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STUDY OF FOAM FORMATION IN POLYMER SOLUTIONS DEPENDING ON THE CONTENT AND NATURE OF SURFACTANTS

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Abstract:

Objective. In this article, the influence of the content and nature of surfactants on the process of foaming in polymer solutions was studied. As a result of the experiment, it was found that the stability of the foam in the polymer system corresponds to the content of surfactants and their foaming properties. Particularly stable foams are formed when using surfactant OP-10 at concentrations of more than 0.3%. When using these surfactants in drilling fluids, their concentration can reach 1-2% or more, so the foam formed can be very stable over time. In addition, the kinetics of foam destruction in polymer drilling fluids with various surfactants can vary significantly depending on the structure and nature of the surfactants used. It was also found that the concentration of surfactants in the solution and the presence of salt ($CaCl_2$) significantly affect the kinetics of foam formation and destruction. In general, the study results make it possible to effectively control the process of foaming in polymer solutions and use the knowledge gained to optimize technological processes in various industries.

Methods. The use of biopolymers for the preparation of drilling fluid reduces the environmental impact, as biopolymers are susceptible to attack by microorganisms and most acids. As a result, biopolymers decompose to complete oxidation. The biopolymer XanFlex was used as the basis for the preparation of the polymer drilling mud.

Results. As shown in the table, the polymer drilling mud containing about 1.5% of the polymeric structure forming agent is characterized by specific viscosity (T) values of about 36 s. It has a good filtration index (V, $cm^3/30$). The density is increased to 1.11 (ρ, g/cm^3) due to the presence of calcium chloride. It forms a thin imperceptible transparent crust which contains a polymer mesh with $CaCl_2$.

Conclusion. The life span of the foam in systems of polymers with different surfactants varies and the stability of the foam in the system corresponds to the content of surfactants and their foaming properties.

Keywords: foaming, defoaming agent, surfactant, OP-10, GKZH-11, adsorption, surface tension, polymer solution, Glamin.

Introduction. Process water is the most accessible and cheapest cleaning agent in the drilling process. It can be suitable for drilling fairly stable rocks [1, 2]. The use of water as the drilling fluid contributes to the achievement of high mechanical speed. However, in terms of the ability to carry out cuttings, water is much inferior to clay drilling fluids. Especially, water cannot keep cuttings in suspension in the absence of circulation. Therefore, at present, water is used only for drilling shallow wells (up to 30–50 m) [3–5].

The advantages of water as a drilling fluid can also include the absence of clogging of the productive zone of the solid phase of the drilling fluid. Nowadays, drilling fluids without a solid phase have become widely practiced instead of clay drilling fluids, i.e. polymer drilling fluids [6-10]. Many years of experience in this area has shown that these types of drilling fluids have high technological characteristics. The use of these solutions provides high drilling speed; they have good bearing capacity due to high values of dynamic shear strain.

Due to the low content of the solid phase or its absence, the wear rate of the drilling tool is reduced and these solutions are indispensable when drilling a productive horizon.

However, in the absence of a solid clay phase, polymer drilling fluids easily foam and the resulting foam remains for a long time. Therefore, when using these types of drilling fluid, the issue of defoaming agent is acute [11-20].

Therefore, the purpose of these studies was to study foaming in polymer solutions depending on the content and nature of surfactants.

Methods. The use of biopolymers for the preparation of drilling fluid reduces the environmental impact, as biopolymers are susceptible to attack by microorganisms and most acids. As a result, biopolymers decompose to complete oxidation. The biopolymer XanFlex was used as the basis for the preparation of the polymer drilling mud.

Experimental part. To obtain polymer drilling fluids, Glamin was used as a structure forming agent in an amount of 0.5%. The content of the main polymer XanFlex was 0.7-1%. Salt $CaCl_2$ in the amount of 3% was used as an inhibitory additive.

The characteristics of drilling fluids were established according to the requirements of State Standard R 56946-2016 (ISO 13500:2008).

Results and its discussion. The drilling fluid obtained in this way has the following technological characteristics (Table 1).

Table 1

Technological characteristics of polymer drilling fluid based on XanFlex and Glamin

T, c	P, мPa*c	pH	B, cm^3/30 c	Peel thickness, mm	CHC_1/CHC_{10}, дПа	ρ, г/cm^3
43	8,5	8	5	0,2	9/13	1,11

P-plastic viscosity, B- fluid loss

As shown in the table, the polymer drilling mud containing about 1.5% of the polymeric structure forming agent is characterized by specific viscosity (T) values of about 36 s. It has a good filtration index (V, cm^3/30). The density is increased to 1.11 (ρ, g/cm3) due to the presence of calcium chloride. It forms a thin imperceptible transparent crust which contains a polymer mesh with $CaCl_2$. The use of this formulation with the addition of a weighting agent to obtain the required density values provides high structural-mechanical, filtration and rheological characteristics of the polymer solution. The use of a low-density solution makes it possible to prevent the fluid loss, caving and to preserve the natural permeability of productive formations to the maximum extent. This type of drilling fluid, due to the content of clay swelling inhibitor salt and Ca^{2+} ions, can be successfully used for drilling clay rocks, various salt and carbonate deposits.

Further, the processes of foaming in polymer solutions were studied. The obtained data are shown in fig. 2.

Without surfactants, when blowing air, polymer drilling fluids form foams no more than 5 cm, which is lower compared to the results of clay BR. Studies of the kinetics of foaming in a polymer drilling fluid system with the addition of XanFlex and Glamin show that the rate of foam formation depends on the concentration of XanFlex in the fluid, temperature, pressure and mechanical impact on the fluid. In the early stages of foaming, there is a rapid increase in foam volume, which then slows down to a stable concentration.

The kinetics of foam formation can be described by the foam growth equation, which has the form:

$$dV/dt = k * C^n * P^m$$

in that form **V** means the volume of foam, **t** is time, **C** is the XanFlex concentration, **P** is pressure, **k** is the rate constant, **n** and **m** are the degree of dependence of the rate on concentration and pressure, respectively.

It has also been found that the kinetics of foaming can be changed by adding foam inhibitors or changing the pH of the solution. These methods can reduce the rate of foam formation and improve drilling efficiency.

As can be seen from fig. 1, the intensity of foaming in the system of clayless drilling fluids is much higher compared to clay fluids at the same concentrations of OP-10.

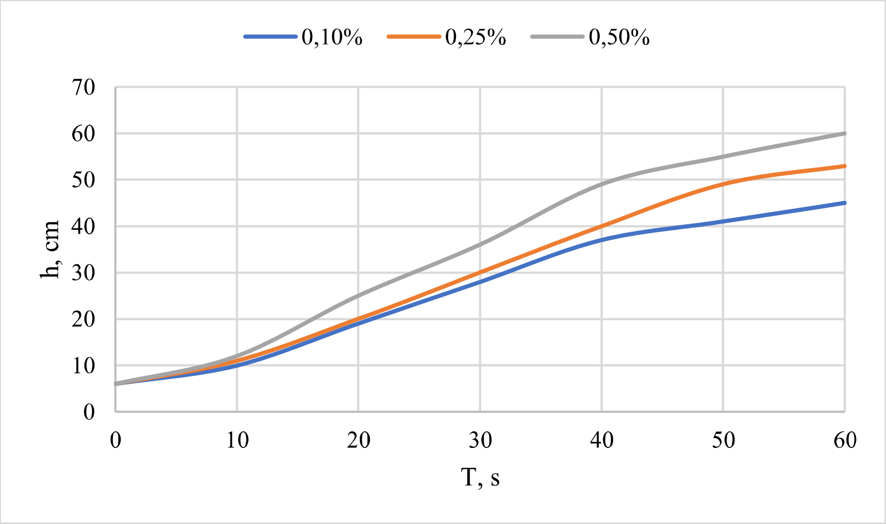

Fig. 1. Kinetics of foam formation in polymer drilling fluid with OP-10

This can be explained by the fact that the system does not contain a solid phase that would prevent the formation of foam. At the same time, a certain amount of surfactant is consumed for adsorption on clay particles; thereby its amount at the liquid/air phase boundary decreases several times. Therefore, in a system without solids, the amount of adsorption at the interface is much lower compared to clay drilling mud and the total foam volume is much larger.

The kinetics of foam formation in an aqueous solution of the OP-10 reagent can be described as a process that depends on many factors, such as reagent concentration, temperature, pressure, the presence of other additives, and mechanical influences on the solution. When adding reagent OP-10 to water, the formation of the smallest microparticles occurs, which are quickly distributed over the volume of the solution. Under the action of mechanical influences, for example, when shaking or stirring, the microparticles begin to combine into bubbles, which then make foam.

The rate of foam formation depends on the concentration of the OP-10 reagent in the solution, since with an increase in concentration, the number of microparticles increases, and, consequently, the number of bubbles in the foam. The temperature also affects the rate of foam formation: with an increase in temperature, the rate of foam formation increases, since the moving force of the molecules increases and the probability of microparticles joining into bubbles increases.

Another factor affecting the foam formation kinetics is the presence of other additives in the solution. For example, the addition of salts can slow down the rate of foam formation, since salts can compete with the OP-10 reagent for the surface of the microparticles and reduce the possibility of their aggregation into bubbles.

Thus, the kinetics of foam formation in an aqueous solution of the OP-10 reagent is a complex process that depends on several factors and can be described by mathematical models that take these factors into account.

Practically similar results were also obtained for the system with GKZh-11. As previously established, the foaming capacity of this system is significantly lower compared to OP-10. However, in a system without a solid phase, surfactant GKZH-11 demonstrates almost the same foaming characteristics (Fig. 2).

Almost identical foam volume values in systems with different surfactants indicate the same surface activity. Probably, when using GKZH-11 in a clay suspension, the main part of the surfactant used to bond with the clay surface due to the high affinity with the clay surface. Therefore, the volume of foam in this system may have had lower values.

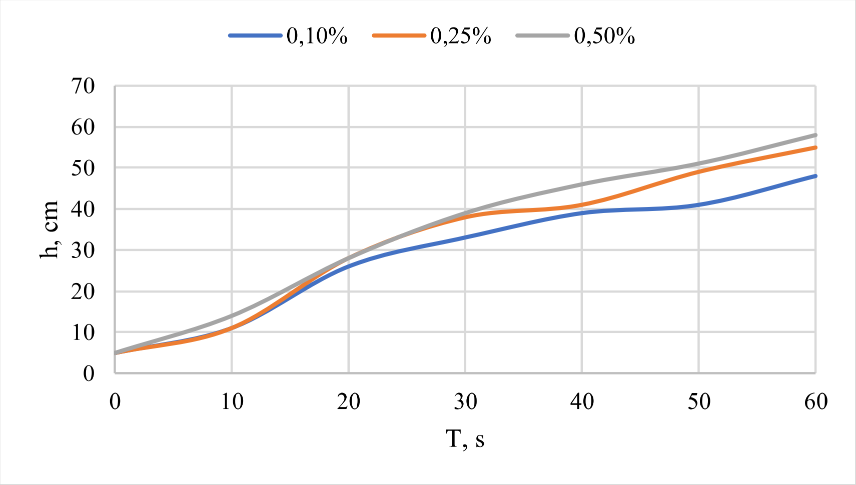

Fig. 2. Kinetics of foam formation in polymer drilling fluid with GKZh-11

Therefore, when using polymer drilling fluid in practice, the possibility of facing problems associated with foaming is much greater. Probably, the greater volume of the foam is due to its stability. Therefore, the use of these systems requires the introduction of a larger amount of defoaming agent, because due to the foaming of the drilling fluid, its density somewhat decreases, due to this, the back pressure in the formations decreases and the rheological parameters deteriorate.

At low surfactant concentrations at the beginning of the foam generation process, the foam height is almost the same for both systems. However, after 10 seconds of blowing air into the system, there is a sharp increase in foam volume, especially at higher surfactant concentrations (0.5%). When air is blown for 20 seconds or more, the height of the foam in the system with GZhZh-11 at concentrations of more than 0.5% reaches more than 30 cm after a minute of generation, while for a concentration of 0.1%, the height is only 24 cm.

If the difference in the volume of clay drilling fluid with 0.5% OP-10 and GKZh-11 was more than 1.36 times, then polymer solutions with these surfactants form 60 and 58 cm of foam per minute. Similar values of the foam height in systems with different surfactants indicate that the mechanism of their interaction and surface activity at the interface is practically the same. Further blowing and shaking do not lead to significant changes in the height of the foam, but affect its stability.

The life span of the foam in systems with different surfactants varies. The stability of the foam in the system corresponds to the content of surfactants and their foaming properties. Systems with OP-10 at concentrations greater than 0.3% are more stable. Considering that the concentrations of these surfactants in the drilling fluid system can reach 1-2% or more depending on the characteristics and conditions of the drilling fluid, the resulting foam can be very stable over time (see Figures 3 and 4).

The kinetics of foam destruction in polymer drilling fluids with various surfactants can vary significantly depending on the structure and nature of used surfactants. OP-10 and GKZH-11 have different structures, different types of surfactants have different chemical structures, which can affect their ability to form and break down foam. Depending on the structure, some surfactants may have surfactant properties that result in a more stable foam, while other surfactants may have a faster foam breakdown rate.

The concentration of surfactants in solution can significantly affect the kinetics of foam formation and destruction. Generally, as the surfactant concentration increases, the rate of foam destruction decreases. The kinetics of foam formation and destruction will also be affected by the presence of salt ($CaCl_2$), which can accelerate foam destruction.

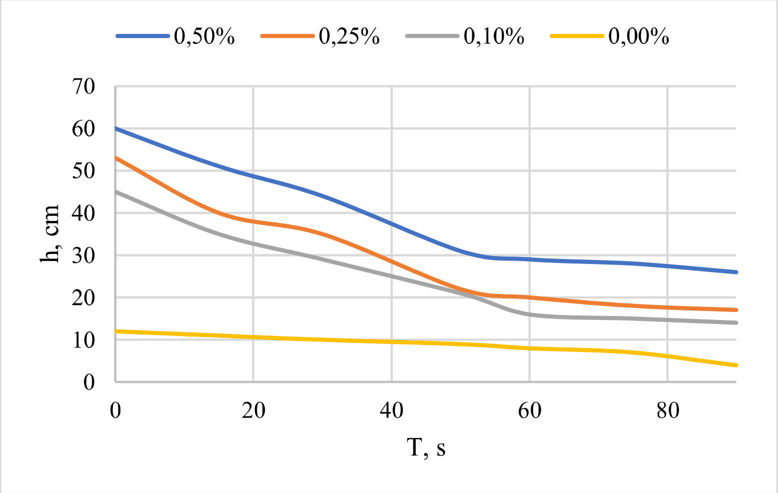

Fig. 4. Kinetics of foam destruction in polymer drilling fluid with OP-10

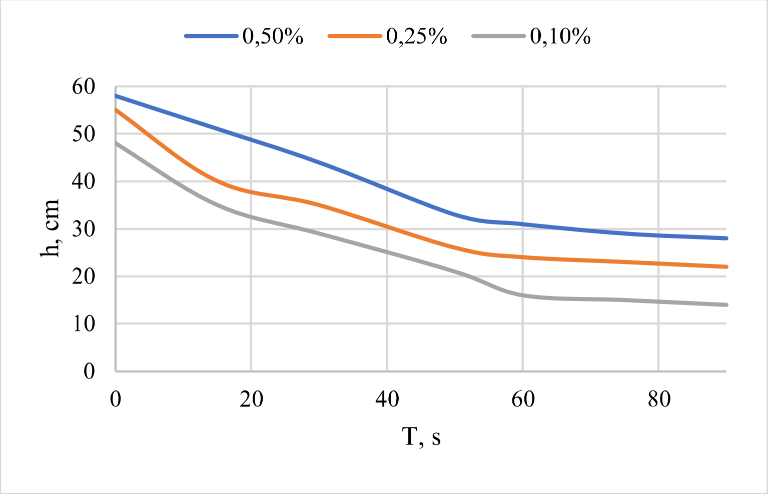

Fig. 5. Kinetics of foam destruction in polymer drilling fluid with GKZh-11

In general, the kinetics of foam destruction in polymer drilling fluids with various surfactants can be very complex and depend on many factors.

From the description of the data, it can be concluded that the kinetics of foam destruction in the system with OP-10 exhibits a decrease in foam height in two stages. First, there is a gradual decrease in foam height over 30 seconds, followed by a sharp decrease in foam height from 44 to 31 cm over the next 20 seconds, followed by stabilization of the total foam volume.

On the other hand, in systems with GKZH-11, foam with a height of 4-5 cm is retained even after 10 minutes of settling, with a content of GKZH-11 of more than 0.2%. This indicates more effective foam retention in the system with GKL-11, which may be due to its hydrophobic properties and the ability to form more stable foam in the system.

For complete destruction of the foam in systems with surfactants, it will take about 30-60 minutes, while for systems without them, about 2 minutes are enough. It can be concluded that the change in the ability of surfactants to form foam and the duration of its existence in the drilling fluid system depends on the nature of these surfactants, and the stability of the foam correlates with their adsorption properties at the water-air interface.

Kinetics of foam destruction may differ in systems with nonionic and ionic surfactants. Nonionic surfactants generally have surface active properties, making them good foam stabilizers. At the same time, they have a low electrolyte character and do not interact with ions in solution. As a result, kinetics of foam destruction in systems with nonionic surfactants can be more stable and slower than in systems with ionic surfactants.

On the other hand, ionic surfactants have surface-active properties and a chemical structure that allows them to interact with ions in solution. This can lead to a change in the surface charge of the foam bubbles and a change in the kinetics of its destruction.

Thus, the kinetics of foam destruction can vary significantly depending on the type of used surfactants.

Conclusions. The life span of the foam in systems of polymers with different surfactants varies and the stability of the foam in the system corresponds to the content of surfactants and their foaming properties. Systems with OP-10 at concentrations greater than 0.3% are more stable, and at concentrations of these surfactants in the drilling fluid system, which can reach 1-2% or more, the resulting foam can be very stable over time. The kinetics of foam destruction in polymer drilling fluids with various surfactants can vary significantly depending on the structure and nature of the surfactants used. The concentration of surfactant in the solution can significantly affect the kinetics of foam formation and destruction, and the presence of salt ($CaCl_2$) can also accelerate the destruction of the foam.

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