AGH DRILLING, OIL, GAS • Vol. 31 • No. 1 • 2014

http://dx.doi.org/10.7494/drill.2014.31.1.73

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IMPROVEMENT OF HIGH-VISCOSITY OIL PRODUCTION TECHNOLOGY

Because of the small oil mobility, the high-viscosity oil fields development by using traditional methods is inefficient. One of the main factors that causes small oil mobility in the bed and low efficiency of oil production is its high-viscosity. That's why for the stimulation of high-viscosity oil production during development such fields it is necessary to reduce their viscosity.

To determine the optimal values of temperature of oil heating and the content of hydrocarbon solvent in it, the studies with the oil sample taken from the 96 wellhead of the Yablunivsk oil-and-gas-condensate field (OGCF), operating the B-5 Horizon were made.

The density, dynamic viscosity factor and limiting dynamic shear resistance (limiting dynamic offset voltage) of oil under different temperatures and different volume content of hydrocarbon condensate in the system were specified.

According to the results of the studies the dependence of the oil sample density from the 96 well on the temperature, it has been determined that the temperature relatively slightly effects on the oil density.

According to the results of the studies the temperature value and the volume content in the system of hydrocarbon condensate, the optimal temperature for clean oil heating is 49.83^{0}C and gradually decreases with the increase of volume content in the system of hydrocarbon condensate.

The studies results found out that the optimal volume content in the system of hydrocarbon condensate decreases from 20.73 to 18.8% or from 26.15 to 23.15% with oil in mind with the temperature increase from 25 to 800 ^{0}C.

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It has been determined that the oil heating and hydrocarbon condensate injection into oil can highly reduce its viscosity and thereby improve the wells yield, prevent complications while operating them and intensify the processes of development of high-viscosity oil deposits.

Different methods for hydrocarbon condensate pumping and heat effect on the high-viscosity oil well bore have been suggested. It was determined that the optimal temperature of oil heating is 48.35^{o}C for the 96 well of the Yablunivsk field and the depth of electrical heaters running is near 1500 m. Depending on the geological-and-field wells characteristics and physical-and-chemical oil properties, the heating of the flow strings with the electrical heaters can be carried out continuously or periodically.

Another method of the heat effect on the high-viscosity oil is the injection of heat transfer agent into the well, as an example, heated condensate through the macaroni pipe strings (coiled tubing type) that are run at the certain depth inside the flow strings.

One more possible way for high-viscosity oil wells stimulation and prevention of complication during the operation is the combined use of hydrocarbon solvents and surfactants. Under their combined application the reduction of oil viscosity and crystallization temperature of solid hydrocarbons from oil is taken place.

To evaluate the possibility of combined use of hydrocarbon solvents and surfactants to reduce the oil viscosity of the Yablunivsk OGCF, the laboratory researches with the high-viscosity oil sample taken from the 96 wellhead of this field were conducted. The researches were performed under the temperatures from 25 to 80^{0}C (every 5^{0}C). Hydrocarbon condensate with the density of 735 kg/m^{3} was used as a hydrocarbon solvent. The volume content of the hydrocarbon condensate in the system (to oil and condensate mixture) was 20%. The rhipox-6 and the niogen P-1000 produced at the Ivano-Frankivsk Joint-Stock Company "Barva" were used as a surfactant. Mass concentration of surfactants in the oil and condensate mixture was 0,125; 0,25; 0,5; 1; 2; 4; 6; 8%.

According to the results of the conducted studies, the optimal mass concentration of surfactants in oil with the content in the system of 20% vol. condensate is arranged. It is about 1% of its mass.

These studies helped to evaluate the surfactant effect on the optimal temperature of oil heating, above which the temperature affects the dynamic factor of oil viscosity not considerably.

The results of the conducted researches show the positive effect of surfactants injection into oil on both – the reduction of dynamic factor of oil viscosity and the reduction of optimal temperature of oil heating in several times.

According to the results of the performed laboratory studies, the technology of high-viscosity oil wells operation of the Yablunivsk field was developed. This is a technology of gas-lift high-viscosity oil wells operation through the gas-lift gas injection into the stream of formation production along the flow strings and feeding hydrocarbon condensate and surfactants with gas. Other effective methods for high-viscosity oil wells operation is the application of progressive cavity pump and sucker rod pumping units with the pumps of special construction. It is reasonably to inject additionally the hydrocarbon solvent with surfactants into the annular space to reduce the pressure losses in the flow strings, to increase the oil production yield and prevent the paraffin sediments under the pumping method of wells operation. The level of condensate in the annular space of the well is maintained at such level that it could enter pump suction under its own pressure.

1. INTRODUCTION

The characteristic feature of the modern oil production is the increase in the world structure of raw materials of hardly-productive resources to which primarily belong heavy crude and high-viscosity oils. As for the literature [1, 6, 3, 10, 5] the world high-viscosity oil resources exceed considerably the low- and middle oil viscosity. The largest resources of heavy crude and high-viscosity oils are in Canada, Venezuela, Mexico. The substantial resources of high-viscosity oil are located in Russia – near 6.2 billion ton, comprising 84% of high-viscosity oil resources of the former USSR countries. According to the data [1, 6, 3, 10, 5] in Tiumen region (Western Siberian oil-and-gas-bearing province) the residual reserves of high-viscosity oil resources of the A+B+C_1 were 2.3 billion tons (37,9% of the high-viscosity oil resources in Russia). In the Komi Republic (Timano-Pechorsk oil-and-gas bearing province) the part on the high-viscosity oil resources in Russia is 14,4% [5]. Together these two provinces comprise more than 50% of high-viscosity oil resources in Russia which causes the interest to examine the high-viscosity oil properties of the Western Siberian and Timano-Pechorsk oil-and-gas bearing provinces.

The fields of Eastern, Western and South oil-and-gas bearing regions of Ukraine (Kokhanivsk, Buhruvativsk, Yablunivsk, Semenivsk etc.) are characterized by the substantial resources of high-viscosity oil. According to the “Oil and Gas of Ukraine till 2010” National program the heavy crude oil resources in the eastern region are estimated to be about 76.885 million ton, in Western – 13.772 million ton, in South – 3.781 million ton, together – 94.438 million ton. Except for separately located heavy crude oil fields, the considerable liquid hydrocarbons resources with abnormal properties are confined to separate beds and oil fringes in the gas-condensate fields which contain high-viscosity oil. It should be mentioned that under the conditions of development of oil fields for depletion at the dissolved gas drive, the oil viscosity increases gradually in reservoir conditions because of dissolved gas escape from oil and the residual oil reserves in fields become hard to recover.

The part of explored hyper- or high-viscosity oil resources and bitumen in the total hydrocarbon reserves balance in the whole world continuously increases because of the intensive easy-productive low viscosity oil fields development and slow high-viscosity oil fields development.

The results of the study of high-viscosity deposits allocation on the depth position are of some interest. Above 68% of high-viscosity oil deposits are at the depth of 1000 to 2000 m in Russia [8]. The majority of the high-viscosity oil deposits (above 82%) are located at the depth to 2000 m and only 18% - from 2000 to 4000 m. Ukrainian high-viscosity oil deposits are characterized by approximately the same depth allocation. Starting with the depth of 2000 m, the number of high-viscosity oil deposits decreases with depth.

The most high-viscosity oil deposits on the Russian territory are allocated at the depth from 1000 to 2000 m [8]. With the further increase of the depth of the deposits position, the oil viscosity decreases and at the depth of 3000-4000 it is 10 times lower as at the depth of 1000-2000 m. The highest oil viscosity value is observed in Mesozoic sediments. The average oil density in Russia 910 kg/m^3, sulfur content – 2.29%, paraffin content – 3.58%, resin content – 17.26%, asphaltene content – 4.56%, the kinematical oil viscosity factor for different fields varies from 35.1-308.2 mm^2/s, that meets the dynamic oil viscosity factor 290-2809 mPa·s.

Concerning the modern state of raw material base of oil production industry in Ukraine it must be pointed out that its state is characterized by the worsening of oil resources structure. The majority of oil fields, from which the main volume of oil was produced, are in the drop down oil production and final stage of development. The part of hardly-productive resources is increased which is focused on the complicated constructed hyper-viscosity oil fields, in the under-gas cap and water-flooded zones. In the fields that were developed using the formation energy depletion drive additional complications appeared in the process of wells operation because of oil viscosity increase under its gas liberation and paraffin sediments intensification.

The main problems that may occur with the high-viscosity oil production are related to the abnormal viscosity and high content of asphalt-resin-paraffin substances. That's why high-viscosity oils are slow-moving, their filtration in bed is mainly characterized by the initial pressure gradient, significant pressure losses appear during oil movement in porous medium, rising pipes and field pipelines, takes place an intensive asphalt-resin-paraffin substances depositing occurs in the bottomhole zone, wellbore and industrial utility lines, oil congelation in the flow strings and blowing lines under wells shut-in can also happen.

Because of slow oil mobility the high-viscosity oil fields development with traditional methods is ineffective [4]. The use of natural drives leads to extremely low rates of oil withdrawal and, as a result, to a small oil recovery factor during the defined terms (volumetric expansion and elastic water regimes) or to the low oil recovery factor at relatively high resources development scope as it takes place under the dissolved gas drive. The use of the traditional water flooding does not give a significant effect due to the low scope of resources development and comparatively low displacement ability of cold water in displacing high-viscosity oil. Thus, the use of the traditional technologies does not provide with high value of oil recovery factor during the high-viscosity fields development.

High viscosity is the main factor that determines small oil mobility in bed and low efficiency of its recovery. Thus to increase the efficiency of high-viscosity oil fields development, it is necessary to increase its viscosity.

To stimulate the high-viscosity oil production practically, we should apply the methods of physical-and-chemical effect by means of heat, hydrocarbon solvents and surfactants – the oil viscosity reducers and paraffin inhibitors – separately or their mixtures

[2, 7, 9]. While making the design engineering of physical-and-chemical effect on high-viscosity oil, it is necessary to ground the process parameters and choose effective reactants – surfactants and their compositions. Due to different physical-and-chemical characteristics, oil composition and geological-and-technical wells characteristics the choice for process parameters and reactants must be made individually for each well and group of wells taking into account technical and financial business opportunities and available set of reactants.

2. MATERIALS AND METHODS

To define the optimal values of oil heating and the content in it of the hydrocarbon solvent, the research has been done with the oil sample taken from the 96 wellhead of the Yablunivsk oil-and-gas-condensate field (OGCF) , operating the Б-5 Horizon. The well depth – 3600 m, initial formation pressure – 37 MPa, formation temperature – 92^{0}C. Oil is heavy, resin-and-asphaltene and contains 25.5% of silica-gel resins mass, 12.2 % of asphaltenes mass, 1.39 % of sulphur mass, 9.9 % of bound water mass and a small amount of paraffin (0.53 % of its mass). Gas-to-oil ratio equals 13.5 m^3/t.

The density, dynamic viscosity factor and limiting dynamic shear resistance (limiting dynamic offset voltage) of oil under different temperatures and different volume content in the system of hydrocarbon condensate were determined in the studies. The laboratory researches were carried out under the temperatures from 25 to 80^{0}C (every 5^{0}C) and volumetric content of hydrocarbon condensate in the system (regarding the volume of oil and condensate mixture) 0; 10; 20; 30; 40; 50; 60%. The hydrocarbon condensate with the density of 735 kg/m^3 was used in the researches. The oil density was measured by means of aerometer but a dynamic viscosity factor and limiting dynamic shear resistance were measured – by means of the "REOTEST-2" rotary viscometer.

To assess the possibility of combined use of hydrocarbon solvents and surfactants in order to reduce the oil viscosity, additional laboratory studies were performed with the oil sample taken from the 96 wellhead of the Yablunivsk OGCF and volumetric content of 20% hydrocarbon condensate in the system (regarding the volume of oil and condensate mixture). The rhipox-6 and the niogen P-1000 produced at the Ivano-Frankivsk Joint-Stock Company "Barva" were used as a surfactant. Mass concentration of surfactants in the oil and condensate mixture was 0.125; 0.25; 0.5; 1; 2; 4; 6; 8%.

3. RESULTS

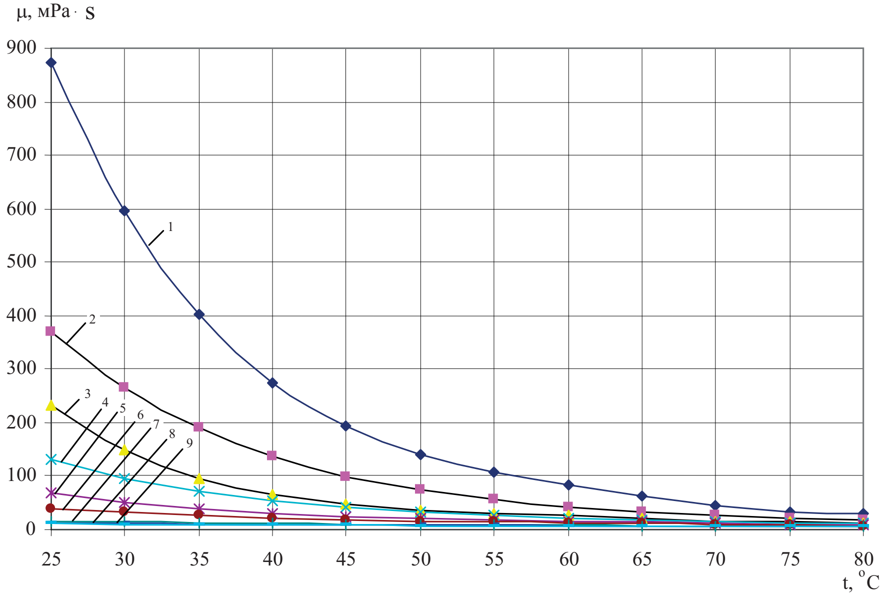
According to the results of the studies the dependence of the density of oil sample from the 96 well on the temperature is of linear value and has the following equation:

$$\rho_н = -0{,}0029t^2 - 0{,}3374t + 93327, \text{ kg/m}^3$$

whereas t – temperature, ^{o}C.

With the temperature increase from the standard (20^0C) to the formation (92^0C) the oil density decreases from 925.36 to 877.68 kg/m^3 (at 5.15%), thus, the temperature affects the oil density relatively slightly.

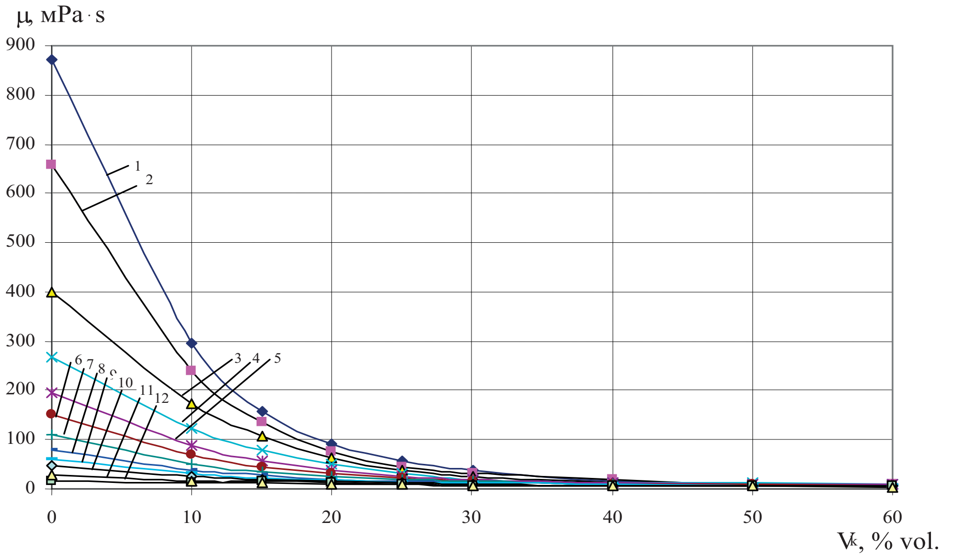
Figure 1 summarizes the dependences of the dynamic oil viscosity factor on the temperature for different volumetric content in the “oil-condensate” system of hydrocarbon condensate, and figure 2 summarizes the dependences of the dynamic oil viscosity factor on the volumetric content of hydrocarbon condensate in the system for different temperatures. With the temperature and volumetric content increase of hydrocarbon condensate in the system, the dynamic oil viscosity factor continuously decreases.



1-0; 2-10; 3-15; 4-20; 5-25; 6-30; 7-40; 8-50; 9-60 % vol

Fig. 1. The graphs of the dependence of the dynamic viscosity factor of the oil sample taken from the 96 well of the Yablunivsk OGCF on the temperature for different volumetric content of hydrocarbon condensate in the system

The results of the performed studies prove the possibility of dynamic oil viscosity factor reduction by heat effect and adding the hydrocarbon solvent into oil. Thus, with the temperature increase from 25 to 80^0C the dynamic oil viscosity factor decreases from 874.07 to 30.04 mPa×s (at 29.1 times). The introduction of hydrocarbon condensate into oil has the similar effect. Thus, under the temperature of 25^0C with the volumetric content increase of hydrocarbon condensate in the system from 0 to to 60% vol., the dynamic oil viscosity factor decreases from 874.07 to 11.56 mPa×s (at 75.61 times) and under the temperature of 80^0C – from 30.04 to 4.96 mPa×s (at 6.06 times).



1-25; 2-30; 3-35; 4-40; 5-45; 6-50; 7-55; 8-60; 9-65; 10-70; 11-75; 12-80 °C

Fig. 2. The graphs of the dependence of the viscosity factor of the oil sample taken from the 96 well of the Yablunivsk OGCF on the volumetric content of hydrocarbon condensate in the system for different temperatures

According to the results of the studies, the values of temperature and volumetric content of hydrocarbon condensate in the system were found out, above which the dynamic oil viscosity factor changes slightly. For this purpose we built the contrast dependences of two successive values of the dynamic oil viscosity factor with different volumetric content of hydrocarbon condensate on temperature and the contrast dependence of two successive values of dynamic oil viscosity factor under different temperatures on the volumetric content of hydrocarbon condensate in the system. The examples of these dependences are given in the Figures 3 and 4. These dependences can be approximated with two straight lines, where the intersection point is the optimal temperature of oil heating or the optimal content of hydrocarbon condensate in the system. These dependences confirm the existence of the optimal temperature and volumetric content values of hydrocarbon condensate in the system, above which the change rate of dynamic oil viscosity oil factor decreases rapidly.

According to the results of the studies, we got the optimal temperature of clean oil heating which is 49.83^{0}C and it gradually decreases with the increase of the volumetric content of hydrocarbon condensate in the system: under 10% of condensate vol. – 49.43^{0}C, under 15% of condensate vol. – 49.07^{0}C, under 20% of condensate vol. – 48.35^{0}C, under 25% of condensate vol. – 47.49^{0}C, under 30% of condensate vol. – 46.91^{0}C, under 40% of condensate vol. – 45.67^{0}C, under 50% of condensate vol. – 44.63^{0}C, under 60% of condensate vol. – 44.62^{0}C. thus, with the increase of volumetric content in the system of hydrocarbon condensate from 0% to 60% the optimal temperature of oil heating decreases from 49.83 to 44.46^{0}C.

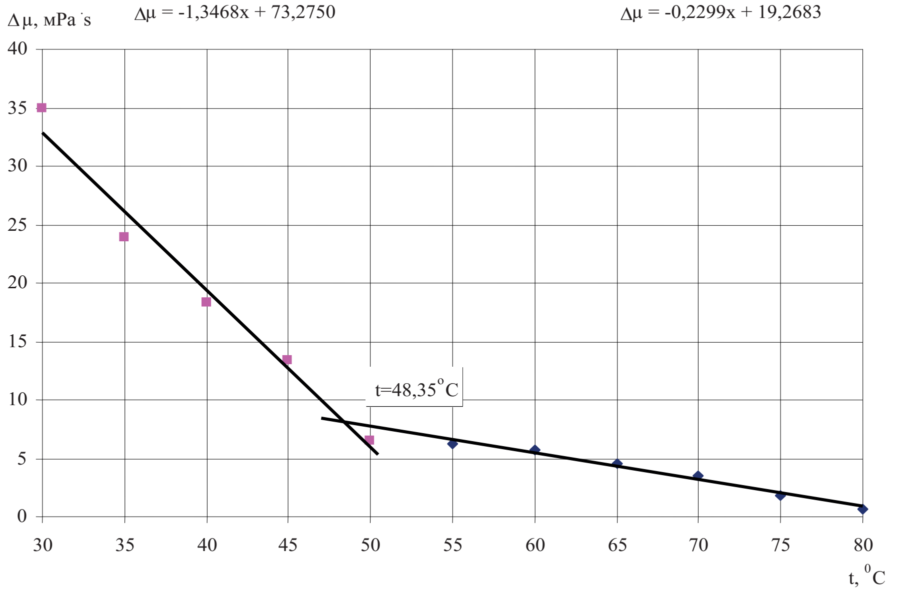


Fig. 3. The graphs of dependence of absolute drop for the dynamic viscosity factor of the oil sample taken from the 96 well of the Yablunivsk OGCF on the temperature for the volumetric content of 20% hydrocarbon condensate in the system

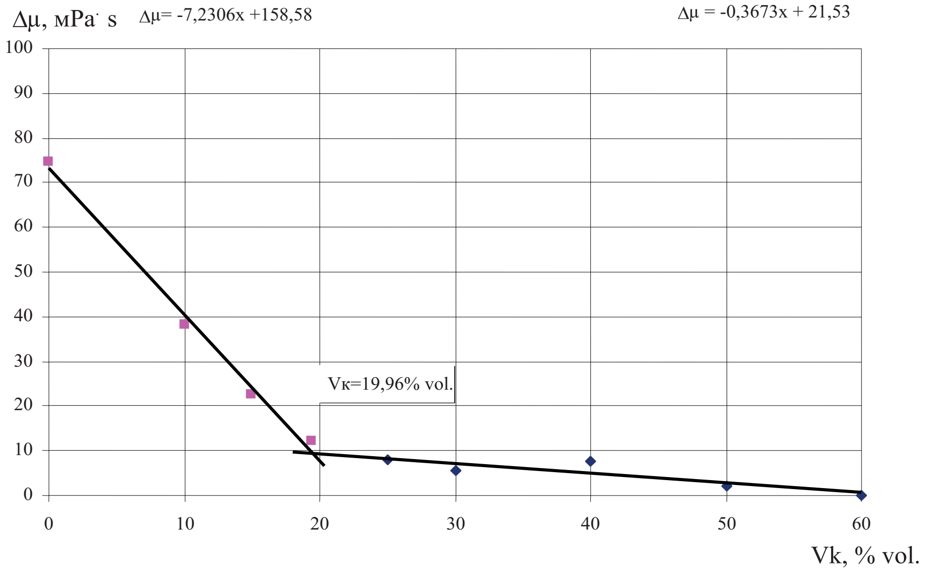


Fig. 4. The graphs of the dependence of absolute drop for the dynamic viscosity factor for the oil sample taken from the 96 well of the Yablunivsk OGCF on the volumetric content of hydrocarbon condensate in the system for the temperature of 45°C

According to the results of studies the optimal volume content of hydrocarbon condensate in the system for different temperatures is the following: under 25^0C – 20.73% vol., under 30^0C – 20.65% vol., under 35^0C – 20.59% vol., under 40^0C – 20.27% vol., under 45^0C – 19.96% vol., under 50^0C – 19.72% vol., under 55^0C – 19.53% vol., under 60^0C – 19.44% vol., under 65^0C – 19.13% vol., under 70^0C – 19.05% vol., under 75^0C – 18.86% vol., under 80^0C – 18.8% vol. Thus, with the temperature increase from 25 to 80^0C the optimal condensate content in the system decreases from 20.73 to 18.8% vol. or from 26.15 to 23.15% vol. in terms of oil.

These data confirm the relative stability of the temperature and volumetric content values of the hydrocarbon condensate in the system for the specific oil sample which correspond to the intersection point of straight-line segments dependences, given in the figures 3 and 4. Thus, with the temperature change from 25 to 80^0C the optimal hydrocarbon condensate content in the system changes from 20.73 to 18.8% (at 9.31%) and with the change of volumetric condensate content in the system from 10 to 60% the optimal temperature, which corresponds to the intersection point of straight-line segments of the studied dependences, changes from 49.43 to 44.46^0C (at 10.05^0C).

For the optimal content of the hydrocarbon condensate in the system of about 20% vol. (25% vol. in terms of oil), the optimal temperature of oil heating is 48.35^0C. For these values of the condensate volumetric content in the system and the temperature of oil heating, the dynamic oil viscosity factor is 35.37 mPa×s (at 24.46 times less than the value of the dynamic oil viscosity factor under the temperature of 25^0C and condensate absence).

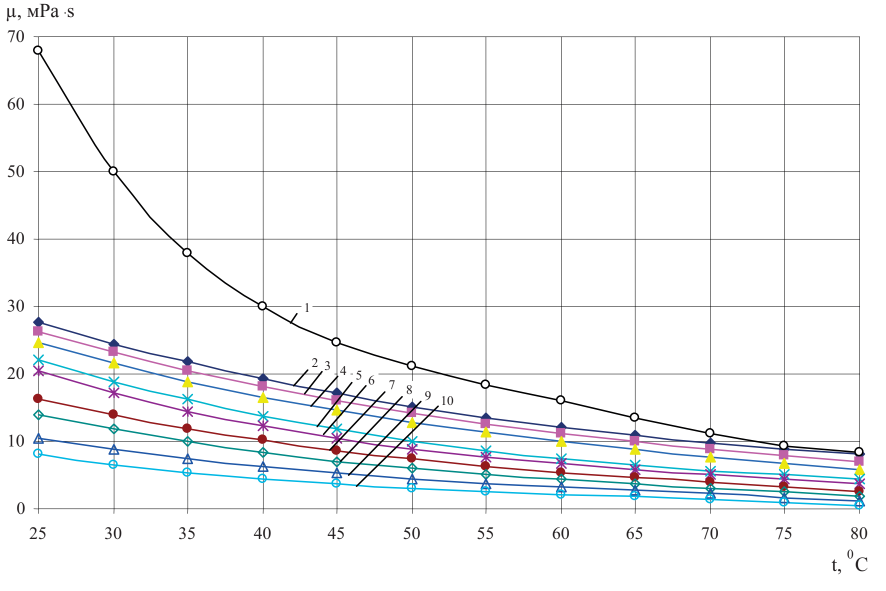
According to the results of the performed researches of the combined effect of the thermal field and hydrocarbon solvent, it is figured out that the highest decrease of dynamic oil viscosity factor is got under the combined effect of the thermal field and hydrocarbon solvent. Thus, with the temperature increase from 25 to 80^0C and adding 60% vol. of hydrocarbon solvent into the system, the dynamic oil viscosity factor decreases from 874.07 to 4.96 mPa×s (at 176.22 times).

So, oil heating and injection of hydrocarbon condensate into oil allows oil to considerably reduce its viscosity and thus to increase the wells yield, prevent complications while operating them and intensify the processes of development of high-viscosity oil deposits. The injection of hydrocarbon solvent into the formation products can be done by its pumping with the controlled volume pump into the wells annular space. To increase the oil temperature it is also possible to pump the heat transfer agent, for example, heated hydrocarbon condensate into the annular space. But hydrocarbon condensate is characterized by the low heat capacity and to achieve the required temperature of oil heating it could have been pumped large amounts of condensate or it could have been heated to high temperatures. Thus, a continuous pumping of the heated condensate into the annular space of high-viscosity oil wells can be economically inefficient. Heated condensate should be used for the periodical thermal wells treatment to destruct the solid hydrocarbons. One of the methods of oil heating in the wellbore is the use of electric heaters that can be run inside the flow strings or be mounted on the pipe connections. Meanwhile, only the upper part of the flow strings should be heated to the depth, at which the temperature during the oil movement through the pipes decreases to the optimal temperature as for its effect on the oil viscosity. For the 96 well of the Yablunivsk field , the optimal temperature of oil heating is 48.35^{0}C and the depth of the electric heaters run is near 1500 m. Depending on the geological-and-commercial well characteristics and physical-and-chemical oil properties, the heating of the flow string with the electrical heaters can be done continuously or periodically.

Another method of the heat effect on the high-viscosity oil is the injection of the heat transfer agent into the well, for example, the heated condensate through the macaroni string (coiled tubing type), which is run at the specific depth inside the flow string.

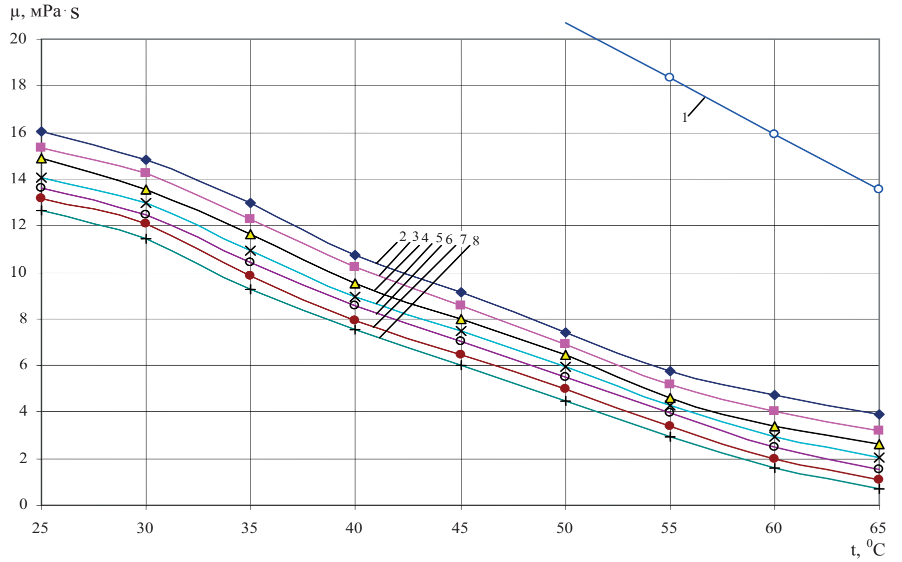
The combined use of hydrocarbon solvents and surfactants belong to the possible ways of high-viscosity wells stimulation and complications prevention during their operation. With their combined use, the decrease of oil viscosity and crystallization temperature from oil of solid hydrocarbons takes place.

The fig. 5 and 6 show the dependences on the temperature of the dynamic viscosity factor of oil sample taken from the 96 well of the Yablunivsk OGCF with the content in the system "oil-condensate" of the 20%vol. hydrocarbon condensate for different content in oil with the rhipox-6 condensate (fig.5) and the niogen P-1000 (fig.6) and the fig. 7 and 8 present the dependences of the dynamic oil viscosity sample factor from the surfactants concentration in the system "oil-condensate" for different temperatures regarding the rhipox-6 condensate (fig.7) and the П-1000 niogen (fig.8).



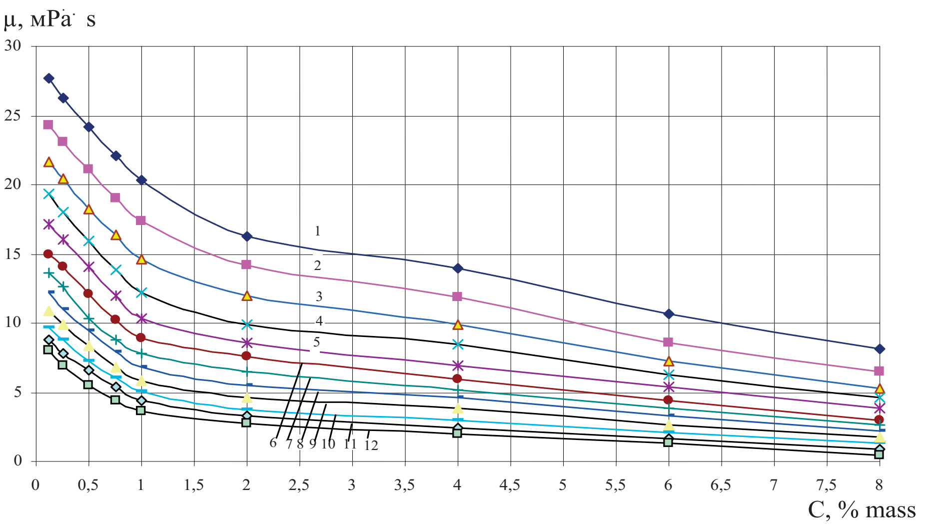
1-0; 2-0,125; 3-0,25; 4-0,5; 5-0,75; 6-1; 7-2; 8-4; 9-6; 10-8 % mass

Fig. 5. The graphs of dependences on the temperature of the dynamic viscosity factor of the oil sample taken from the 96 well of the Yablunivsk OGCF with the content in the system of the 20% vol. condensate and different mass content of the rhipox-6



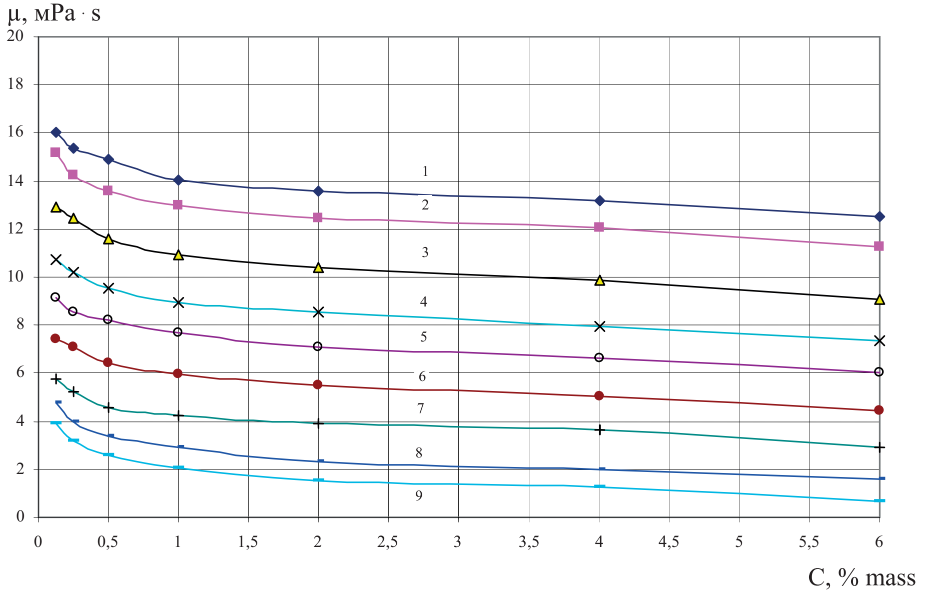
1-0; 2-0,125; 3-0,25; 4-0,5; 5-1; 6-2; 7-4; 8-6 % mass

Fig. 6. The graphs of dependences on the temperature of the dynamic viscosity factor of the oil sample taken from the 96 well of the Yablunivsk OGCF with the content in the system of the 20% vol. condensate and different mass content of the niogen P-1000



1-25; 2-30; 3-35; 4-40; 5-45; 6-50; 7-55; 8-60; 9-65; 10-70; 11-75; 12-80 oC

Fig. 7. The graphs of the dependences of the dynamic viscosity factor of the oil sample taken from the 96 well of the Yablunivsk OGCF with the content in the system of the 20% vol. condensate on the mass concentration of the rhipox-6 for different temperatures



1-25; 2-30; 3-35; 4-40; 5-45; 6-50; 7-55; 8-60; 9-65°C

Fig. 8. The graphs of the dependences of the dynamic viscosity factor of the oil sample taken from the 96 well of the Yablunivsk OGCF with the content in the system of the 20% vol. condensate on the mass concentration of the niogen P-1000 for different temperatures

According to the results of the performed researches the surfactants usage is very effective and it leads to the oil viscosity decrease. For clean oil (free from condensate and surfactant mixture) the dynamic viscosity oil factor under the temperature of 25^{0}C is 874.07 mPa·s, under 50^{0}C – 140.88 mPa·s, under 60^{0}C – 82.85 mPa·s and under 80^{0}C – 30.04 mPa·s and for oil with the condtent of 20% vol. condensate (regarding the oil mixture with condensate) under 25^{0}C is 67.87 mPa·s, under 50^{0}C – 21.13 mPa·s, under 60^{0}C – 15.95 mPa·s, under 80^{0}C – 8.32 mPa·s.

Surfactants injection into oil mixture leads to additional dynamic oil viscosity factor decrease. Thus, with the content in the system of 20% vol. condensate and with the temperature of 25^{0}C the dynamic oil viscosity factor equals 67.87 mPa·s and with the rhipox-6 injection is the following: under 0.125% mas. – 27.62 mPa·s;under 0.25% vol. – 26.19 mPa·s; under 0.5% vol. – 24.71 mPa·s; under 1% mas. – 20.43 mPa·s; under 2% mas. – 16.31 mPa·s, under 6% mas. – 10.47 mPa·s; under 8% mas. – 8.04 mPa·s. For the niogen P-1000 we got the values of dynamic oil viscosity mixture with condensate factor under the temperature of 25^{0}C: 0.125% mas. – 16.11 mPa·s, 0.5% mas. – 14.95 mPa·s, 1% - 14.16 mPa·s, 2% mas. – 13.69 mPa·s, 6% mas. – 12.6 mPa·s.

The analysis of the research data shows that the surfactant effect on the dynamic oil viscosity factor decreases with the temperature raise (fig. 5,6) and surfactant content (fig. 7,8).

According to the performed researches, the optimal mass surfactant concentration in oil with the content in the system of 20% vol. condensate was determined. It is near 1% of mass. For this surfactant concentration in the system "oil-condensate" the dynamic oil viscosity factor decreases comparatively with the system free from surfactant for the rhipox-6: under the temperature of 25^0C – to 20.43 mPa·s (by 3.32 times), under 50^0C – to 8.94 mPa·s (by 2.36 times), under 60^0C – to 6.84 (by 2.33 times), under 80^0C – 3.66 mPa·s (by 2.27 times), the the niogen П-1000: under 25^0C – to 14.16 mPa·s (by 4.79), under 50^0C – to 5.79 mPa·s (by 3.65 times).

According to the research results we evaluated the surfactant effect on the optimal temperature of oil heating above which the temperature influences the dynamic oil viscosity factor not considerably. It was built the dependences on the difference temperature of two consequent values of the dynamic oil viscosity factor with the content in the "oil-condensate" system of the 20% vol. hydrocarbon condensate and different surfactant content. These dependences are approximated with two straight lines: a left line with a large obliquity to the X-axis and a right one – with a less obliquity. Their intersection point is the optimal temperature of oil heating. For the oil mixture with condensate without surfactant this temperature equals 47.49^0C. With the surfactant injection into the oil with condensate the optimal temperature of oil heating is lower. For the niogen П-1000 it varies $47.34\text{-}44.5^0$C and depending on its mass concentration is the following: under 0.25% – 47.34 ^{0}C; under 0.5% – 46.44^0C; under 1% – 45.7 ^{0}C; under 2% – 47.15 ^{0}C; under 4% – 44.58^0C; under 6% – 44.5^0C. The similar affect of the decrease of oil heating optimal temperature is got with the rhipox-6 studies.

The results of the performed studies confirm the positive effect of the of the surfactant injection into oil on both the decrease of dynamic oil viscosity factor by several times and the decrease of optimal temperature of oil heating. That's why to stimulate the high-viscosity oil wells operations on the Yablunivsk OGCF we recommend to inject the surfactants, like the rhipox-6 or the niogen П-1000 with mass concentration of 1% simultaneously with the condensate injection into the formation products.

4. DISCUSSION OF THE RESULTS

According to the results of the performed laboratory studies, the high-viscosity oil well operation technology of the Yablunivsk field was developed. At the initial period of the field development, under high formation pressure (hydraulic fluid pressure) the hydrocarbon solvent (condensate) with the surfactants or without them is recommended to inject through the annular space on the wellhead. It will help the oil viscosity decrease. With the formation pressure decrease during the well development and natural well blowing stoppage, the application of gas-lift operation method with additional hydrocarbon solvent with surfactant injection in the gas-lift gas flow. To reduce the operating pressure and gas-lift gas losses, to increase oil yields and to continue the gas-lift well operation period we recommend to inject gas into the formation products along the flow strings. At the final period of field development under low formation pressure and high formation products water flooding we recommend to use the pump methods of wells operation by means of sucker rod pumping units of special design, progressive cavity and jet pumps.

The developed high-viscosity wells stimulation technology is tested and introduced on the 96 well of the Yablunivsk OGCF. As the well stopped its natural blowing but the periodical hydrocarbon condensate pumping into the annular space appeared to be ineffective, the well was transformed to the gas-lift operation with gas inject into formation products flow through the flow string according to the recommendation of the Ivano-Frankivsk National Technical University of Oil and Gas. For this the flow string with the 73 mm diameter at the depth of 3450 m was run into the well. The well was equipped with three kick-off valves of special design. According to the made calculations, the kick-off valves were mounted at the different depths of 1200 m; 1900 and 2600 m and lower the valves – operating holes: one 5 mm hole at the depth of 2500 m; one 5.5 mm hole at the depth of 2800 m; two 4 mm holes at the depth of 3100 m. With the kick-off valves application the well triggering is done by gas injection into the flow string with further gas injection change into the annular space. The advantage of gas injection into the flow string is the reduction of kick-off valves number, the depth increase of well blowing and decrease of gas-lift gas pressure value. The technological scheme of the 96 well equipment for gas-lift operation is shown in the fig.9.

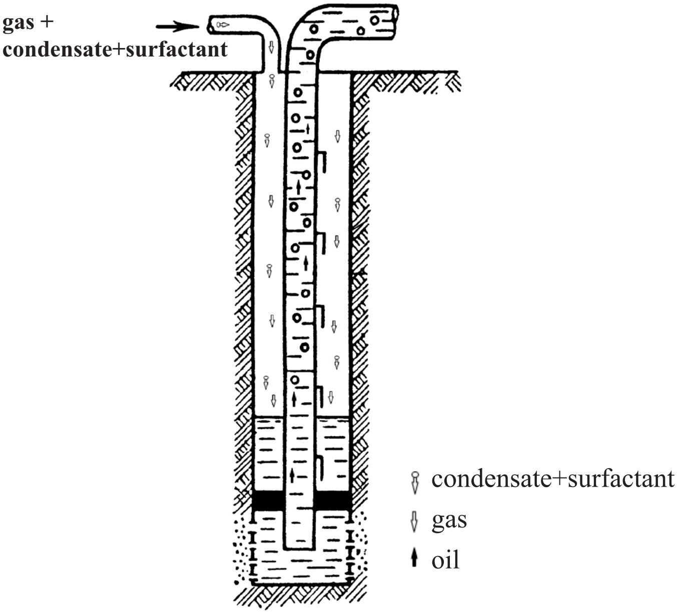


Fig. 9. The technological scheme of the 96 well for gas-lift operation of Yablunivsk OGCF with gas injection into formation products flow through the flow string

For the gas-lift 96 well operation we used gas from the available high-pressure gas wells in the fields which operate gas-condensate horizon of the same deposit: at first gas from the

102 well and later gas from the 87 well. Gas from the 102 well was feed through the gas-lift manifold and from the 87 well through the specially designed girth. To prevent the hydrating on the gas-lift manifold, methanol was feed in the gas-lift gas flow.

According to the results of the made studies we recommend to operate the 96 well periodically with the gas injection every two days for 2-3 hours from the gas-lift manifold with the pressure 10-12 MPa and 20 thousand m^3/d input with the simultaneous hydrocarbon condensate injection into the gas-lift gas flow regarding 20% vol. on the volume of oil mixture with condensate and 1-2% of surfactant mass (the rhipox-6) considering all the fluid produced from the well (oil, condensate, water).

The 96 well is operated periodically with the gas-lift method with the high pressure feed every two days for 2 hours from the 87 gas-condensate well. Average oil yield varies 1.03-6.73 t/d, water content in the production – 1.6-1.84%.

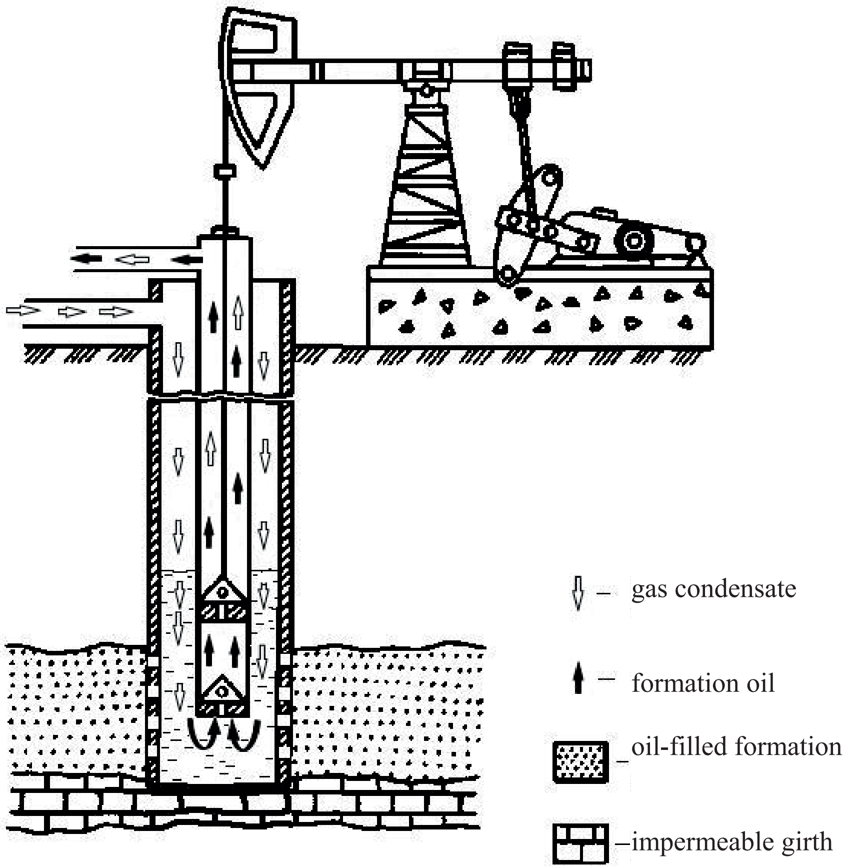


Fig. 10. The technological scheme of the high-viscosity wells operation which are equipped with sucker rod pumping units of the Yablunivsk OGCF

The results of the 96 well operation prove the possibility of practical use of the gas-lift high-viscosity well operation technology by the gas-lift gad feed in the formation pressure flow through the flow string and hydrocarbon condensate with surfactants injection with gas.

Other effective high-viscosity oil wells operation is the progressive cavity pumps and sucker rod pumping units application. These methods are introduced on the several oil fields of the GPU "Poltavagazvydobuvannia". The scheme of the high-viscosity wells operation with the sucker rod pumping unit is shown in the fig. 9. But in this case to reduce the pressure losses in the flow strings, to increase the oil yield and to prevent the paraffin sediments it is worth to inject hydrocarbon solvent with surfactant into the annular space. The condensate level in the well annular space is maintained at such level that it could enter pump suction under its own pressure.

5. CONCLUSIONS

The results of the made researches confirm the efficiency of the thermal effect, hydrocarbon solvents and surfactants used in combination with the mechanical means of the well operation for high-viscosity oil production stimulation, increase of wells yield and paraffin sediments prevention while their operation. Hydrocarbon condensate, its refined products and other hydrocarbon fluids can be used as hydrocarbon solvents. Instead of hydrocarbon solvents, oil-dissolving solvent made on the basis of surfactants mixture and chemical reagents can be used.

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