Rheological studies of waterproof polymeric compounds under high pressure and temperature

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Abstract. In the article there are presented results of rheological studies of waterproof polymeric compounds at reservoir thermobaric conditions (high pressure and temperature). The carried-out complex of research showed that the addition of nonionic surface-active agent with hydrophobic properties provides improvement of rheological characteristics of the initial polymeric structure (decrease of critical shear stress and effective viscosity), and this action will remain at reservoir conditions (with elevated pressure and temperature). The developed polymeric compound is brought to industrial production and it is recommended to application at oilfields with low-permeable collectors.

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Keywords: polymeric compound, water cut, waterproof, surface-active agent, effective viscosity, critical shear stress, rheology, flow curve, reservoir thermobaric conditions, high pressure, high temperature.

Introduction

The considerable share of producing oil fields is subject to water breakthrough and a premature water cut rise. The problem of high water cut of well production is observed practically in all oil-extracting regions of the globe. In the world about 33 million m^3 of water are daily extracted, thus expenses for water utilization are rather high: on the average from 5 to more than 50 cents for 1 barrel of water [1].

In oil companies situations when unprofitable drowned wells prematurely stop are rather frequent, and missing oil production is compensated at the expense of other high rate wells which are maintained with violation of requirements of design documents. As a result of such a disbalance in the development system there are additional water breakthroughs that lead to decrease in oil recovery and blocking of oil reserves in pores [1, 2].

One of the most effective methods directed at reduction of water cut and stabilization of oil production is influencing a reservoir by the flow deviation technologies. Water pumped into a reservoir after carrying out such a processing arrives in not flooded zones increasing sweep efficiency and involving blocked oil reserves in exploitation. Technology of carrying out such a processing was studied by many scientists and it is now efficiently used by oil companies [1-9].

Efficiency of these actions in many respects is defined by an appropriate choice of a waterproof compound. A large amount of reagents and compositions is known, however, despite all variety, under field conditions (for various reasons) no more than ten of them are used [2]. One of the most promising technologies relies on the gelation of polymers in reservoir conditions at which gel creates barriers and screens with high filtrational resistance [7-9].

There are some disadvantages of polymeric waterproof compounds: low penetration ability, instability in reservoir conditions, toxicity and high cost. Elimination of these shortcomings can essentially increase competitiveness of this way of water isolation [2].

In this article there are presented results of rheological studies of waterproof polymeric compounds at reservoir conditions (high pressure and temperature). Water-alkaline solutions of the hydrolyzed acrylic polymer with an addition of the nonionic surface-active agent (surfactant) with hydrophobic characteristics were chosen as objects of the research.

The choice of the high-molecular composition and the surfactant as the basis of the developed compound is explained by the unique ability of the first to vary in a wide range of the structural and mechanical properties and of the second to regulate them by changing the intensity of polyelectrolytic interaction [10].

It is widely known that properties of polymeric structures depend on temperature, however their explorations at high pressure cause great difficulties that often do not allow to make experiments with a complete simulation of the reservoir thermobaric conditions.

Technique

Studies of rheological properties of waterproof polymeric structures in reservoir thermobaric conditions were carried out at the unique automated rheometer (Physica-MCR) with use of a special cell for measurements under high pressure and

temperature (fig. 1) that has allowed to carry out tests with the complete simulation of the reservoir conditions.

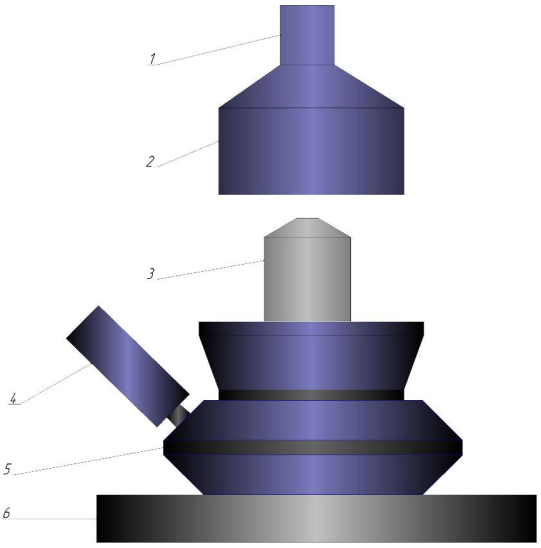

Figure 1 – Scheme of the cell for high pressure and temperature measurements Physica-MCR (Anton Paar)

The method of research of rheological properties under pressure used in rheometer is based on creation of high pressure in the capsule (3) with a studied liquid. The rotary motion from the electric motor is transferred through the shaft (1) and the magnetic coupling (2). High pressure is created by supply of gas (nitrogen) in the capsule (3) through the valve (4). All system is fixed on the table (6). Maintenance of the set temperature is provided with the heat-carrier circulation in the pillow (5) round the capsule (3) with a studied liquid.

For differentiation of the factors (reservoir pressure and temperature) influencing rheological properties of the studied structures at the first stage experiments with serial simulation of one of the factors were made: in the first case – the temperature increases from 20 to 80 °C at the constant atmospheric pressure, in the second case – the pressure increases from atmospheric to 20 MPa at the constant temperature of 20 °C. The experiment with simulation of both factors (temperature of 80 °C and pressure of 20 MPa) was the final stage of the research. The experiments were carried out both for the initial polymeric structure and for the polymeric structure with an addition of the nonionic surfactant with hydrophobic characteristics at the smooth increase in the shear stress from 0 to 10 Pa during 300 seconds.

Main body

The results of the research of rheological properties of the polymeric structures which have been carried out by the 1st method, are presented in drawing 2. As you can see on the graph, the surfactant and temperature differently influence rheological characteristics of samples of the polymeric structure. The surfactant plastifies the submolecular structure reducing its durability. Thus the observable effect hardly depends on temperature. Temperature is a factor of a wider action, reducing rheological indicators of a flow at stages of not destroyed and destroyed structure. This is a positive effect which reduces hydrodynamic resistance of the polymeric compound at the stage of penetration into porous medium of reservoir.

An important consequence of the described experiments is definition of the type of the submolecular structure. An existence of S-shaped sites with a negative tilt angle on the flow curve of the polymeric compound indicates a mode of viscoelastic rheological bodies where decrease in the shear stress results in the sharp increase in the shear rate [10-12].

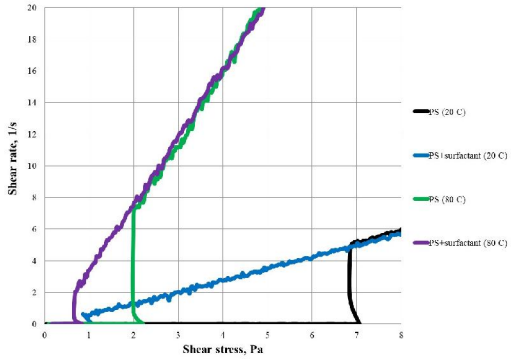

Figure 2. Polymeric structures ("PS" and "PS+surfactant") flow curves at atmospheric pressure and temperature of 20 and 80 °C

The comparison of the results at atmospheric and high pressure shows that extent of influence of this factor is much less and the character of the flow does not change (fig. 3). The presence of the surfactant decreases the effective viscosity of the polymeric compound at a stage of submolecular structure destruction.

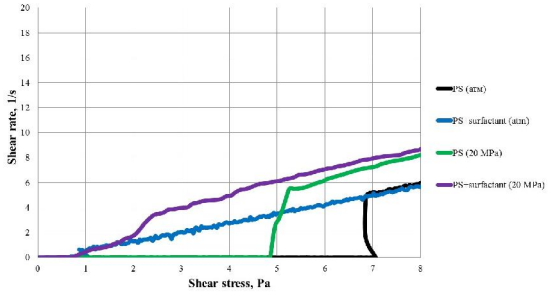

Figure 3 – Polymeric structures ("PS" and "PS+surfactant") flow curves at atmospheric and high pressure and temperature of 20 °C

The carried out research of the developed waterproof compound at reservoir thermobaric conditions has shown (fig. 4) the defining role of the temperature factor. Some decrease in the rheological properties at the stage of destruction of the submolecular structure in comparison with the data of the one-factor experiments suggests that the considered sample will show high penetrating and water isolating properties in operational (reservoir) conditions.

From the provided data also follows that there is a possibility of regulation of rheological properties by using the surfactant in different concentrations.

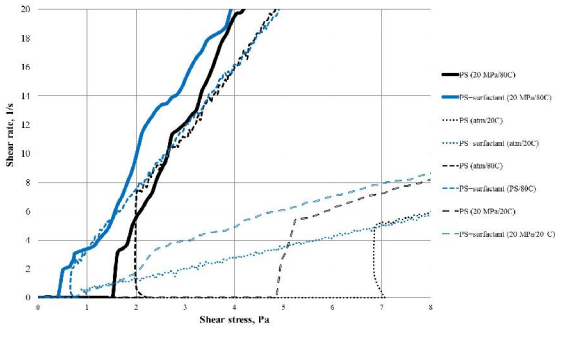

Figure 4 – Polymeric structures ("PS" and "PS+surfactant") flow curves at reservoir thermobaric conditions (pressure of 20 MPa and temperature of 80 °C)

Conclusions

1) The new polymeric waterproof compound (water-alkaline solutions of hydrolyzed acrylic polymer with an addition of the nonionic surface-active agent with hydrophobic characteristics) is developed for water isolation in low-permeable heterogeneous reservoirs.

2) Results of rheological studies with the simulation of reservoir thermobaric conditions allowed to reveal and estimate influence of these factors on structural-mechanical and functional properties of the developed waterproof polymeric compound.

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