AZƏRBAYCAN RESPUBLİKASI ELM VƏ TƏHSİL NAZİRLİYİ
AZƏRBAYCAN DÖVLƏT NEFT VƏ SƏNAYE UNİVERSİTETİ

MINISTRY OF SCIENCE AND EDUCATION
REPUBLIC OF AZERBAIJAN
AZERBAIJAN STATE UNIVERSITY OF OIL AND INDUSTRY

“NEFTİN, QAZIN GEOTEXNOLOJİ PROBLEMLƏRİ VƏ KİMYA”
ELMİ-TƏDQİQAT İNSTİTUTUNUN

ELMİ ƏSƏRLƏRİ

SCIENTIFIC PROCEEDINGS

SCIENTIFIC RESEARCH INSTITUTE

“GEOTECHNOLOGICAL PROBLEMS OF OIL, GAS AND CHEMISTRY”

VOLUME 23 Number1

BAKU-2023

ISSN 2218-5054

Scı. Proc. SRI GPOGC. 2023. Volume 23, Number 1

Contents

Research of rheological characteristics of two-phase systems

T.S. Babayeva

Scientific Research Institute of Geotechnological Problems of Oil, Gas and Chemistry, ASOIU, 227 Dilara Aliyeva Ave., Baku, AZ-1010 Azerbaijan

Abstract.

Field practices shows that many wells that produce oil, gas and condensate in the final period watered. In this case, in the lift, in the pipeline, the capacitive system moves two-phase system, such as “water-oil”.

Conducted a large literary analysis showed that insufficiently studied hydrodynamics of two-phase systems.

In this paper, based on laboratory and field data, proposed a new movement model emulsion systems. It was proposed a method for determining the basic indicators such systems. On the basis of this method, it was receipted a formula for determining the dynamic viscosity of such systems.

Keywords: emulsion, two-phase system, shear stress, velocity gradient, watercut.

Corresponding author. Tel.: +994 55 767 64 16

E-mail address: tamilla.babaeva.85@mail.ru

1. Introduction.

On the basis of laboratory studies, a mathematical equation for the movement of emulsion systems “water-oil” is proposed, in a wide range of changes in the water cut of the formation production. Taking into account this design scheme, expressions are proposed for determining the main indicators of emulsion systems, such as average speed, volumetric content of components, as well as the dynamic viscosity of the “water-oil” system.

In the technological processes of oil production, pipeline transport and processing, as a rule, there is a flow of a two-phase system (oil and formation water). Due to the fact that reservoir water is enriched with various surfactants during filtration in a porous medium [1], favorable conditions are created for the formation of direct and reverse water-oil emulsions in reservoir conditions, between which conversion is observed. In theoretical studies of these systems, methodological difficulties arise, the elimination of which is associated with the adoption of a number of assumptions both when considering the liquids themselves and when compiling models [5÷7].

The results of studies by domestic and foreign authors show that, in contrast to viscosity, when estimating the density of emulsion systems, it is possible to use the additivity rule [3, 4].

This uses the known values of the density of oil and water that form the emulsion, and their relative content. Other properties of stable emulsions depend to a greater extent on the conditions of their formation and the composition of the adsorption shell on the drops of the disperse medium.

Many authors note that there is still no more accurate method for calculating the dispersion of stable emulsions, and only methods for its experimental determination have been developed. It is difficult to determine the viscosity of stable emulsions. Only for very dilute emulsions (with a dispersed phase content of less than 0.05), it is sufficient to describe the dynamic viscosity of any emulsions by the Einstein equation [7].

With an increase in the content of the dispersed phase, the armoring shells on the drops affect the volume of the dispersed phase and the coagulation of the drops with the formation as a result of their merger.

In hydrodynamic calculations, it is impossible to take into account these factors and lead to the need to study the viscosity of oil-water emulsions of individual reservoirs and deposits. This requires obtaining numerous empirical formulas for the viscosity of stable emulsions, which have certain coefficients that must be determined empirically.

Some authors offer empirical formulas in a small range of the content of an individual phase or component [5,6,7].

In this work, the hydrodynamic properties of stable and unstable emulsions of the "water-oil" and "oil-water" types are investigated.

An unstable emulsion is a two-phase dispersed system consisting of two mutually insoluble liquids, so that one of them is distributed in the other in the form of droplets, on the surface of which there are no strong stabilizing shells. It should be noted that in stable emulsions, formation water itself has a stabilizing shell [2].

The conducted laboratory analyzes have shown that an unstable emulsion is formed in the turbulent regime of motion of at least one of the phases separately. Formation water has multimolecular layers of surfactants on the interface, which partially do not prevent crushing or coalescence of drops of one of the components. The first such proposal was made by Academician A.Kh.Mirzajanzade in 1948.

Our laboratory studies have shown that only with the steady motion of unstable emulsions of the "oil-water" type, a dynamic equilibrium is established between the processes of coagulation and crushing. During the transition to the laminar regime of motion of one of the phases or both phases, the separation of the constituent phases occurs [2].

An unstable emulsion is characterized by non-equilibrium rheological properties and dispersion. At the same time, it was found that simultaneously with the transition of laminar motion to turbulent, the nature of the distribution of velocities over the pipe section, as well as the nature of hydraulic resistance, change. The analysis showed that in the laminar regime of motion of emulsion systems, the distribution of velocities over the cross section has a parabolic character. It should be noted that the velocities are equal to zero directly at the walls, and as they move away from them, they continuously and smoothly increase, reaching a maximum on the pipe axis.

2. Methodological part.

Processing the experimental material, the authors came to the conclusion that, similarly to the phenomenon of shear in solids, the following relationship between stress and strain for emulsion systems was obtained:

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

where τ is the tangential shear stress;

μ is the dynamic viscosity of the emulsion system;

$\frac{du}{dr}$ is the speed gradient.

Considering that

$$\tau = \frac{r}{2}\frac{\Delta P}{L} \tag{2}$$

solving together equation (1) and (2) with respect to speed we have:

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

where r is the radius;

ΔP is the pressure drop;

L is the length of the area under consideration.

Integrating the differential equation, we get:

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

If $n = 1$, we have the Stokes equation.

The emulsion flow rate in the pipe can be found by summing up the elementary flow rates passing through the annular platforms and described by the following expression:

$$Q = \int_0^R v \cdot 2\pi r dr \quad (5)$$

Substituting its value instead of speed (4) and integrating, we get:

$$Q = \frac{\pi}{\mu}\left(\frac{\Delta P}{2L}\right)^{\frac{1}{n}} \frac{n}{3n+1} R^{\frac{3n+1}{n}} \quad (6)$$

For $n = 1$, from this equation we have the Poiseuille equation.

The average speed of emulsion systems is defined as

$$v_a = \frac{Q}{\omega} = \frac{1}{\mu}\left(\frac{\Delta P}{2L}\right)^{\frac{1}{n}} \frac{n}{3n+1} R^{\frac{n+1}{n}} \quad (7)$$

where ω is the cross-sectional area of the round pipe.

Solving this equation with respect to dynamic viscosity, we have:

$$\mu = \frac{n}{3n+1} \cdot \frac{\pi}{Q}\left(\frac{\Delta P}{2L}\right)^{\frac{1}{n}} R^{\frac{3n+1}{n}} \quad (8)$$

where n is a coefficient that depends on the water cut of the product.

To compare this formula and the calculation method with laboratory data, the measured dynamic viscosity was compared with the calculated one obtained by formula (8).

3. Results and discussion.

As can be seen from the graph, with a correlation coefficient of 0.88, with an average deviation of ±3%, the data fit well on a straight line with a slope of 45°, which shows the practical acceptability of this method for calculating the main indicators of water-oil emulsionsystems (Figure 1).

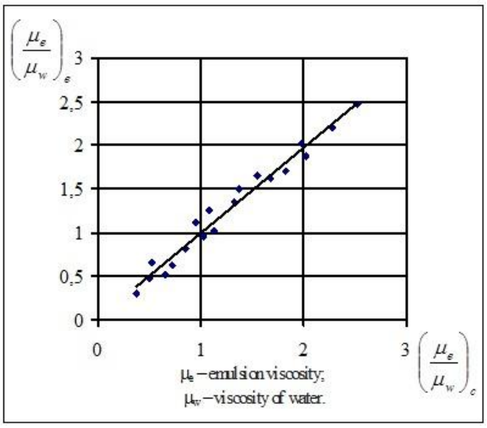

Figure 1. Comparison of laboratory data with calculated data

$\left(\frac{\mu_e}{\mu_w}\right)_e$ and $\left(\frac{\mu_e}{\mu_w}\right)_c$ – are the experimental and calculated value of the dimensionless viscosity.

1. Conclusion.

A method and model of emulsion systems during their movement in tubing and pipelines are proposed.The use of this method makes it possible to control the conditions for the formation and separation of direct and reverse emulsions in various technological processes.

Conflict of interest

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

2. References

1. Mirzajanzadeh A.Kh. The expediency of preparing clay solution based on groundwater. // Azerbaijan Oil Industry. 1948. No. 11. P. 10-13 [in Russian].
2. Babayeva T.S. Non-traditional methods of determination of rheological parameters of water-oil emulsions and their consideration// Scientific Research Institute of Geotechnological Problems of Oil, Gas and Chemistry, "Scientific works", Baku - 2021.Volume XXI. P. 277-281[in Russian] .
3. Emtsev B.T. Technical hydromechanics // M.: Mashinostroenie, 1978. - 463 p.
4. Loitsyansky L.G. Mechanics of liquids and gases // 3rd ed. - M.: Nauka, 1970. - 904 p [in Russian].
5. Mansurov M.N. Research of transportable properties of oil-water emulsions// Ufa, 1977. - 132 p.
6. Chugaev R.R. Hydraulics. - L.: Energoizdat, 1982. - 682 p . [in Russian]
7. Emulsions. Textbook for high schools. Ed. F. Sherman//L.: Energoizdat, 1982. - 235 p [in Russian].