DOI: 10.6060/ivkkt.20206306.6181

УДК: 66.021:665.6/.7

ПАРАМЕТРЫ ПРОЦЕССОВ КРИСТАЛЛИЗАЦИИ И РАСТВОРЕНИЯ ТВЕРДЫХ УГЛЕВОДОРОДОВ НЕФТИ

Ю.П. Гуров, Е.О. Землянский, А.Г. Мозырев, С.Г. Агаев

Юрий Петрович Гуров*, Евгений Олегович Землянский, Андрей Геннадьевич Мозырев, Славик Гамид оглы Агаев

Кафедра переработки нефти и газа, Тюменский индустриальный университет, ул. Володарского, 38, Тюмень, Российская Федерация, 625000
E-mail: gurovjp@tyuiu.ru*, zemljanskijeo@tyuiu.ru, mozyrevag@tyuiu.ru, agaevsg@tyuiu.ru

В предлагаемой работе сопоставлены экспериментальные данные по процессам кристаллизации, а также рекристаллизации парафиновых углеводородов различной природы в углеводородных растворителях. Использовались технический парафин Т-1 (ГОСТ 23683-89) с температурой плавления 54 ºС и церезин-80 (ГОСТ 2488-79) с температурой каплепадения 80 ºС. В качестве углеводородных растворителей применялись керосин марки РТ-1 (ГОСТ 10227-86) и депарафинированное масло фракции 420-490 ºС. Приводятся экспериментальные данные по процессам кристаллизации и рекристаллизации твердого парафина с температурой плавления 54 ºС и церезина с температурой каплепадения 80 ºС в керосине и депарафинированном масле. Для исследуемых систем определялись температуры начала кристаллизации (помутнения) t_n (ГОСТ 5066) и растворения t_p. Основное влияние на процессы кристаллизации и рекристаллизации оказывает химическое строение твердых углеводородов нефти. Обнаружено превышение температур растворения tp твердых углеводородов над температурами начала их кристаллизации tn, что объясняется гистерезисными процессами. Разница температур $\Delta t = t_p - t_n$ зависит от природы твердых углеводородов и их содержания в растворителях. Растворители на углеводородной основе оказывают существенное влияние на температуры начала кристаллизации. Растворы парафина в керосине имеют более высокие значения Δt относительно растворов церезина, что объясняется различием в химическом строении твердых углеводородов. С увеличением содержания твердых углеводородов в растворителях из-за различий в скорости диффузии твердых углеводородов Δt уменьшается. Обнаруженные закономерности по кристаллизации и рекристаллизации твердых углеводородов должны учитываться в процессах добычи парафинистых нефтей, их транспортировки и переработки.

Ключевые слова: парафины, твердые углеводороды нефти, процессы кристаллизации и растворения, гистерезис

PARAMETERS CRYSTALLIZATION PROCESSES AND SOLID PETROLEUM HYDROCARBONS DISSOLUTION

U.P. Gurov, E.O. Zemlianskii, A.G. Mozyrv, S.G. Agaev

Yuri P. Gurov*, Evgeny O. Zemlianskii, Andrey G. Mozyrev, Slavik G. Agaev

Department of Oil and Gas Refining, Industrial University of Tyumen, Volodarsky st., 38, Tyumen, 625000, Russia
E-mail: gurovjp@tyuiu.ru*, zemljanskijeo@tyuiu.ru, mozyrevag@tyuiu.ru, agaevsg@tyuiu.ru

In the proposed work, the experimental data on the processes of crystallization and different nature waxy hydrocarbons recrystallization in hydrocarbon solvents have been compared. T-1 technical paraffin (GOST 23683-89) with the melting point of 54 °C and ceresin-80 (GOST 2488-79) with the dropping temperature of 80 °C have been used. PT-1 kerosene (GOST 10227-86) and de-

waxed oil of fraction 420-490 °C have been used as hydrocarbon solvents. The experimental data on crystallization and recrystallization processes of paraffin wax with a melting temperature of 54 ºC and ceresin with a dropping temperature of 80 °C in kerosene and dewaxed oil are presented in this paper. It is shown that chemical structure has the main influence on the processes of crystallization and recrystallization of solid petroleum hydrocarbons. An exceedance of solid hydrocarbons solution temperatures t_p above their cloud points t_n has been observed which is explained by hysteretic processes. The temperature difference $\Delta t = t_p - t_n$ depends on the solid hydrocarbons nature and their content in solvents. Wax solutions in kerosene have higher values Δt relative to ceresin solutions in kerosene, which can be explained by the difference in chemical structure of solid hydrocarbons. With the increase in solid hydrocarbons content in their solvents due to the differences in solid hydrocarbons diffusion rate, Δt decreases. The discovered regularities of solid hydrocarbons crystallization and recrystallization should be taken into account in the processes of paraffin oil production, transportation and processing.

Key words: paraffin wax, solid petroleum hydrocarbons, dissolution and crystallization processes, hysteresis

Для цитирования:
Гуров Ю.П., Землянский Е.О., Мозырев А.Г., Агаев С.Г. Параметры процессов кристаллизации и растворения твердых углеводородов нефти. *Изв. вузов. Химия и хим. технология*. 2020. Т. 63. Вып. 6. С. 90–94

For citation:
Gurov U.P., Zemlianskii E.O., Mozyrv A.G., Agaev S.G. Parameters crystallization processes and solid petroleum hydrocarbons dissolution. *Izv. Vyssh. Uchebn. Zaved. Khim. Khim. Tekhnol.* [Russ. J. Chem. & Chem. Tech.]. 2020. V. 63. N 6. P. 90–94

INTRODUCTION

Solid hydrocarbons crystallization processes and their structure formation complicate waxy oils production, gathering and transportation. Waxing tubing pipes leads to a reduction in the flow rate of wells. Waxing field pipes and pumping equipment leads to their breakdown and mechanical destruction. Pumping of waxy oils is accompanied by waxing trunk pipelines, which leads to an increase in hydraulic resistance in them. For such pipelines, the problems of re-start after their temporary stop arise [1-5].

The processes of low-temperature dewaxing and de-oiling of petroleum products based on waxy hydrocarbons crystallization of wax are also accompanied by many problems, including waxing regenerative crystallizers and difficulties in filtering solid hydrocarbon suspensions on vacuum filters [6, 7]. Solid waxy hydrocarbons determine the performance properties of oils and diesel fuels. The occurrence of C_{14-26} *n*-paraffin hydrocarbons in diesel fuels complicates their operation at low temperatures: the cloud point (the beginning of crystallization), the cold filter plugging point and chilling point increase [8, 9]. The problems of oil production, gathering, transportation and processing and the use of petroleum products determined by the occurrence of solid hydrocarbons in them should be solved taking into account their chemical composition, as well as the processes of their crystallization [4, 10].

EXPERIMENTAL PART

In the proposed work, the experimental data on the processes of crystallization and different nature waxy hydrocarbons recrystallization from hydrocarbon solvents have been compared. T-1 technical paraffin (GOST 23683-89) with the melting point of 54 °C and ceresin-80 (GOST 2488-79) with the dropping temperature of 80 °C have been used. PT-1 kerosene (GOST 10227-86) and de-waxed oil of fraction 420-490 °C have been used as hydrocarbon solvents. The choice of kerosene and de-waxed oil was defined by the fact that they do not contain any *n*-alkane hydrocarbons affecting the crystallization processes of relatively high-melting waxes. The used de-waxed oil and kerosene differ mainly in viscosity: the viscosity of kerosene at 20 °C is 1.25 mm^2/s (own data), the viscosity of the de-waxed oil is 190.1 mm^2/s [11].

The study of the processes of solid hydrocarbons crystallization and recrystallization was carried out on their model systems in kerosene. The solid hydrocarbon content (C_{SH}) in kerosene was 5, 10 and 20%. For the systems under study, the cloud point t_n (GOST 5066) and the solution temperature t_p were defined. There is no commonly accepted method for determining the temperatures of solid hydrocarbons solution from oil dispersed systems.

The method of determining the cloud point was adopted as a basis for the method of determining the solution temperature. Conventional thermostatic test tubes provided with plastic plugs and mechanical stirrers were used. The stirrers excluded the influence of local overheating and supercooling on the processes of crystallization and dissolution of solid hydrocarbons in kerosene. The solid hydrocarbons crystallization processes depend on the rate of their cooling [12] and the content of solid hydrocarbons in the solvent [13]. And the processes of recrystallization depend on the rate of heating. The rate of temperature variation in the tubes was provided with the help of the Lauda RE-107 thermostat and amounted 40, 60 and 120 °C/h. The thermostat provided temperature control with an accuracy of ±0.1 °C. The temperature in the tubes was recorded with thermometers TH-8.

The cloud points and solution temperatures were determined sequentially in several stages. Initially, within 15 min, the model mixtures of solid hydrocarbons in kerosene were subjected to heat treatment at 90 °C, which provided complete dissolution of solid hydrocarbons. Then, the temperature in the thermostat was decreased to 10 °C with a given cooling rate. At clouding of the studied systems, the cloud point $t_{п}$ was recorded visually, for more precise definition of which lighting was used. For a formation of stable reproducible spatial colloidal structures, the model systems were kept in tubes at a temperature of 10 °C for 15 min. Further, to determine the solution temperatures, the temperature in the thermostat was risen to 90 °C with heating rates of 40, 60 or 120 °C/h. The temperature of complete solution of the solid $t_{р}$ was also recorded visually using lighting. The determination of cloud points and solution temperatures was repeated 3-4 times. The average values of $t_{п}$ and $t_{р}$ were calculated according to parallel experiments (Table).

The analysis of the table data shows that the cloud points $t_{п}$ and solution temperatures $t_{р}$ depend on the nature of solid hydrocarbons, their content in kerosene C_{SH} (% wt.), cooling and heating rates, as well as the direction of the process (crystallization and recrystallization).

The discrepancy between the temperatures $t_{п}$ and $t_{р}$ is conveniently assessed by their difference $\Delta t = t_{р} - t_{п}$. In general, the solution temperatures in almost all cases exceed the cloud points: the value of Δt depends on all the factors above. Paraffin T-1 solutions have slightly higher values of Δt relative to ceresin solutions in kerosene. With increasing C_{SH} in kerosene Δt decrease. The maximum values of Δt, ranging from 6.0 to 7.5, are observed in 5% solutions. Δt Also decreases, with rare exception (ceresin content 5% by weight., cooling rate 120 °C/h), with the growth of cooling rates and heating of solid hydrocarbon models in kerosene. The more pronounced effect of crystallization-recrystallization parameters on paraffin models relative to ceresin models in kerosene (see Table) may be due to the difference in the chemical structure of solid hydrocarbons. T-1 paraffin consists mainly of *n*-alkanes, and ceresin – mainly of paraffin-naphthene-aromatic hydrocarbons [6]. Pure paraffin hydrocarbons have a higher degree of crystallinity, which is the cause of the observed differences. A higher melting point (dropping point) of ceresin compared to T-1 paraffin is a secondary factor.

Table

Crystallization and recrystallization indicators of solid hydrocarbons in kerosene

***Таблица.* Показатели кристаллизации и рекристаллизации твердых углеводородов в керосине**

Solid	Solid content in kerosene C_{SH}, % wt.	Cloud points (°C) and solution temperatures of model systems	Rate, °C/h		
			40	60	20
Paraffin	5.0	$t_{п}$	16.0	16.0	18.0
		$t_{р}$	23.5	23.5	24.0
		$t_{р} - t_{п}$	7.5	7.5	6.0
	10.0	$t_{п}$	23.7	23.6	24.5
		$t_{р}$	27.4	27.4	24.5
		$t_{р} - t_{п}$	3.7	3.6	0.0
	20.0	$t_{п}$	30.0	29.5	29.5
		$t_{р}$	32.4	32.4	30.0
		$t_{р} - t_{п}$	2.4	2.9	0.5
Ceresin	5.0	$t_{п}$	50.6	50.6	50.5
		$t_{р}$	57.0	57.0	58.0
		$t_{р} - t_{п}$	6.4	6.4	7.5
	10.0	$t_{п}$	61.3	61.3	62.3
		$t_{р}$	62.0	61.9	62.0
		$t_{р} - t_{п}$	0.7	0.6	-0.3
	20.0	$t_{п}$	64.8	64.8	64.8
		$t_{р}$	65.6	65.7	64.0
		$t_{р} - t_{п}$	0.8	0.9	-0.8

Note: $t_{п}$ – cloud point, $t_{р}$ – solution temperature

Примечание: $t_{п}$ – начало кристаллизации, $t_{р}$ – температура растворения

RESULTS AND DISCUSSIONS

According to the authors, the main reason for the detected regularities in the processes of crystallization and recrystallization of solid oil hydrocarbons is hysteresis processes.

Solid hydrocarbons crystallization processes depend not only on their nature (see table), but also on the nature of the dispersion medium [10]. The effect of the dispersion medium nature has been studied on the example of T-1 paraffin and ceresin in PT-1 kerosene and de-waxed oil (Figure).

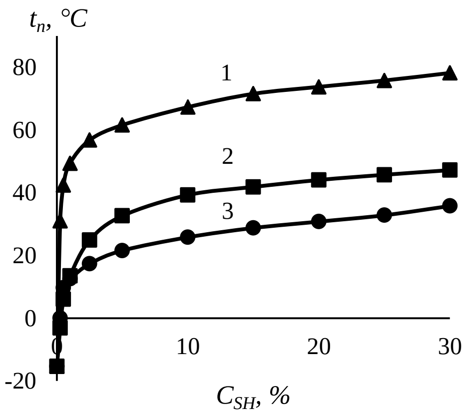

Fig. Relationships of solid hydrocarbons cloud points tп and their content CSH in de-waxed oil and kerosene: 1 – ceresin in oil, 2 – wax in oil, 3 – wax in kerosene

Рис. Соотношения начала кристаллизации твердых углеводородов tп и их содержания в депарафинизированном масле и керосине: 1 – церезин в масле, 2 – воск в масле, 3 – воск в керосине

The relationships of solid hydrocarbons cloud points and their content in solvent $t_п = f(C_{SH})$ are presented. The common character of the paraffin and ceresin crystallization curves does not depend on the dispersion medium. The cloud points of the solid hydrocarbons solutions in oil (see curves 1, 2 in the figure) increase with an increase in melting temperature (dropping) of solid hydrocarbons, i.e. with the transition from paraffin to ceresin.

The cloud points of paraffin solutions (see curves 2, 3 in the figure) increase with an increase in the disperse medium viscosity, i.e. with the transition from paraffin-in-kerosene systems to the paraffin-in-oil systems. In the area of spontaneous (quick) crystallization, (paraffin content in solvent is over 5% of weight) the cloud points of paraffin in oil are 11-13 °C higher than the temperatures of crystallization of paraffin in kerosene.

Thus, it has been shown that the chemical composition and crystal structure of solid oil hydrocarbons have a major effect on the processes of their crystallization and recrystallization. An exceedance of solid hydrocarbons solution temperatures above their cloud points has been observed which is explained by hysteretic processes. The hydrocarbon-based solvents have a significant effect on cloud points. The discovered regularities in solid hydrocarbons crystallization and recrystallization should be taken into account in the processes of paraffin oil production, transportation and processing.

ЛИТЕРАТУРА

1. **Халин А.Н., Агаев С.Г., Землянский Е.О., Мозырев А.Г.** Депрессорные присадки для нефтей Западной Сибири. *Изв. вузов. Нефть и газ.* 2007. № 3. С. 72-77.
2. **Агаев С.Г., Гуров Ю.П., Землянский Е.О.** Фазовые переходы и структурообразование в модельных системах твердых углеводородов и депрессорных присадок. *Нефтепереработка и нефтехимия*. 2004. № 9. С. 37-40.
3. **Кожабеков С.С., Дидух А.Г.** Влияние температуры термообработки и скорости охлаждения на процессы структурообразования и реологическое поведение парафинистой нефти. *Нефтяное хозяйство.* 2008. № 7. С. 118-122.
4. **Барская Е.Е., Ганеева Ю.М., Юсупова Т.Н.** Состав высокомолекулярных парафинов асфальтосмолопарафиновых отложений. Тез. докл. IV Междунар. конф. по интенсификации нефтехимических процессов "Нефтехимия-2005". Нижнекамск: Фэн. 2005. С. 115-117.
5. **Шарифуллин А.В., Хамидуллин Р.Ф., Байбекова Л.Р., Сулейманов А.Т., Шарифуллин В.Н.** Особенности состава и строения нефтяных отложений. *Технологии нефти и газа*. 2006. № 6. С. 241-246.
6. **Баруткин В.В., Георгиев О.В., Байда А.А.** Вязкостное и структурное застывание нефтяных базовых масел. Тез. докл. IV Междунар. научно-практ. конф. «Новые технологии - нефтегазовому региону». Тюмень: ТИУ. 2018. С. 21-23.
7. **Агаев С.Г.** Улучшение низкотемпературных свойств дизельных топлив. Тюмень: ТюмГНГУ. 2009. 143 с.
8. **Агаев С.Г., Гебнев А.Н.** Влияние физико-химических свойств асфальтосмолопарафиновых отложений (АСПО) на парафинизацию скважин. Тез. докл. Всеросс. науч.-

REFERENCES

1. **Khalin A.N., Agaev S.G., Zemlyansky E.O. Mozyrev A.G.** Depressor additives for oils of Western Siberia. *Izv. Vyssh. Uchebn. Zaved. Neft Gaz.* 2007. 2007. N 3. P. 72-77 (in Russian).
2. **Agaev S.G., Gurov Y.P., Zemlyansky E.O.** Phase transitions and structure formation in model systems of solid hydrocarbons and depressants. *Neftepererab. Neftekhim.* 2004. N 9. P. 37-40 (in Russian).
3. **Kozhabekov S.S., Didukh A.G.** The effect of heat treatment temperature and cooling rate on the processes of structure formation and rheological behavior of paraffinic oil. *Neftyan.Khoz.* 2008. N 7. P. 118-122 (in Russian).
4. **Barskaya E.E., Ganeyeva Y.M., Yusupova T.N.** Composition of high molecular weight paraffins of asphalt-resin-paraffin deposits. Tez. dokl. IV Mezhdunar. konf. po intensifikatsii neftekhimicheskikh protsessov "Neftekhimiya-2005". Nizhnekamsk: Fen. 2005. P. 115-117 (in Russian).
5. **Sharifullin A.V., Khamidullin R.F., Baybekova L.R., Suleymanov A.T., Sharifullin V.N.** Features of the composition and structure of oil deposits. *Tekhnol. Neft Gaza.* 2006. N 6. P. 241-246 (in Russian).
6. **Barutkin V.V., Georgiyev O.V., Bayda A.A.** Viscous and structural solidification of petroleum base oils. Tez. dokl. IV Mezhdunar. nauchno-prakt. konf. «Novyye tekhnologii - neftegazovomu regionu». Tyumen: TIU. 2018. P. 21-23 (in Russian).
7. **Agayev S.G.** Improving the low temperature properties of diesel fuels. Monografiya. Tyumen: TyumGNGU. 2009. 143 p. (in Russian).
8. **Agayev S.G., Gebnev A.N.** The influence of physico-chemical properties of asphalt-resin-paraffin deposits on the waxing of wells. Tez. dokl. Vseross. nauch.-tekhn. konf. «Neft i gaz Zapadnoy Sibiri». Tyumen: TIU. 2009. P. 254-257 (in Russian).

техн. конф. «Нефть и газ Западной Сибири». Тюмень: ТИУ. 2009. С. 254-257.

9. **Агаев С.Г., Землянский Е.О., Гебнев А.Н., Халин А.Н.** О механизме действия ингибиторов парафиновых отложений. Тез. докл. Всеросс. науч.-техн. конф. «Нефть и газ Западной Сибири». Тюмень: ТИУ. 2007. С. 219-222.
10. **Агаев С.Г., Землянский Е.О., Мозырев А.Г.** Моделирование процесса образования парафиновых отложений в промысловых условиях. *Изв. вузов. Нефть и газ.* 2006. №5. С. 59-62.
11. **Чащин Е.М., Аллаяров А.Р., Агаев С.Г., Яковлев Н.С.** Улучшение низкотемпературных свойств дизельного топлива утяжеленного фракционного состава. Тез. докл. Междунар. науч.-техн. конф. «Нефть и газ Западной Сибири». Тюмень: ТИУ. 2017. С. 265-267.
12. **Титова Л.Э., Давыдов Д.В., Потапова Д.В., Джужома Ф.О., Гуров Ю.П.** Влияние природы твердых углеводородов на процессы их кристаллизации. Тез. докл. Междунар. науч.-техн. конф. «Энергоснабжение и инновационные технологии в ТЭК». Тюмень: ТИУ. 2016. С. 241-244.
13. **Фарляева А.Ф., Филиппова А.Р., Трапезникова Е.Ф.** Асфальтосмолопарафнистые отложения их свойства, причины и условия образования. *Вестн. молод. уч. УГНТУ.* 2015. № 3. С. 101-106.
14. **Лоскутова Ю.В., Юдина Н.В., Данекер В.А.** Влияние низкочастотного акустического поля и полимерной присадки на структурно-механические параметры нефти. *Изв. вузов. Химия и хим. технология*. 2019. Т. 62. Вып. 1 С. 70-77. DOI: 10.6060/ivkkt.20196201.5766.
15. **Шарифуллин А.В., Шарифуллин В.Н.** Особенности состава и структуры органической части нефтяных отложений. *Нефтепромысл. дело.* 2010. № 9. С. 39-45.
16. **Агаев С.Г., Землянский Е.О., Гребнев А.Н., Гультяев С.В., Яковлев Н.С.** Парафиновые отложения в условиях добычи нефти и депрессорные присадки для их ингибирования. *Журн. приклад. химии.* 2006. Т. 79. Вып. 8. С. 1373-1378. DOI: 10.1134/S1070427206080295.
17. **Агаев С.Г., Гребнев А.Н., Землянский Е.О.** Ингибиторы парафиновых отложений бинарного действия. *Нефтепромысл. дело.* 2008. № 9. С. 46-52.
18. **Башкатова С.Т.** Присадки к дизельным топливам. М.: Химия. 1994. 256 с.
19. **Гришина И.Н.** Физико-химические основы и закономерности синтеза, производства и применения присадок, улучшающих качество дизельных топлив. М.: Нефть и газ. 2007. 230 с.
20. **Таранова Л.В., Гуров Ю.П., Землянский Е.О., Агаев В.Г.** Влияние депрессорных присадок на кристаллизацию твердых углеводородов нефти. *Усп. современ. естествозн.* 2005. № 7. С. 81.
21. **Волкова Г.И., Калинина Т.В., Морозова А.В.** Изменение структурных параметров асфальтенов под влиянием ультразвуковых волн. *Изв. вузов. Химия и хим. технология*. 2019. Т. 62. Вып. 12 С. 71-77. DOI: 10.6060/ivkkt.20196212.6016.

9. **Agayev S.G., Zemlyanskiy E.O., Gebnev A.N., Khalin A.N.** On the mechanism of action of paraffin scale inhibitors. Tez. dokl. Vseross. nauch.-tekhn. konf. «Neft i gaz Zapadnoy Sibiri». Tyumen: TIU. 2007. P. 219-222 (in Russian).
10. **Agayev S.G., Zemlyanskiy E.O., Mozyrev A.G.** Modeling the process of formation of paraffin deposits in commercial conditions. *Izv. Vyssh. Uchebn. Zaved. Neft Gaz.* 2006. N 5. P. 59-62 (in Russian).
11. **Chashchin E.M., Allayarov A.R., Agayev S.G., Yakovlev N.S.** Improving the low-temperature properties of heavy weight fractional diesel fuel. Tez. dokl. Mezhdun. nauch.-tekhn. konf. «Neft i gaz Zapadnoy Sibiri». Tyumen: TIU. 2017. P. 265-267 (in Russian).
12. **Titova L.E., Davydov D.V., Potapova D.V., Dzhuzhoma F.O., Gurov Y.P.** The influence of the nature of solid hydrocarbons on the processes of their crystallization. Tez. dokl. Mezhdun. nauch.-tekhn. konf. «Energosnabzheniye i innovatsionnyye tekhnologii v TEK». Tyumen: TIU. 2016. P. 241-244 (in Russian).
13. **Farlyayeva A.F., Filippova A.R., Trapeznikova E.F.** Resin-asphalt-resin-paraffin deposits, their properties, causes and conditions of formation. *Vestn. Molod. Uch. UGNTU.* 2015. N 3. P. 101-106 (in Russian).
14. **Loskutova Yu.V., Yudina N.V., Daneker V.A.** Influence of low-frequency acoustic field and polymer additive on structural and mechanical properties of oil. *Izv. Vyssh. Uchebn. Zaved. Khim. Khim. Tekhnol. [Russ. J. Chem. & Chem. Tech.].* 2019. V. 62. N 1. P. 70-77 (in Russian). DOI: 10.6060/ivkkt.20196201.5766.
15. **Sharifullin A.V., Sharifullin V.N.** Features of composition and structure of the organic part of oil deposits. *Neftepromysl. Delo (.* 2010. N 9. P. 39-45 (in Russian).
16. **Agaev S.G., Zemlyansky E.O., Grebnev A.N., Gultyaev S.V. and Yakovlev N.S.** Paraffin deposition in crude oil production and depressor additives for paraffin inhibition. *Rus. J. Appl. Chem.* 2006. V. 79. N 8. P. 1360-1364. DOI: 10.1134/S1070427206080295.
17. **Agaev S.G., Grebnev A.N., Zemlyansky E.O.** Wax deposits short stopping agents of binary effect. *Neftepromysl. Delo.* 2008. N 9. P. 46-52 (in Russian).
18. **Bashkatova S.T.** Diesel fuel additives. M: Khimiya. 1994. 256 p. (in Russian).
19. **Grishina I.N.** Physical and chemical bases and regularities of synthesis, production and application of additives improving the quality of diesel fuels. M.: Neft Gaz. 2007. 230 p. (in Russian).
20. **Taranova L.V., Gurov Yu.P., Zemlyansky E.O., Agaev V.G.** The effect of depressant additives on the crystallization of solid petroleum hydrocarbons. *Usp. Sovremen. Estestvozn.* 2005. N 7. P. 81 (in Russian).
21. **Volkova G.I., Kalinina T.V., Morozova A.V.** Change in structural parameters of asphalten under influence of ultrasonic waves. *Izv. Vyssh. Uchebn. Zaved. Khim. Khim. Tekhnol. [Russ. J. Chem. & Chem. Tech.].* 2019. V. 62. N. 12. P. 71-77 (in Russian). DOI: 10.6060/ivkkt.20196212.6016.

Поступила в редакцию 12.12.2019
Принята к опубликованию 23.04.2020

Received 12.12.2019
Accepted 23.04.2020