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DEVELOPMENT OF A NEW TECHNOLOGY FOR THE FIGHT AGAINST WAX DEPOSITS

Abdulaga Gurbanov
Department of Transportation and Storage of Oil and Gas[1]

Ijabika Sardarova
Department of Electronics and Automation[1]

***Javida Damirova*✉**
Department of Electronics and Automation[1]
cavida.damirova@asoiu.edu.az

Zarifa Mahmudova
Department of Electronics and Automation[1]

[1]Azerbaijan State Oil and Industry University
27 Azadliq str., Baku, Azerbaijan, AZ1010

✉**Corresponding author**

Abstract

One of the most serious complications in the production, transport and treatment of oil is asphaltene-resin-paraffin deposits. Their formation in underground well equipment, as well as in flow lines, collection system pipelines increase the cost of oil production. There are no sufficiently effective reagents to solve these problems. The results of implementation in many other wells testify to the high efficiency of the new reagent. The effect of reagents on the rheological properties of oil was also studied. Sangachal Deniz oil was used as a crude oil sample. We have developed multicomponent and multifunctional reagents M-R, P-R. In addition, due to paraffin formations in the tubing, they had to change 50–60 pipes for new ones every month. As a result of the introduction of M-R reagents, no paraffin deposits were found in the tubing for almost a year The effect of these reagents on the pour point of oils, dispersion, dissolution, and paraffin deposition has been studied. The use of the new reagent was tested at the mines of the oil and gas production department (OGPD) «28 May». The results of implementation in many other wells testify to the high efficiency of the new reagent. The effect of reagents on the rheological properties of oil was also studied. Sangachal Deniz oil was used as a crude oil sample.

The proposed three-parameter Herschel-Bulkley model can be used to assess the rheological parameters of oils during their transportation. This layer, of course, cannot thicken indefinitely. Highly effective multicomponent composite compositions were developed to combat complications in the production of high-asphaltene-resin-paraffin oils. As can be seen from, during the reagent dosing period, there were no particular changes in the well performance. Treatment with hot oil on certain days was, as it were, of a preventive nature, since no changes were observed in the well parameters before and after heat treatment. When a certain layer thickness is formed in the tubing, the linear velocity of oil increases and begins to wash it away.

Keywords: paraffin deposits, reagents, rheology, viscosity, pour point, tubing, oil, asphaltene, formations, parameter.

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1. Introduction

The formation of asphaltene-resin-paraffin deposits (ARPD) in underground wells, as well as in flow lines, pipelines and other oil gathering systems, is one of the main factors that increase the cost of oil production [1, 2]. The consequences of complications caused by AFS are mainly premature failure of downhole equipment, reduction of overhaul and cleanout periods of well operation, oil losses associated with well downtime, deterioration of technical and economic indicators of well operation. In recent years, Azneft has been using new technologies to combat paraffin deposits:

1. Chemical methods.
2. Scrapers (paus-2).

SNPKh-2005 is mainly used as a chemical reagent, the volume of which is quite large in compressor wells. However, its use in practice was not so effective, although very good results were obtained in laboratory conditions. The advantage of using a reagent is that it is relatively easier to clean pipes from paraffin deposits at a repair base. There are also a number of problems with padus. A characteristic of them is twisting and wire breaks. In wells with high flow pulsation, descent is difficult or even impossible. In our opinion, another problem is associated with the deposition of the purified paraffin solid phase in oil pipelines. On the «Neft Dashlari» area in flow lines and underwater pipelines, where the temperature is 4–10 °C during the cold season, the deposition of pieces of the solid phase of paraffin is inevitable. In the future, this may lead to the formation of paraffin plugs.

Mixing of various oils with each other, as well as with formation water, in the exploitation of offshore oil and gas fields leads to repeated complications in most offshore fields during the transportation process. For this reason, there is a great need to study the optimal parameters of oils in the process of storage and transportation of produced well products and make certain adjustments to the storage and transportation system from a technical and technological point of view based on this research. Operation in the same deposits and the joint transportation of well products to the shore are considered the most important process in the exploitation of sea deposits. Since it is not economically efficient to build underwater pipelines separately for each well, investigating the impact of mixing different well oils separately extracted from seabeds on their optimal parameters is differentiated by its relevance. It should be taken into account that the formation of emulsions and their stability depend greatly on the physical-chemical properties of oil, the amount of heavy components (paraffin, resin, asphaltene, etc.) in its composition, the rate of movement and temperature of water-oil mixture in the pipe.

It is not an exception to have multi-phase heterogeneous systems in the pipelines where well products are stored and transported. In this regard, the formation of complex emulsions during the joint transportation of oil and water through the pipeline, the impact of the increase in the percentage of dilution of the product on the rheological properties of oil emulsions, the selection and specification of a generalized model for their movement are of special scientific and practical importance.

Oil fields which are at the final stage of development are characterized by a significant decrease in oil reserves and oil formations being flooded. The application of methods for intensifying extraction and increasing oil recovery from oil reservoirs leads to a further increase in the water cut of oils, a change in the composition of natural stabilizers of water-oil emulsions and, as a result, an increase in the aggregative stability of water-oil emulsions.

As a result of laboratory research of water-oil emulsions of Sangachal Deniz and «28 May» Oil and Gas Extraction Department, it was found that the main reasons for the increase in the stability of water-oil emulsions of stone oil field are the side effects of technological processes of intensifying oil extraction using chemical reagents.

As a result of the use of chemical reagents, finely dispersed and aggregately stable emulsions are formed, which are introduced to the oil refining unit. The high stability of emulsions is due to the high content of surface-active substances (SAS), mechanical impurities in the form of sand, bound formation water in a finely dispersed state, and stable foaming in a large volume of well production. Water-oil emulsions of Sangachal Deniz and «28 May» Oil and Gas Extraction Department are also stabilized by natural stabilizers – resins and paraffins.

2. Materials and methods

It is urgent to develop new multifunctional reagents to eliminate the problems arising during the production and transportation of tarry oils. Therefore, the development of new multi-functional and multi-component reagents has been identified through experimental methods and it is important to check them in combating against resins. In order to carry out these works, it is necessary to investigate the preparation and testing of reagents of better quality and different from conventional reagents. The likelihood of complications is also explained by the fact that paraffin, removed by a scraper from the wall of tubing, cannot dissolve in oil due to the lack of heating. On the other hand, the paraffin inhibitor SNPKh-2005 does not have dissolving and dispersing properties. Such types of reagents, such as SNPCH-3740, were not of particular interest from an industrial point of view [3–5]. The assessment of the quality of reagents in laboratory conditions only by their indicators against paraffin deposits from a practical point of view needs to be clarified. The effectiveness of the SNPKh-2005 and padus in preventing paraffin deposits, apparently, did not satisfy the fishermen. Therefore, they began to implement them together. Since the cost of each operation separately is quite high, it is not known whether this is justified from an economic point of view.

As a result of increasing the aggregative stability of water-oil emulsions at the oil refining unit, the process of oil dehydration is disturbed and the quality of the oil being prepared is deteriorated.

In order to improve the efficiency of oil preparation process, composite demulsifiers were developed under industrial brands M-R and P-R. Laboratory experiments of demulsifying efficiency of demulsifiers showed the best results of the composition of M-R and P-R in comparison with the base reagent. When developing oil refining process, it was found that the developed composition of M-R and P-R provides both the best dynamics of water separation and the best depth of oil dehydration due to the presence of the synergy of components action that make up the developed composition. The value of the residual water content of the composite demulsifiers M-R and P-R is somewhat lower compared to the base reagents.

Thus, according to the results of laboratory research of demulsifiers M-R and P-R, which has the best demulsifying efficiency in the destruction of water-oil emulsions of «Sangachal Deniz» and «28 May» oil field, was recommended for pilot testing during the storage and transportation of oils.

3. Results and discussion

In order to prevent the formation of paraffin deposits in oilfield equipment, their removal, as well as to improve transportation in underwater oil pipelines, highly inhibited multifunctional chemicals, conventionally named M-R and P-R, [6–8] have been developed for their industrial production.

The composite compositions of these reagents are a mixture of various aromatic hydrocarbons with the addition of a surfactant substitute, dispersants and modifiers, which, due to the synergistic effect of the mixture of reagents, give a positive result. Evaluation of the effectiveness of reagents against paraffin deposits was carried out on a specially made unit simulating a cold cylinder. Oil from wells on «28 May» was used as a sample of crude oil: asphaltenes – 1.8, resin – 4 and paraffin – 12 % (t = 12 °C); «Sangachal Deniz»: asphaltenes – 1.08, resin – 4.4 and paraffin – 16 % (t = 12 °C). The conducted experiments showed (**Fig. 1**) that the addition of M-R and P-R reagents to the oil of the «28 May» area significantly reduces the complication of paraffin.

At the same time, the amount of paraffin deposits affects the content of reagents in oil. The influence of the M-R and P-R reagents on the effectiveness against deposits from asphaltene-resinous and paraffinic oil «Sangachal Deniz» was also studied (**Table 1**).

Experiments have shown that the optimal addition of reagents is 0.04–0.06 % by weight of oil. Approximately the same result was obtained in the study of «Sangachal Deniz» oil. It should be noted that when conducting experiments with the addition of reagents M-R and P-R, in addition to a layer of solid paraffin, a layer of relatively mobile asphaltene-resin-paraffin oil was formed on the surface of the cylinder, with a viscosity of shear stress lower than that of ASPO.

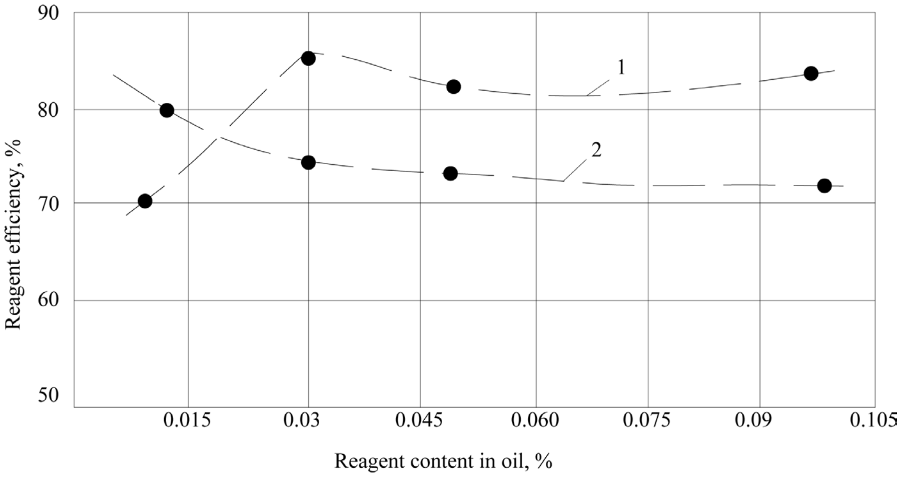

Fig. 1. Effect of P-R (1) and M-R (2) reagents on wax deposition efficiency. Reagent content in oil, %

Table 1
The influence reagents on the effectiveness against deposits from asphaltene-resinous and paraffinic oil «Sangachal Deniz» area

Oil	Mass of deposits on a cold cylinder, g	Reagent efficiency, %
	Oil temperature + 25 °C, water in a cold cylinder +5 °C	
«Sangachal-Deniz»	65.40	–
Also + 0.01 % PC-R	13.40	79.50
Also + 0.03 % PC-R	10.80	83.50
Also + 0.1 % PC-R	9.10	86.00
Also + 0.3 % PC-R	11	83.20

This near-wall layer of increased viscosity in real conditions, apparently, is in dynamic equilibrium with the flow of flowing oil, since its viscosity is comparable to that of oil. This layer, of course, cannot thicken indefinitely. When a certain layer thickness is formed in the tubing, the linear velocity of oil increases and begins to wash it away. Let's assume that oil moves laminarly along a circular cross-section of a pipe. The maximum shear stresses occur in the flow near the pipe wall:

$$\tau_{max} = \frac{\Delta p r}{2l}, \quad (1)$$

where Δp is the pressure difference in a flow of length – l; r is the radius of the flow. These maximum shear stresses characterize the shear force acting on a unit of the flow contact surface with the pipe wall and, therefore, tending to destroy (wash away) the solid phase formed under the action of molecular diffusion on the pipe wall. The deposition of solid phases on the inner surface of the pipe and the formation of a paraffin layer is possible only if the strength of adhesion of particles to the wall and the shear resistance of deposits is not less than the value of the maximum shear stresses.

Let's use the Buckingham formula and find the value of $\Delta p/l$. Neglecting the third term in this formula:

$$\frac{\Delta p}{l} = \frac{8\eta Q}{\pi r^4} + \frac{8\tau_0}{3r}, \quad (2)$$

where Q – the volumetric flow rate of oil; η – the plastic viscosity of oil; τ_0 – limiting dynamic shear stress. Substituting expression (2) into formula (1), let's obtain:

$$\tau_{max} = \frac{4\eta Q}{\pi r^3} + \frac{4}{3}\tau_0. \quad (3)$$

Or for $r = R - \sigma$:

$$\tau_{max} = \frac{4\eta Q}{\pi (R-\sigma)^3} + \frac{4}{3}\tau_0, \quad (4)$$

where R is the radius of the pipe, σ is the thickness of deposits on the pipe wall. As can be seen, at a given volumetric flow velocity, the shear stresses at the interface between the flow and the deposit change as the crust thickness increases and become constant only from the moment the deposit thickness stabilizes, i.e. the onset of dynamic equilibrium between the deposition of new layers of solid phases and their flushing. It should be noted that all this is possible only if the reagents used to combat paraffin deposits have a dissolving property. Reagents M-R and P-R have high dissolving and dispersing properties [7]. Reagents are recommended to be introduced into the oil before the formation of solid deposits on the pipe wall. These reagents with positive results were introduced into wells in the «28 May» area. So, in the well depth of 2270 m, located on an offshore individual platform due to paraffin formation in the II row of tubing, hot oil treatment was carried out every 3–4 days. In addition, due to paraffin formations in the tubing, they had to change 50–60 pipes for new ones every month. As a result of the introduction of M-R reagents, no paraffin deposits were found in the tubing for almost a year (they specially lifted the pipe and checked it). Moreover, it is quite characteristic that the average daily gas consumption decreased from 5000 to 3420 m^3. For clarity, the results of the introduction of the reagent M-R «28 May» were carried out (**Table 2**).

Table 2

The results of the introduction of the reagent M-R in «28 May» area

Date	P_u	P_k	P_{zt}	D_{th}	$Q_{n/k}$	Note
13.05.2019	5/8	24/25	30/31	9	7/–	Hot oil treatment (1.0 m^3). The dispenser works (D+)
14.05.2019	5/8	24/25	30/31	9	7/–	D+
17.05.2019	5/8	24/25	30/31	9	7/–	D+
20.05.2019	5/8	24/25	30/31	9	7/–	D+
23.05.2019	5/8	24/25	30/31	9	7/–	D+
26.05.2019	5/8	24/25	30/31	9	N	D+
01.06.2019	4/7	24/25	31/32	9	N	D+
04.06.2019	4/7	24/25	31/32	9	–	D+
07.06.2019	4/7	24/25	31/32	9	N	D+
01.07.2019	5/7	25/26	31/32	9	N	D+
03.07.2019	5/7	25/26	31/32	9	N	D+
06.07.2019	5/7	25/26	31/32	9	N	D+
09.07.2019	5/7	25/26	31/32	9	N	D+
01.08.2019	5/7	25/26	31/32	9	N	D+
04.08.2019	5/7	25/26	31/32	9	N	D+
08.08.2019	5/7	25/26	31/32	9	N	D+
10.08.2019	5/7	25/26	31/32	9	N	D+

Data D_{ek} = 152.4 mm, H_{dow} = 1665 m, I_f = 1635–1626 m, I_{row}–d_1 = 63.5 mm, l_1 = 1618 m, I_{Irow}–d_1 = 38.1 mm, l_{II} = 1509, d_{sht} = 9 mm. Before the introduction of the reagent due to paraffin formation, every 3–4 days heat treatment with hot oil was carried out. The lift pipes were replaced with new ones every 2.5–3 months. As can be seen from **Table 2**, during the reagent dosing period, there were no particular changes in the well performance. On some days, the productivity of the well not only did not decrease, but, on the contrary, increased. Treatment with hot oil on certain days was, as it were, of a preventive nature, since no changes were observed in the well parameters before and after heat treatment (**Table 2**). The results of implementation in many other wells testify to the high efficiency of the new reagent. The effect of reagents on the rheological properties of oil was also studied. Sangachal Deniz oil was used as a crude oil sample. The experiments were carried out on a rotational viscometer «Reotest-2», which makes it possible to determine the steady-state dependences of the stress-shear rate at a strain rate of 1.8–437.4 c^{-1}. It is shown that the Herschel-Bulkley three-parameter rheological model quite accurately describes the behavior of the studied oils in the entire range of shear rates. The relationship between flow rate Q and pressure drop ΔP in oil pipelines in the case of using the Herschel-Bulkley model is expressed by the formula [1, 9, 10]:

$$Q=\frac{4\eta Lk}{\Delta p(1+n)}\left[\frac{dkL}{\Delta p}\left(\frac{\Delta pd}{4kL}-\frac{\tau_0}{k}\right)^{\frac{1}{n}+2}-\frac{2kL}{\Delta p}\cdot\left(\frac{\Delta pd}{4kL}-\frac{\tau_0}{k}\right)^{\frac{1}{n}+3}-\left(\frac{\Delta pd}{4kL}-\frac{\tau_0}{\tau}\right)^{\frac{1}{n}+1}\cdot\frac{d^2}{8}\right], \quad (5)$$

where L is the length of the pipeline, m; d is the inner diameter of the pipeline, m; k, n, τ_0 – rheological constants. It is difficult to solve this equation for Δp_0. Therefore, to plot the dependence:

$$Q=f(\Delta p), \quad (6)$$

the value Δp is set. For the following conditions τ_0 = 13.62 Pa; n = 0.47; k = 2.77 and d = = 0.2032 m; L = 9 km. **Fig. 2** shows the relationship between flow and pressure in the system according to the Herschel-Bulkley rheological model.

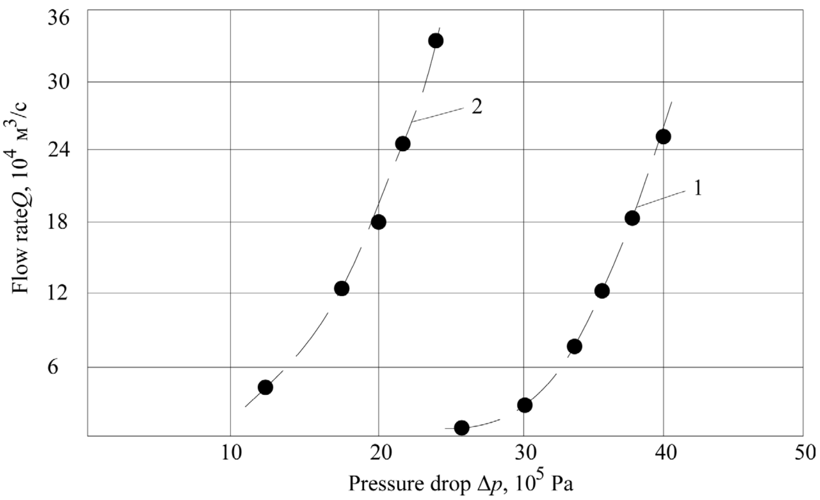

Fig. 2. Relationship between flow and pressure in the system according to the Herschel-Bulkley rheological model: 1, 2 – respectively without and with the reagent 0.07 % M-R

The viscosity of the newly processed reagents must be optimally proportional to the percentage of viscosity of the oil, otherwise the formation of paraffin and tar deposits will not be properly prevented. In this case, the influence of the concentration of reagents on the dissolution of paraffin and resin, that is, their dissolution depends on the percentage of the reagent, otherwise the effect on deposition will be weakened. When using reagents M-R and P-R, the formation of resin-paraffin deposits on belts and equipment will be significantly reduced. As a result of this, cases of losses and possible accidents on pipelines during oil transportation will be excluded. Due to the formation of an inhibitor layer on the surface of the belts, deposits will be reduced and the amount of losses will be minimized.

4. Conclusions

The use of new multi-functional and multi-component reagents developed by us is of great importance in eliminating the difficulties caused mainly by resins and paraffins during the production and transportation of oils. The newly developed reagents, unlike other traditional reagents, have the advantage of creating a certain hard surface and melting paraffins on the internal surfaces of equipment used in oil production and transportation pipelines. The use of these reagents had a positive effect on productivity. Economically, the newly developed reagents cost less than the market prices of the used conventional reagents.

M-R and P-R reagents are made from local chemical products and are more efficient than conventional reagents.

During the use of M-R and P-R reagents, the pressure loss in rapid cooling of tar and paraffin oils (t_{set} = 330 °C) is reduced by half. As a result, paraffin and resin deposits are reduced in the lines.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

Manuscript has no associated data.

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