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STUDY OF THE COMBINED EFFECT OF MAGNETIC FIELD AND THE ADDITION OF NEW COMPOSITION ON THE RHEOLOGICAL PARAMETERS OF HIGH PARAFFIN OIL

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The article is dedicated to the study of separate and joint impact of the magnetic field and the addition of newly prepared composition on the rheological properties of high-paraffin emulsion oil. The new composition has been prepared in a 1:1 ratio of Difron-4201 to BAF-1 reagents under laboratory conditions. The sample taken from well number 208 of the SOCAR oil field has been used as high paraffin oil. Separate and joint impact of the magnetic field and composition on the freezing temperature, effective viscosity and amount of asphaltene-resin-paraffin deposits of high-paraffin oil has been studied. It has been determined that the joint impact of the magnetic field and the addition of composition on all three parameters is more effective that the use of a separate impact. Thus, the separate action of magnetic field and composition resulted in reducing the oil freezing temperature from $+17^0$C to $+4^0$C and $+2^0$C, respectively, while the freezing temperature of oil drops to -2^0C under the joint impact. The effective viscosity of oil under the impact of the magnetic field is 0.66 Pa·s; it is 0.44 Pa·s under the impact of the addition of composition; and it is equal to 0.003 Pa·s under the joint impact. The separate and combined impact of the magnetic field and the composition addition on the amount of paraffin deposits have been studied by «coldfinger test» method. It has been determined that the effect of the magnetic field on paraffin deposits accumulated on the surface of the coldfinger test is 52%, the effect of the composition addition is 74%, and the effect of the combined impact is 90%.

Keywords: magnetic field, composition, coldfinger test, high paraffin oil, effective viscosity, freezing temperature.

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Introduction

Currently, the produced oils are very diverse in terms of their physicochemical properties, such as viscosity, amount of asphaltenes, resin and paraffins. Therefore, oils are rheologically different and have different freezing temperature [1–4].

The main objective in oil extraction and oil refining processes is to develop technological processes that will reduce energy loss and prevent additional losses of hydrocarbon raw materials. Oils with anomalous physicochemical properties involve difficulties in the solution of these problems [5,6]. In this regard, studying the scientific basis of improving the physicochemical and rheological properties of anomalous oils with high paraffin and high freezing temperature is of great importance. It is important to create conditions for the economically efficient pipeline transportation of oil and its scientific and technological efficient transportation through pipelines. The proper researches enable the safe transportation of oil through pipelines [7–10].

Based on the above-mentioned works, one can conclude that the studies on the impact of high paraffin oils on oil characteristics and the improvement of their rheological properties to successfully carry out the transportation process have not lost their relevance. Facilitating the transportation of high viscosity oils, reducing viscosity and increasing the transmission capacity of oil pipelines are the important issues that are constantly in the focus of attention [11,12].

In order to improve the transport properties of high-paraffin oils, polymeric substances-additives are widely used, which prevent the formation of a paraffin space crystal lattice in the oil and, as a result, lower the freezing temperature. Currently, there is no general methodology for selecting the optimal additives for any non-Newtonian oil. Since some of the additives lower the freezing temperature, some lower the static viscosity, and some lower the dynamic viscosity, it is impossible to determine which of them is better. The selection of the additive and adjustment of its concentration are conducted experimentally [13–15].

Recently, the application of the magnetic field jointly with other methods of impact has given effective results. The application of the magnetic field partially compensates for the role of chemical reagents, which are expensive and rarely found. Thus, it is possible to obtain the effect of a solid solution by magnetizing solutions of low-concentrated and expensive reagents. It should be noted that there are various scientific-research and mining-testing works on increasing the effect of various chemical reagents via the impact of the magnetic field [16–19].

In this study, a new composition was prepared, which reduces the consumption of expensive inhibitors used against paraffin deposition and provides long-term protection of equipment and the downhole environment from asphaltene-resin-paraffin deposition (ARPD). We present here the results of our study on the separate and joint impact of magnetic field and the addition of new composition on some rheological properties of high paraffin oil.

Experimental

Physicochemical parameters of the oil sample taken from well number 208 of SOCAR oil field on May 28, 2022 are summarized in Table 1.

Table 1

Physicochemical properties of high-paraffin oil

Property	Value	Testing method
Paraffin content	15.1%	SS 11851-85
Asphaltene content	6.3%	SS 11851-85
Resin content	11.9%	SS 11851-85
Freezing temperature	+17^{0}C	SS 20287-91
Amount of water	52	–

As can be seen from Table 1, the oil sample taken for research belongs to the group of high-paraffin oils and is characterized by a high amount of paraffin hydrocarbons.

The freezing temperature of oil was determined according to the method of RD 39-3-812-82. Determining the amount of paraffin in the oil was then carried out by the Engler-Glade method and adsorption in a Soxhlet apparatus with freezing at -20^0C. In addition, the amount of silica-gel resin and asphaltenes was determined according to ref. [20].

«Coldfinger test» method is used for the evaluation of the effectiveness of depressor additives and determination of the optimal consumption rate. This method was used to study the formation process of ARPD in high paraffin oil without reagents and with the presence of reagents [20]. This method is based on the deposition of asphaltene-resin-paraffin deposits from oil moving on a cold metal surface. In the experiments, the mass of oil deposits accumulated on the surface of «coldfinger test» at the temperatures of 0, 5, 10, 15, 20, and 25^{0}C was determined by having been weighed on an analytical balance. The mass share of asphaltene component in the oil deposit was determined through the separation of asphaltenes by Golden's «cold» method, and resin substances were determined by the chromatographic (column adsorption) method. The new composition was prepared by mixing of Difron-4201 and BAF-1 reagents at the ratio of 1:1; its optimal consumption rate during the study was 700 g/t. Viscometric researches were carried out using a «Reotest-2» rotary viscometer. Depressor additive of «Difron-4201» is produced by enterprise «EKOC» (Russian Federation). «BAF-1» reagent is produced on the basis of local raw materials of Azerbaijan.

In order to implement the effect of the magnetic field, a magnetic device was used, which was attached to a cold grid, connected to a constant current source and had a power of 77812.0 A/m.

Results and discussion

The effectiveness of the composition prepared under laboratory conditions was studied on the emulsion oil sample taken from the well number 208 of the field on May 28, 2022.

Separate and joint impact of the magnetic field and the addition of new composition on asphaltene-resin-paraffin deposits in high-paraffin oil was determined by using «coldfinger test» method. The results obtained from the experiment are given in Tables 2–4.

As follows from the obtained results, an increase in both the temperature and the composition concentration leads to a decrease in the amount of oil deposits accumulated on the surface. In all three series

Table 2

Impact of magnetic field on paraffin deposition

Temperature, ^{0}C	The amount of paraffin in the oil, g	The amount of paraffin after the impact of the magnetic field (30 min), g	The effect of the magnetic field, %
0	16.60	13.28	20
5	14.30	10.72	25
10	10.20	6.43	37
15	7.40	4.29	42
20	2.10	1.10	48
25	1.30	0.62	52

Table 3

Impact of the addition of composition on paraffin deposition

Temperature, ^{0}C	The amount of paraffin in the oil, g	The amount of paraffin after the impact of the composition, g	The effect of the addition of composition, %
0	16.60	10.79	35
5	14.30	8.29	42
10	10.20	4.69	54
15	7.40	2.59	65
20	2.10	0.63	70
25	1.30	0.34	74

Table 4

Joint impact of magnetic field and the addition of composition on paraffin deposition

Temperature, ^{0}C	The amount of paraffin in the oil, g	The amount of paraffin after the joint impact of the composition addition and magnetic field, g	The effect of the composition addition and magnetic field, %
0	16.60	8.96	46
5	14.30	6.86	52
10	10.20	3.26	68
15	7.40	1.92	74
20	2.10	0.38	82
25	1.30	0.13	90

of experiments (Tables 2–4), the highest effect was observed at 25^{0}C, and it was 52%, 74% and 90% for the separate action of magnetic field, separate action of the composition addition and their joint effect, respectively. Thus, the joint combination of the magnetic field and composition addition provides the higher effect against paraffin deposition.

Separate and joint impacts of the magnetic field and the addition of new composition on the freezing temperature of high-paraffin oil were studied at the composition consumption rate of 200, 300, 400, 500, 600 and 700 g/t. The effect of the magnetic field was studied for 5, 10, 15, 20, 25 and 30 minutes. In the case of the joint impact, the effect of the magnetic field at each concentration of the composition was studied for 30 minutes. The results obtained during these series of experiments are given in Figs. 1 and 2.

As is seen from Fig. 1 (curve 2), the freezing temperature of high-paraffin oil decreases consistently as the concentration of the composition increases. Thus, it was determined that the optimal concentration of the new composition is 700 g/t. The freezing temperature of the studied oil sample decreases when the duration of the action of magnetic field increases (Fig. 1, curve 1). During the joint impact of the composition addition and magnetic field, the freezing temperature of high paraffin oil decreases from +17^{0}C to 10, 7, 2, –2 and –5^{0}C at the concentrations of the composition of 200, 300, 400, 500, 600 and 700 g/t, respectively. The conducted experiment once again suggests that the joint impact is more effective.

Separate and joint impact of the magnetic field (within 30 minutes) and newly prepared composition on the effective viscosity of high-paraffin oil were studied under laboratory conditions (Table 5).

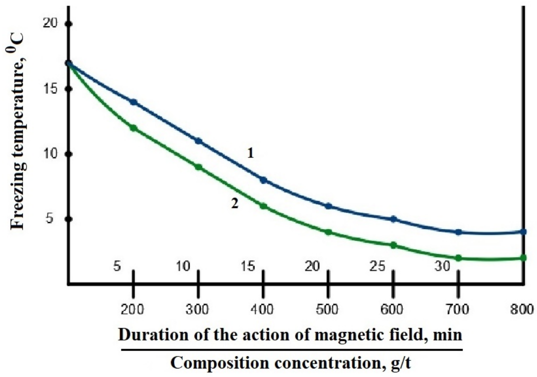

Fig. 1. Impact of the magnetic field (1) and composition concentration (2) on the freezing temperature of high paraffin oil

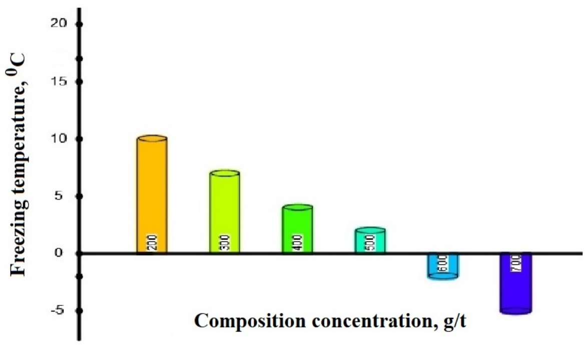

Fig. 2. Joint impact of the magnetic field (30 min) and composition concentration on the freezing temperature of high paraffin oil

Table 5

Impact of the magnetic field and composition addition on the effective viscosity of high paraffin oil at different temperatures

Composition concentration/time	Oil temperature, ^{0}C	Effective viscosity, Pa·s
–/–	5	15.8
–/–	10	9.73
–/–	15	6.06
–/–	20	2.37
–/–	25	1.78
Impact of the magnetic field		
–/30 min	5	8.01
–/30 min	10	5.1
–/30 min	15	3.5
–/30 min	20	1.03
–/30 min	25	0.66
Impact of the composition concentration		
300 q/t/–	5	5.38
400 q/t/–	10	3.38
500 q/t/–	15	2.02
600 q/t/–	20	0.98
700 q/t/–	25	0.44
Joint impact of the magnetic field and composition addition		
300 q/t/30 min	5	0.2
400 q/t/30 min	10	0.01
500 q/t/30 min	15	0.003
600 q/t/30 min	20	0.008
700 q/t/30 min	25	0.003

As is seen from Table 5, the increase in temperature from 5^{0}C to 25^{0}C without external impact reduces the viscosity of oil from 15.8 to 1.78 Pa·s, respectively. Under the impact of the magnetic field for 30 minutes, the viscosity decreases from 8.01 to 0.66 Pa·s in the specified temperature range. The viscosity decreases from 5.38 to 0.474 Pa·s at the specified temperatures in the range of 300–700 g/t of the composition concentration. The viscosity decreases from 0.2 to 0.003 Pa·s due to both the impact of the magnetic field (30 minutes) and joint impact of the composition (in the concentration range of 300–700 g/t). Thus, the results of experiments show that the viscosity is reduced by 88.7%, 91.7%, and 98.5% under the action of magnetic field, the composition addition, their joint impact, respectively. These data show once again that the joint impact of two factors under study is more effective in terms of decreasing the viscosity of the high paraffin oil.

The mechanism of effect of the magnetic field against the formation of deposits in high-paraffin oils can be explained in the following two directions:

1. Although highly paraffinic oils belong to dielectric liquids, they form a colloidal system in general. Most of the dispersed phases in their composition have a dipole moment. In this regard, the influence of the magnetic field causes a decrease in the amount of silica gel resins and asphaltenes in oil deposits by changing the group composition. The reason for the decrease in the amount of asphaltenes in paraffin sediments can be explained by the increase in its dispersibility under the influence of the magnetic field and, as a result, the increase in sedimentation stability in the dispersed medium.

2. The effect of the magnetic field is directly based on asphaltenes, which cause the formation of oil deposits and are the most important component of formation, because asphaltenes play a key role in the structure of oil deposits. Metals contained in oil are also reflected in the structure of asphaltenes. In this regard, the influence of the magnetic field in the oil colloidal system is more noticeable in asphaltenes compared to other components. The magnetic field changes the directions of the asphaltenes and prevents sediment formation. This, in turn, leads to a decrease in the viscosity and freezing point of oil.

Achieving a high effect during the joint action of a magnetic field and a chemical reagent can be explained based on the principles of synergism.

Conclusions

1. The effect of the magnetic field, the addition of new composition and the joint effect of the magnetic field and composition on the rheological parameters of high paraffin oil were studied under laboratory conditions and their optimal values were determined.

2. It was shown that the highest effect against paraffin deposition in oil determined by the «coldfinger test» method was observed under the combined action of these two factors. The protective effect was 90%.

3. It was determined that the minimum value of the viscosity was about 0.003 Pa·s under the joint impact of the magnetic field and composition addition.

4. The results obtained can be used to improve the transportation of high-paraffin oils at low temperatures in the oil industry.

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ДОСЛІДЖЕННЯ СПІЛЬНОГО ВПЛИВУ МАГНІТНОГО ПОЛЯ І ДОБАВКИ НОВОЇ КОМПОЗИЦІЇ НА РЕОЛОГІЧНІ ПАРАМЕТРИ ВИСОКОПАРАФІНІСТОЇ НАФТИ

Гусейн Р. Гурбанов, Айсель В. Гасімзаде

Стаття присвячена вивченню роздільного та спільного впливу магнітного поля та додавання нової композиції на реологічні властивості високопарафіністої емульсійної нафти. Нова композиція була виготовлені у співвідношенні 1:1 реактивів Дифрон-4201 і БАФ-1 в лабораторних умовах. Проба, відібрана зі свердловини № 208 нафтового родовища SOCAR, була використана як високопарафіниста нафта. Досліджено роздільний і сумісний вплив магнітного поля і добавки композиції на температуру замерзання, ефективну в'язкість і кількість асфальтеново-смолопарафінових відкладень високопарафінистої нафти. Встановлено, що спільний вплив магнітного поля і додавання композиції на всі три параметри є більш ефективним, ніж окремий вплив одного фактора впливу. Так, при роздільній дії магнітного поля і додавання композиції температура замерзання нафти знижувалася з +17^{0}C до +4^{0}C і +2^{0}C відповідно, тоді як при спільному впливі температура замерзання нафти падає до –2^{0}C. Ефективна в'язкість нафти під дією магнітного поля становить 0,66 Па·с; під дією складу вона становить 0,44 Па·с; і дорівнює 0,003 Па·с при спільній дії обох чинників. Досліджено окремий вплив магнітного поля і додавання композиції, а також комбінований вплив магнітного поля і композиції на кількість парафінових відкладень методом «холодного пальця». Встановлено, що вплив магнітного поля на парафінові відкладення, накопичені у тесті на поверхні «холодного пальця», становить 52%, ефект впливу композиції – 74%, а ефект комбінованого впливу – 90%.

Ключові слова: магнітне поле; композиція; тест «холодного пальця»; нафта з високим вмістом парафіну; ефективна в'язкість; температура замерзання.

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The article is dedicated to the study of separate and joint impact of the magnetic field and the addition of newly prepared composition on the rheological properties of high-paraffin emulsion oil. The new composition has been prepared in a 1:1 ratio of Difron-4201 to BAF-1 reagents under laboratory conditions. The sample taken from well number 208 of the SOCAR oil field has been used as high paraffin oil. Separate and joint impact of the magnetic field and composition on the freezing temperature, effective viscosity and amount of asphaltene-resin-paraffin deposits of high-paraffin oil has been studied. It has been determined that the joint impact of the magnetic field and the addition of composition on all three parameters is more effective that the use of a separate impact. Thus, the separate action of magnetic field and composition resulted in reducing the oil freezing temperature from +17^{0}C to +4^{0}C and +2^{0}C, respectively, while the freezing temperature of oil drops to –2^{0}C under the joint impact. The effective viscosity of oil under the impact of the magnetic field is 0.66 Pa·s; it is 0.44 Pa·s under the impact of the addition of composition; and it is equal to 0.003 Pa·s under the joint impact. The separate and combined impact of the magnetic field and the composition addition on the amount of paraffin deposits have been studied by «coldfinger test» method. It has been determined that the effect of the magnetic field on paraffin deposits accumulated on the surface of the coldfinger test is 52%, the effect of the composition addition is 74%, and the effect of the combined impact is 90%.

Keywords: magnetic field; composition; coldfinger test; high paraffin oil; effective viscosity; freezing temperature.

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