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Study of the movement of unstable water-oil emulsions in the field

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Abstract. High rates of oil production require finding ways to improve the efficiency of wells.

The analysis shows that in oil and gas condensate fields, marginal and bottom formation waters often break through to the bottom of the well. Wells are gradually flooded, which leads to the formation of oil emulsions.

The motion of emulsion unstable systems in the field has a number of important features, the knowledge of which is necessary for the correct solution of the problem of increasing the efficiency of collecting oil, gas and water.

Keywords: emulsion systems, volume-flow water content, power model, shear stress.

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1. Introduction. High rates of development of oil production in the Azerbaijan Republic, large investments require finding ways to improve the efficiency of wells. This approach makes it possible to apply all new scientific achievements in the area of hydrocarbon production technology in the design and development of oil and gas fields. The application of these studies ensures the maximum use of reservoir energy during the production and transport of multiphase and multicomponent systems.

The construction of large, centralized points for the separation of oil and water instead of small ones makes it possible to drastically reduce the cost of hydrocarbons and oil losses, improve the quality of its preparation and carry out deeper purification of formation water, which plays a huge role from an environmental point of view.

In the process of the accelerated rate of operation of oil and gas condensate fields, the marginal and bottom formation waters break through to the bottom of the well [1]. Due to the presence of surfactants in formation waters [2], as well production is flooded, the formation of water-oil emulsions is observed in reservoir conditions. Currently, about 70% of oil wells in the world are flooded to varying degrees. At the same time, a rheologically complex gas-liquid mixture - a water-gas-emulsion system - moves in the reservoir, lifter and in the pipeline. Therefore, a further increase in the efficiency of oil production, taking into account the hydrodynamic features of emulsion systems, is an urgent task [3].

The movement of emulsion unstable systems in field communications has a number of important features, the knowledge of which is necessary for the correct solution of the problem of increasing the efficiency of oil production.

It should be noted that the viscosity of water-oil emulsions is an order of magnitude higher than the viscosity of its constituent components, i.e. oil and water. Thus, we have the right to assert that the application of the additivity rule in assessing the viscosity of oil-water emulsions will be erroneous. On

the other hand, the results of experimental studies show that the coarsening of drops in a turbulent flow of unstable emulsions not only facilitates the subsequent dehydration of oil, but also leads to a decrease in hydrodynamic resistance due to damping of turbulent pulsations of the dispersion medium by drops of the dispersed phase [4, 5].

According to laboratory data, oil-water emulsions are non-equilibrium systems that are constantly in motion in the elevator, pump, and pipelines, tend to reach a state of equilibrium. However, as field observations have shown, the stability of such systems can occur after a few seconds and in some cases even after a long time.

Laboratory studies of emulsion systems have shown that the main physical properties of stable oil emulsions are the density, viscosity and dispersion of the system. However, the methods of hydrodynamic calculation of the dispersity of stable emulsions have not been fully studied, only methods for its experimental determination have been developed. The situation is more complicated with the determination of the viscosity of stable emulsions. It should be noted that only for very dilute emulsions with a dispersed phase content of less than 0.05, the dynamic viscosity of the emulsion could be described quite well by the Einstein equation [5].

To solve numerous problems of field technology in the conditions of an oil lift, a laboratory installation was designed and manufactured, consisting of pumps, tanks, a linear part of the pipeline, a shut-off device and measuring equipment. The container makes it possible to obtain stable emulsions using a laboratory mixer.

The linear part consists of a horizontal pipeline with a diameter of 0.025 and a length of 5 m, the side connections are made of rubber-fabric sleeves. The temperature of the pumped water-oil system was measured using laboratory thermometers, the flow rate of individual components was measured using a volumetric meter. The pressure drop was measured with a differential pressure gauge. Before measuring emulsion systems, calibration of measuring instruments is carried out on the basis of a homogeneous liquid. The phase concentration and viscosity of the emulsion were measured using capillary viscometer-samplers, which make it possible to take samples and determine the viscosity of the emulsion directly in the flow at any point in the pipeline section.

To prepare an emulsion of the required composition, the calculated amount of constituent components is loaded into the container. Then the mixture is pumped through the container into the linear part until a homogeneous emulsion is obtained. A homogeneous emulsion is formed approximately 1–2 hours after the start of pumping. The next step is to set up the devices. In 20–30 minutes after the mode is established, the hydrodynamic characteristics of the flow of formation water and oil are measured (Figure 1).

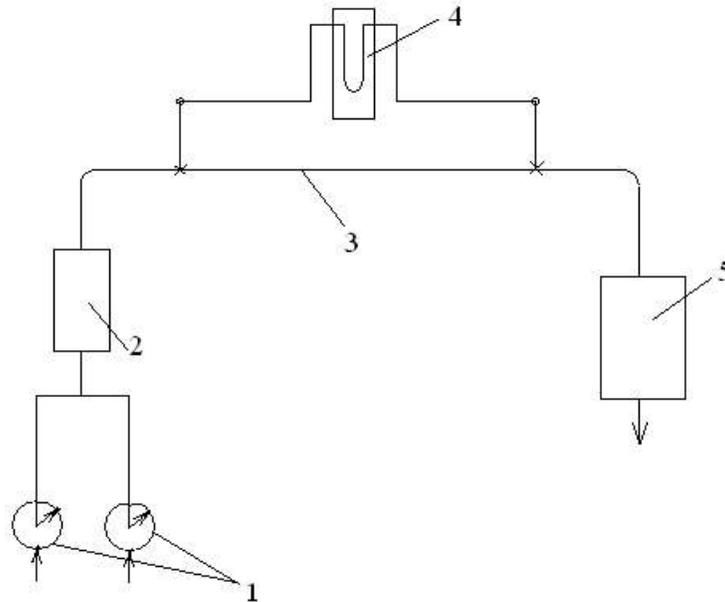


Figure 1. Experimental setup:

- 1 - liquid flow meters;
- 2 - mixer;
- 3 - working area;
- 4 - differential pressure gauge;
- 5 - collection container.

This installation makes it possible to obtain the following hydrodynamic characteristics of the emulsion flow in the pipeline:

- to measure hydraulic resistance;
- to distribute the concentration and viscosity of the emulsion;
- to measure the dispersion of the emulsion.

As a result of the research, three structures of the emulsion flow were determined (by analogy with gas-liquid systems): homogeneous water or oil; oil-water mixture; oil and water system.

2. Methodological part. Dependence (Figure 2) can be written as

$$\tau = \left(\mu_s \frac{dv_s}{dr} \right)^n \tag{1}$$

where μ_s is the dynamic viscosity of emulsion systems;

$\frac{dv_s}{dr}$ is the velocity gradient of the emulsion system;

n coefficient taking into account the water cut of the system.

By solving equation (1) with respect to velocity or flow rate, this parameter can be determined with respect to water cut. We accept, according to the general laws of hydrodynamics, that the shear stress depending on the pressure drop has the form

$$\tau_s = \frac{r\Delta P}{2L} \quad (2)$$

where ΔP is the pressure drop; r is the required radius; L is the length of the section in which the emulsion moves.

Solving equations (1) and (2) together, we have:

$$dv_s = \frac{1}{\mu} \left(\frac{r\Delta P}{2L} \right)^{\frac{1}{n}} dr \quad (3)$$

but about the speed

$$v = \frac{1}{\mu_s} \left(\frac{\Delta P}{2L} \right)^{\frac{1}{n}} \frac{n}{n+1} \left(R^{\frac{1+n}{n}} - r^{\frac{1+n}{n}} \right) \quad (4)$$

If $n = 1$, we have the Stokes formula. Deciding on the flow, we have:

$$Q = \frac{n}{3n+1} \frac{\pi}{\mu} \left(\frac{\Delta P}{2L} \right)^{\frac{1}{n}} R^{\frac{3n+1}{n}} \quad (5)$$

At $n = 1$, we have the Poiseuille equation for a homogeneous liquid.

3. Results and discussion.

The analysis showed that it is convenient to plot the experimental data as a function of the shear stress versus the velocity gradient (Figure 2).

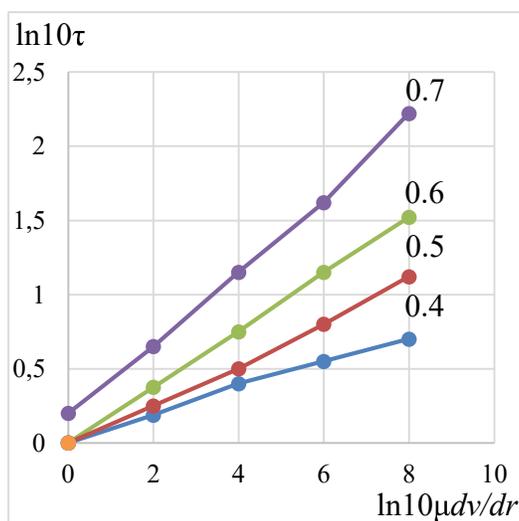


Figure 2. Dependence of the shear stress on the velocity gradient for given water cuts.

4. Conclusion. 1. An experimental setup was assembled under field conditions and the results obtained were processed by the grouping method depending on the water cut. 2. The results of bench experiments formed the basis of the model for emulsion systems, taking into account the varying degree of water cut in well production. 3. Based on the results of experimental studies, equations were obtained for determining the speed and flow rate of the system, which in a particular case are converted into the Stokes and Poiseuille equations.

Conflict of interest.

The authors declare that they have no conflict of interest in relation to this research.

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