight-run gasoline from GC	Gas condensate varieties of gasoline		
Octane number	64	72	93	95
Fractional composition, % mass at °C start of boiling not lower	35	40	40	45
10	76	76	70	-
50	135	130	135	130
90	185	185	185	15

End of boiling Not higher	193	190	195	190
Saturated vapor pressure, mm Hg, not higher	560	600	650	600
Sulfur content % mass not more than	0,015	0,015	0,010	0,010

Gas condensate varieties of AI grade gasolines were distinguished by high quality indicators during tests on motor stands, which is reflected in the data in Table 2. By means of the developed isomerization and alkylation technologies, environmentally friendly components of motor fuels were obtained based on local raw materials - gas condensate. Obtaining such results is typical for many light gas condensates produced at gas fields in the Republic. Consequently, in order to improve the quality of gasoline, it is necessary to carry out their petrochemical conversion into environmentally friendly motor fuel compositions with a high octane number.

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