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Ultrasonic cavitation processing of diesel fuel

The influence of ultrasonic cavitation on diesel fraction of oil in the presence of iron-based catalysts was investigated to identify the chemical transformations of hydrocarbons and clarify possible practical applications of cavitation for oil cracking processes. The change of individual chemical composition of diesel fuel is established at the aspect of increase the amount of light fractions.

Key words: ultrasound cavitation processing, diesel fuel, cracking process, chemical transformations of hydrocarbons, individual chemical composition of diesel fuel.

Currently, the main aim of fuel industry is improvement of the quality and cost-effective use of petroleum fuel, so more stringent requirements are toughened up on this issue [1]. The petroleum industry of foreign countries (USA, Russia, the Ukraine, China, Brazil) benefits from industrial applications of the cavitation as it results in substantial energy savings, reduced fuel costs, and corresponds to a step towards greater energy independence [2].

Cavitation is one of the most important method of purposeful change of physical and chemical characteristics of motor fuel. All physical and chemical characteristics of petroleum fuels depend on its fractional and component composition, so it is possible to manage the properties of fuels by changing their fractional and component composition [3]. Although much experimental work has been done on the cavitation processing of fuels, there is still a demand by the industry for an economical and efficient commercial process [3, 4].

Literary analysis shows that the influence of catalytic cavitation on the chemical transformations of hydrocarbons remains unexplored. It was assumed that the use of catalysts in cavitation processing of crude oil can increase the quantity and quality of light fractions. Thus, in the present work cavitation processing of diesel fuel was investigated in the presence of iron-based catalysts.

Experimental studies were carried out in air atmosphere using the ultrasonic cavitation which allows to conduct the high-intensity processing of small volumes of liquid with a capacity about 600 watts. The intensity of the ultrasonic processing is 250 W/cm^2, the operating frequency is ±22 kHz.

The diesel fraction was obtained by direct distillation of crude oil at temperature range 200–300 ºC. To study the influence of catalytic cavitation processing on chemical transformations of hydrocarbons of diesel fuel the iron-based catalysts (FeS_2 and nanocatalyst Fe_2O_3) were used due to their low cost, high activity, low toxic and eco-friendly performance. Nanocatalyst Fe_2O_3 was prepared according to the procedure [5]. The processing time was 1 min 30 sec, the volume of processed samples was 50 ml.

The fraction composition of the hydrocarbons of diesel fuel was detected by high performance liquid chromatography Agilent Technologies 5975 and identification of compounds was quantified by mass spectral database NIST 98. The products field of diesel fuel processed by ultrasonic cavitation is given in the Table 1.

Table 1

The products field of diesel fuel after ultrasonic cavitation

Compounds	Product yield, %			
	Initial diesel fuel	Diesel fuel after cavitation	Diesel fuel after cavitation in the presence of catalyst FeS_2	Diesel fuel after cavitation in the presence of nanocatalyst Fe_2O_3
Decane	5.87	6.37	8.35	11.63
Undecane	3.63	1.75	3.46	4.06
Dodecane	2.82	1	3.54	2.53
2,6,11-Trimethyldodecane	6.35	2.12	0.84	1.14
Tridecane	10.62	12.99	12.47	11.15
Tetradecane	2.33	1.84	3.8	2.95
Pentadecane	1.91	9.8	1.19	1.01
Nonadecane		7.78	8.54	4.07
1-Hexadecene	1.56	5.45	1.32	4.73
1-Nonadecene	–	5.07	1.62	0.45
1,2,3-Trimethylbenzene	4.15	1.59	1.18	–
4-Ethyl-1,2-dimethylbenzene	2.56	0.42	0.24	3.49
2,3,6-Trimethylnaphthalene	4.3	6.1	3.19	1.91
2,7-Dimethylnaphthalene	3.68	1.75	–	1.65

It is established that the destruction reactions proceed intensively in the cavitation processing of diesel fuel. As a result of these processes in the system «activated» particles were accumulated [6]. Lifetime of activated particles is short, however some of them possess the defined stability and are capable to exist individually for definitive time. The disappearance of radicals proceed in two ways: such as a result of disproportionation and recombination. As a result of repeating stages of growth and chain breakage the number of *n*-alkanes accumulates in the reaction system.

The obtained data illustrate that the cavitation allows to impact on the conversion of organic mass of diesel fuel. The amount of light fractions increases due to destruction of heavier fractions. During the destruction of hydrocarbons of diesel fuel atomic hydrogen obtained by dehydrogenation processes stabilizes the radical products. It is suggested that in the presence of hydrogen donors cavitation processing provides destruction of C–C bonds and increases the content of the light fractions.

The chemical group composition of diesel fuel after cavitation is shown in the Table 2.

Table 2

The chemical group composition of diesel fuel

Name	Initial diesel fuel	Diesel fuel after cavitation processing	Diesel fuel after cavitation in the presence of catalyst FeS_2	Diesel fuel after cavitation in the presence of catalyst Fe_2O_3
Alkanes	38.24	43.65	45.02	47.4
Alkenes	3.99	11.43	4.2	7.25
Naphthenes	2.86	0.78	1.1	4.19
Arenes	14.69	9.86	5.93	7.24

There is a noticeable change of chemical composition of diesel fuel after the cavitation processing which describes with increase of alkanes, alkenes and decrease of arenes. The alkane yield increases from 38.24 % to 43.65 % after cavitation processing without catalysts. In the presence of catalysts FeS_2 and Fe_2O_3 the alkane yields are 45.2 % and 47.4 %, respectively. The arenes yield decreases about twice in the presence of catalyst Fe_2O_3. In the presence of both catalysts the conversion of hydrocarbons is deeper than without them in the cavitation processing of diesel fuel. The decrease of arenes yield can be explained by the activity of catalysts. It is known from literary analysis that oxide and pyrite catalysts accelerate the hydrogenation of polyaromatic hydrocarbons. The high activity of pyrite is connected with participation of H_2S in the hydrogenation process by following scheme [7]:

$$H_2S + R^{\cdot} \rightarrow HS^{\cdot} + RH \quad (1)$$
$$HS^{\cdot} + R_1H \rightarrow H_2S + R_1 \quad (2)$$

R — radical; R_1H — hydrogen donor. It is known that polycyclic aromatic hydrocarbons are more active hydrogen donors in the hydrogenation process, so they can cause of a deep conversion of a feedstock.

It should be noted that the size of particles of catalyst FeS_2 decreases from 140,66 nm to 119,78 nm after cavitation processing of diesel fuel (Fig. 1, 2). It should be pointed out that cavitation processing has effect on specific surface which is proportional to chemical activity of catalyst, so the same catalysts can be used for several times at cavitation processing of fuels, moreover, the activity and selectivity of this catalysts will be improved after each application.

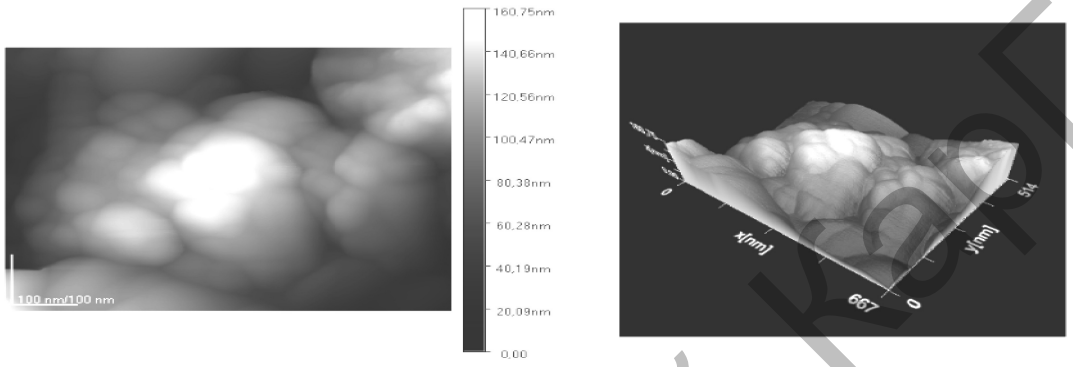

Figure 1. The surface topography of catalyst FeS_2 before the cavitation processing

Figure 2. The surface topography of catalyst FeS_2 after the cavitation processing

Thus, the study of the cavitation processing of diesel fuel shows that the conversion of hydrocarbons proceeds on complex mechanisms including hydrocracking by C–H and C–C bonds with forming low-molecular alkanes and olefins which take part in the secondary processes of hydrogenation, cyclization and alkylation on catalyst surface.

Overall, cavitation processing of diesel fuel can provide destruction processes of hydrocarbons and increase the content of light fractions of fuels. Cavitation processing of petroleum fuels can be used in technological processes of oil-refining industry, particular for obtaining light fractions from heavy oil.

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Дизельді отынның ультрадыбыстық кавитациялық өңдеуі

Мұнай өндіру саласында көмірсутектердің крекинг үрдісі үшін практикалық қолдану мүмкіндігі мен көмірсутектердің химиялық айналымдарды анықтау мақсатымен әр түрлі катализаторлар қатысында мұнайдың дизель отынның фракциясына ультрадыбыстық кавитациялық әсері зерттелген. Дизельді отынның құрамындағы жеңіл қайнайтын фракциялардың артуы байқалған.

Хинтай Су, М.И.Байкенов, А.Б.Татеева, А.Ж.Матаева, Б.Есебаев, А.Мадреимов, Г.Мукышева, Р.С.Бержанова, Б.Ш.Сарсембаев

Ультразвуковая кавитационная обработка дизельного топлива

Исследовано влияние ультразвуковой кавитации на дизельную фракцию нефти в присутствии различных катализаторов с целью выявления химизма превращений углеводородов, а также выяснения возможности практического использования кавитации для крекинга углеводородов в нефтепереработке. Установлено изменение индивидуального состава дизельного топлива в сторону увеличения количества легких фракций в результате кавитационной обработки.

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