INTERNATIONAL JOURNAL OF POLITICAL SCIENCES AND ECONOMICS
Impact Factor (research bib) - 9,78
https://ijmri.de/index.php/ijpse , German international journals company
ISSN 2751-9708

USE OF SURFACTANTS FOR INTENSIFICATION OF OIL PRODUCTION DURING PRIMARY AND SECONDARY FORMATION PENETRATIO

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Abstract: A complex study of surface-active substance SCA containing Neonol AF 9-12 - oxyethylated monoalkylphenol as a nonionic surfactant has been performed. It is shown that the SCA does not interact with the deposit water, shows demulsifying properties, reduces the interfacial tension to ultralow values, adsorbs slightly on the core. The effects of ionic strength and nature of electrolyte on the surface properties of surfactant have been studied. The composition of the punching liquid for secondary access technologies based on the surface-active substance SCA-515 and an aqueous solution of potassium chloride has been found. Researches of the designed punching fluid have shown its high inhibitory ability, compatibility with formation fluid and mud filtrate. Industrial (Peschanoozerskoe field) tests have shown high efficiency of surfactants: flow rates increasing, the term reduction of well development and decrease of skin effect.

Key words: drilling fluids, surface-active reagents, surfactants, oil production, perforation fluid.

Аннотация: Проведено комплексное исследование поверхностно-активного вещества SCA, содержащего в качестве неионогенного ПАВ Неонол АФ 9-12 - оксиэтилированный моноалкилфенол. Показано, что SCA не взаимодействует с пластовой водой, проявляет деэмульгирующие свойства, снижает межфазное натяжение до сверхнизких значений, слабо адсорбируется на керне. Изучено влияние ионной силы и природы электролита на поверхностные свойства ПАВ. Найден состав перфорационной жидкости для технологий вторичного доступа на основе поверхностно-активного вещества SCA и водного раствора хлорида калия. Исследования разработанной перфорационной жидкости показали ее высокую ингибирующую способность, совместимость с пластовым флюидом и фильтратом бурового раствора. Промышленные (Песчаноозерское месторождение) испытания показали высокую эффективность ПАВ: увеличение дебитов, сокращение сроков освоения скважин и снижение скин-эффекта.

Ключевые слова: буровые растворы, поверхностно-активные реагенты, ПАВ, добыча нефти, перфорационная жидкость.

Introduction: Analysis of oil production practices and the results of scientific studies convincingly shows that the potential productivity of wells is directly related to the quality of work during their completion. In recent years, during the development of oil fields, areas with complex geological and technical conditions have been drilled more and more often, while productive horizons have low reservoir properties and abnormally low reservoir pressures, which predetermines increased requirements for the choice of completion technologies and, in particular, for the issues of primary and secondary penetration of productive formations.
The main cause of damage (contamination) of pay zones is successive penetration of water-based process fluids - drilling mud filtrates, cement slurry and perforation fluid. Studies have shown

that the permeability of reservoir rocks decreases to the greatest extent under the influence of mud filtrate. The reasons for the decrease in the permeability of formations in the zone of penetration of filtrates of process liquids are diverse These include:
- swelling of clay minerals contained in the formation;
- formation of emulsions during partial displacement of formation fluid

Penetration of filtrates into the formation can occur not only under the influence of the pressure drop "well-formation," but also under the influence of capillary pressure in the case when the walls of pore channels are hydrophilic. Obviously, capillary pressure, by promoting filtrate penetration into the porous medium, prevents its displacement from the pores of the formation during operation, blocking part of the pores and thereby reducing the permeability of the porous medium. In addition, oil-water emulsions may be formed to prevent the movement of formation fluid.

The capillary pressure value according to Laplace's formula is:

РК = 2a ≈ cos 0/r,

where a - interfacial tension, 0 - wetting angle, r - capillary radius.

Capillary pressure should be reduced to facilitate removal of penetration products from the bottomhole zone and improve oil filtration conditions.

Therefore, to achieve high-quality drilling-in of oil formations, it is necessary to reduce the surface tension at the "solution filtrate - formation fluid" boundary by using surface-active substances (SAS), and to reduce surface wetting with water and to increase surface wetting with hydrocarbons (increase the wetting angle) by using water repellents.

The most radical means of preventing contamination of the bottomhole formation zone is to use hydrocarbon-based solutions as process fluids when drilling in productive horizons. However, due to their high cost, increased environmental hazard, fire hazard, and a number of other reasons, these solutions have limited application. The use of inverse emulsions in drilling and oilfield practice is expanding.

It should be noted that water-based process fluids are most widely used in well completion technologies during primary and secondary formation drilling. Reduction of their negative impact on the natural reservoir properties of the oil-bearing formation is achieved by introducing nonionic and anionic surfactants into the composition; under certain conditions, the use of cationic surfactants is optimal. Surfactants used during formation drilling and treatment must meet the following basic requirements.
- dissolve in formation and process water;
- have high surface activity, reduce the interfacial tension at the "solution filtrate - oil" boundary to 3^5 mN/m, at least;
- be slightly adsorbed on the surface of rocks;
- prevent swelling of clay rocks;
- lead to hydrophobization of the interstitial surface of the reservoir;
- prevent the formation of an emulsion in the bottomhole zone of the formation, and if it does form, reduce its stability;
- do not have a negative effect on the properties of process fluids;
- do not enter into chemical interaction with formation fluids and reservoir minerals with precipitation of insoluble sediments;
- be safe to operate, low-toxic and have no negative impact on the environment.

Obviously, from all the variety of synthetic surfactants, it is still difficult to find those that would meet all the necessary requirements at the same time. Therefore, when developing process fluids (drilling muds, cement slurries and perforation fluids), a surfactant is selected that meets more significant requirements; mixtures of surfactants are used quite often.

One of the defining stages of well completion is the secondary opening of productive formations. Secondary opening consists not only in the formation of a hydrodynamic connection between the formation and the well by means of perforation channels, but also in overcoming the negative consequences of the primary opening and casing of the well. In this work, the authors pursued the goal of significantly reducing the negative impact of perforation fluids on productive formations and achieving a reduction in development time and high flow rates of anhydrous oil without significantly changing the perforation processes due to the optimal selection of chemical treatment of water-based process solutions. One of the ways to increase well productivity is to use an effective perforation fluid, which allows not only to facilitate the process of well development after formation suppression, but also to partially restore the productivity coefficient. The task set in the work was to develop a perforation fluid formulation to improve the quality of secondary formation opening based on aqueous solutions of complex-action surfactants in presence of low-molecular electrolytes.

The developed perforation fluid was tested during secondary opening of productive formations at the Peschanoozerskoye field.

According to its geological structure, the Peschanoozerskoye field belongs to complex, uneven in area and size, pore-type reservoirs with numerous small oil and gas deposits. The depth of occurrence of productive horizons varies from 1300 to 1800 m, the thickness of the reservoirs - from 1 to 15 m, formation pressures are close to hydrostatic. The material composition of the reservoir rocks is represented mainly by sandy, clayey siltstones with interlayers of weakly cemented sandstones. In addition to the complex mineral composition, the rocks are distinguished by a significant content of montmorillonite in the clay cement, which has the property of swelling when in contact with fresh water, thereby reducing the filtration capacity of the reservoirs. The open porosity of the reservoirs is on average 20-32%, and in terms of permeability the reservoirs are classified as medium-permeable.

Objects and methods of research

Objects of research - reagents of complex action, which include surfactants:

Determination of adsorption of surface-active reagents from a solution on the surface of the core material was carried out by the static method. Specific adsorption A was calculated by the formula:

$A = tPKD / t = (C0 - C) V / t$,

where tPKD is the mass of the adsorbate (PCD-515), adsorbed on the core; t is the mass of the adsorbent sample (core); Co, C are the concentrations of PCD-515 solutions before and after adsorption, respectively; V is the volume of the PCD-515 solution taken for adsorption. The adsorption isotherm was described by the Freundlich equation:

$A = K \blacksquare Cn$,

where A is the specific adsorption; C is the equilibrium concentration of PCD-515 (surfactant) after adsorption; K, n are constants.

The concentrations (Co, C) of PKD-515 solutions were determined using the Shenfeld method (precipitation with ferricyanide acid). This method for analyzing non-ionic surfactants in this case gives good results, since the main active component of the PKD-515 reagent is a non-ionic surfactant - oxyethylated alkylphenol (neonol AF 9-12). The average relative error of the method for adducts containing more than 9 oxyethyl fragments does not exceed 5% with a confidence level of 0.95.

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The swelling value of benthoglay powder in potassium chloride and calcium chloride solutions was determined using an improved Zhigach-Yarov device.

The compatibility of the perforation fluid with the formation fluid and the drilling mud filtrate was studied photometrically on a KFK-3 spectrophotometer. The demulsifying capacity of surfactants was determined by studying the stability of emulsions (oil/water) depending on the concentration of the dispersed phase.

Results of the study Surface and interfacial tension

Isotherms of surface (at the boundary with air) and interfacial (at the boundary with hydrocarbon and oil) tension are shown in Fig. 1. The experiments showed that the reagents PKD-515 and containing complex surfactants approximately equally reduce the surface tension of water to 31.0 mN/m in the case of PKD-515 and to 26.5 mN/m. (Fig. 1a). At the interfacial boundary with hydrocarbon (Fig. 1b), the most effective additive is PKD-515, which reduces the interfacial tension to ultra-low values of σ < 1.5 mN/m at SPCD > 0.3%. It should be noted that at the water/heptane boundary σ = 50.85 mN/m. In this case, the surface activity of PKD-515 is 2.29 x 10-2 Nm2/kg, and the surface activity is 1.37 x 10-2 Nm2/kg, which also indicates the high efficiency of PKD-515 at the interphase boundary with the hydrocarbon. The work also studied the combined effect of surfactants in their mixed solutions - on the decrease in interfacial tension with a wide variation in the ratio of components. As an example, Fig. 1 shows the isotherms of the interfacial tension of surfactant mixtures. As can be seen from Fig. 1 a, the interfacial tension of the mixture at a constant concentration of the additive and a change in concentration from 0.05 to 0.4% changes insignificantly, decreasing from 4.2 to 1.0 mN/m. These values \u200b\u200bcorrespond to a solution without additive. At the same time, as shown in Fig. 2b, the minimum value of σ, equal to 1.0-0.9 mN/m, was achieved in almost all cases at different concentrations and the concentration of PKD-515 from 0.2 to 0.4%. Thus, the interfacial tension of mixed aqueous solutions is determined exclusively by adsorption.

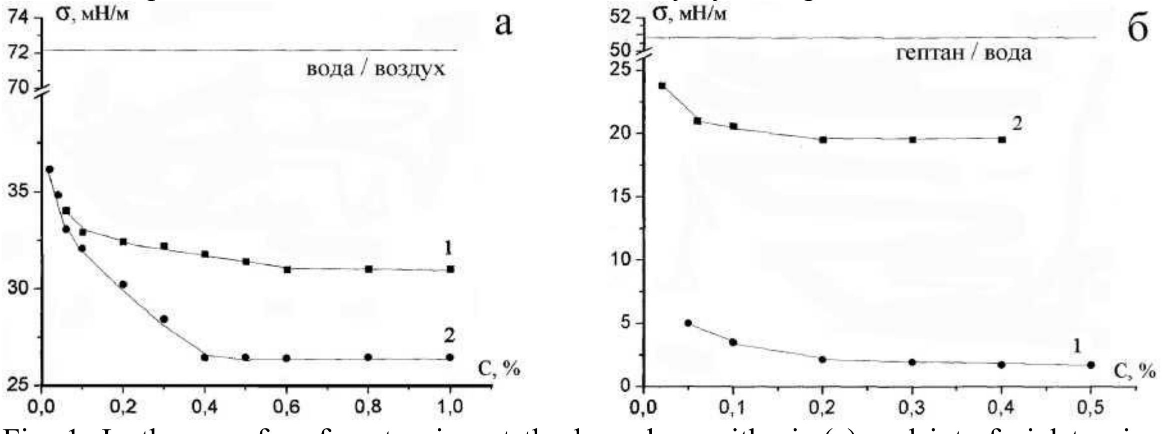

Fig. 1. Isotherms of surface tension at the boundary with air (a) and interfacial tension at the boundary with heptane (b) of surfactant solutions: PKD-515 (1), "Sonbur-1101" (2) at t = 24°C.

Fig. 2. Dependence of interfacial tension at the boundary with heptane

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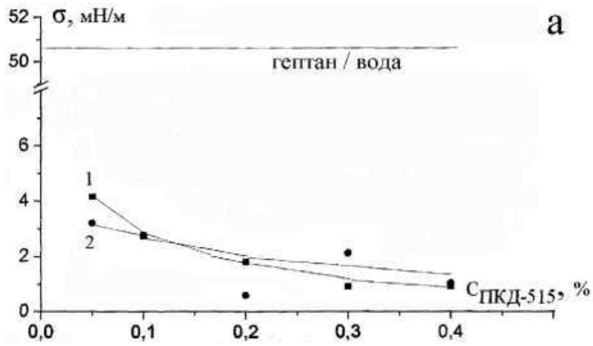

of mixed solutions of PKD-515 and "Sonbur-1101" on concentration:
The perforation fluid contains a low-molecular electrolyte. As is known, ionic strength has a certain effect on the adsorption value of surfactants and surface tension. Therefore, in the work below, we investigated the decrease in surface and interfacial tension of solutions in the presence of CaCl2 and KCl. The range of salt concentrations was determined by the required density p of the perforation fluid (p = 1.05-1.10 g/cm3) and was from 9 to 12% for CaCl2 and from 8 to 16% for KCl. Fig. 3 shows the surface tension values of solutions in the presence of potassium chloride. As expected, with an increase in the concentration of KCl, the surface tension of the solutions increases slightly at low concentrations of PKD-515 and remains virtually unchanged at high concentrations. For example, at SPKD = 0.2%, the surface tension increases from c = 31.7 mN/m at SKa = 8% to a = 33.4 mN/m at SKa = 16%. At a high surfactant concentration SPKD = 1.0%, a = 31.2 mN/m and does not change with a change in the SKC1 concentration in the range from 8 to 16%. Similar results were obtained in studying the surface tension of PCD-515 solutions in the presence of calcium chloride. The interfacial tension a of an aqueous solution at the boundary with heptane in the presence of KO and CaCl2 was measured. In the presence of mineral salts, the solutions also effectively act at the water/hydrocarbon interphase boundary, reducing the interfacial tension to ultra-low values of a < 1.5 mN/m. It should be noted that in the presence of KO, the interfacial tension decreases to 0.5 mN/m at SPCD> 0.4%, which is slightly lower compared to CaCl2, in the presence of which a decreases to a maximum of 1.5 mN/m at SPCD> 0.6%. Thus, according to the results of measuring the surface and interfacial tension, the most promising from the point of view of use in the composition of perforation fluids are PKD-515 solutions in the presence of KCl electrolyte.

Results: The results of the study of emulsions based on mixtures of oil (oil from the Peschanoozerskoye field) and aqueous solutions of in the presence of KCl, obtained at different volume ratios of the oil and water phases, are shown in Fig. 3 a as an example. The type of the resulting emulsion: oil/water or water/oil depends mainly on the ratio of the phase volumes, as well as on the temperature and interfacial tension at the boundary of the aqueous phase with oil. To characterize the demulsifying capacity of PKD, the stability of the emulsions to coalescence was determined by measuring the volumes of the separated liquid phases: water and oil.

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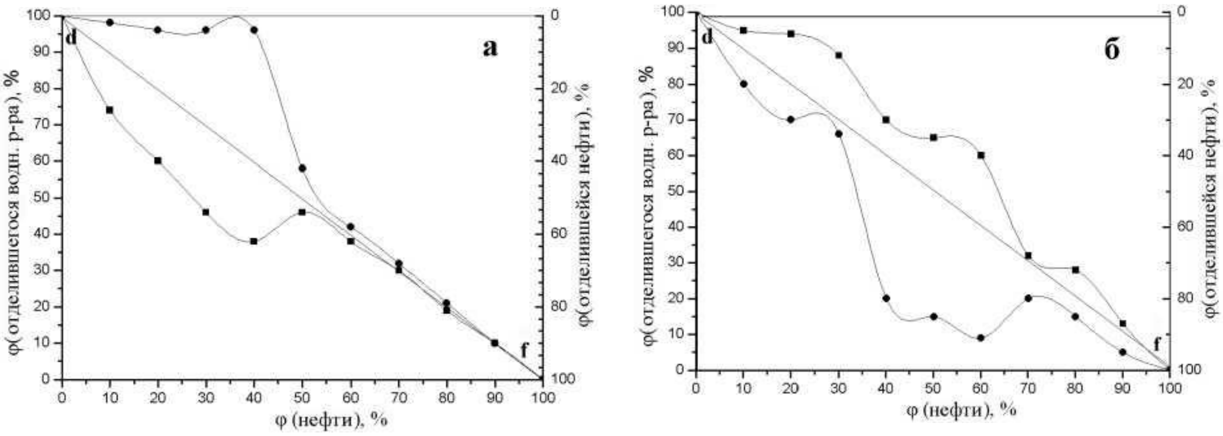

Fig. 3. Stability diagram of water-oil emulsions.
(a) Aqueous phase: PKD-515 solution (C = 1.0%) in the presence of KCl\
(b) (C = 16.0%). (b) Aqueous phase: KCl solution (C = 16.0%).
The diagrams were plotted 1 min after the emulsion was obtained, t = 22° C.

Complete stratification of the emulsions occurs 8-9 minutes after obtaining. In this case, the stability diagram turns into a straight line df (Fig. 3 a). This indicates the extreme instability of the emulsions, which is due to the lack of emulsifying capacity of the complex action reagent.

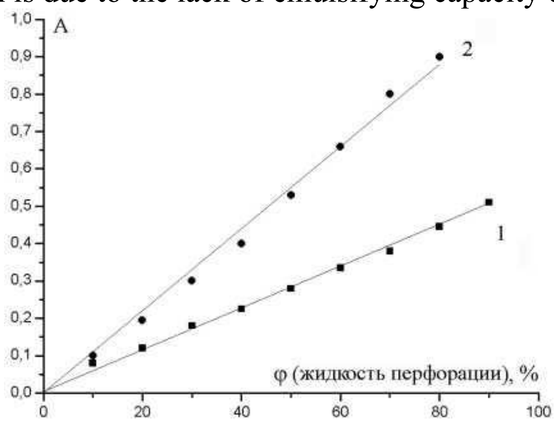

Fig. 4. Dependences of the optical density of perforation fluid mixtures
(aqueous solution (C = 1.0%) in the presence of KCl (C = 16%))
with formation water (1) and with drilling mud filtrate (2) on the volume fraction of perforation fluid; l = 5 mm; X = 400 nm (1), X = 490 nm (2)

Thus, the experimental data on the study of the stability of water-oil emulsions obtained in laboratory conditions show that the complex action reagent PKD-515 has demulsifying properties and does not stabilize water-oil emulsions. This minimizes the possibility of forming emulsions that impede the movement of formation fluid during formation opening.

Fig. 8 shows the dependences of the optical density of mixtures of perforation fluid with formation water (1) and with drilling mud filtrate (2) on the volume fraction of perforation fluid. The obtained dependences are linear, which indicates the absence of any physical and chemical interaction between the components of the system: perforation fluid and formation water, as well as perforation fluid and drilling mud filtrate with the formation of, for example, highly dispersed particles or colored substances. Thus, the experimental results indicate the compatibility of perforation fluid based on KC1 with formation fluid and drilling mud filtrate.

Conclusion. The conducted studies have shown that the complex surfactant is characterized by a higher surface activity compared to the reagent and the ability to reduce the interfacial tension at the boundary with the hydrocarbon (heptane) to values of < 1.5 mN/m and lower at SPCD > 0.4%. It acts most effectively in the presence of potassium chloride. In the concentration of the non-ionic surfactant solution as a result of its adsorption on the core leads to an increase in the surface and interfacial tension. At the boundary with air, o increases by an average of 4-2 mN/m, at the boundary with the hydrocarbon by 0.5-0.3 mN/m. At SPCD > 0.8%, the effect of adsorption on the core material of the well on the decrease in interfacial tension is practically leveled. The interfacial tension of aqueous solutions in the presence of KCl still remains extremely low o < 1 mN/m. The conducted comprehensive studies made it possible to substantiate the necessary concentrations of surfactants and, accordingly, develop a formulation for perforation fluid for secondary opening of productive formations based on a complex action surfactant (1%) and an aqueous solution of KCl. Laboratory studies of the proposed perforation fluid showed its high inhibitory ability in relation to easily swelling clay materials of the formation, compatibility with formation fluid and drilling mud filtrate penetrating into the bottomhole zone during formation opening by drilling, as well as an extremely demulsifying ability during the formation of water-oil emulsions. The results obtained during industrial well testing using the developed perforation fluid,

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