**Improving the technology for producing lightweight drilling fluid for complex well workover operations**

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**Abstract.** This work examines the specifics of using drilling fluids during well workover operations aimed at restoring and increasing oil and gas production. Emphasis is placed on the importance of stabilizing wellbore walls and minimizing damage to the productive formation. Particular attention is paid to the problem of reservoir pressure drop, which leads to the risk of gas kicks and pore contamination with clay particles. A composite multifunctional lightening agent based on local raw materials has been developed, possessing stabilizing and improved rheological properties when introduced into the composition of the lightweight drilling fluid intended for complex well workover operations. The influence of the introduced additive on the structural-mechanical and rheological characteristics of the drilling fluid has been experimentally substantiated, including a decrease in fluid loss, increased resistance to degradation, and the effectiveness of composite multifunctional lightweight drilling fluids (CMO) has been demonstrated, ensuring stability at reduced density. A critical analysis of modern technological solutions used in addressing various complications arising during well workover operations has been conducted. The mechanism of action of the lightweight drilling fluid during well workover operations at the fields of JSC “Uzbekneftegaz” has been clarified, and its technological effectiveness and degree of adaptation to various geological and technical conditions have been assessed. The need to regulate the technological properties of the drilling fluid to preserve the reservoir characteristics of productive formations and increase the efficiency of well workover operations under abnormally low pressure conditions has been substantiated.

**INTRODUCTION**

The current state of development and application of drilling fluids is characterized by an active search for optimal technological solutions capable of ensuring wellbore stability, minimizing accidents, and increasing efficiency during well workover operations, especially under complex geological and technical conditions. Researchers are paying special attention to modifying the composition of drilling fluids by introducing new chemical reagents, weighting agents, stabilizers, and inhibitors. It has been established that high temperature, pressure, and the active surface of metals contribute to the formation of thermal, catalytic, radical, and other types of polymerization. In this regard, to form tribopolymers in the contact zone, it is advisable to introduce various polymers and oligomers into the drilling fluid [1-2].

Enhancing the properties of drilling fluids through the use of lubricating additives is necessary to prevent lost circulation, sticking of drill strings and bottomhole assemblies, as well as casing strings during their run into the second wellbore, and to reduce wear of interacting surfaces. It has been established [3] that during tribopolymerization in the friction process, high-molecular-weight compounds are formed, and less wear of the interacting surfaces is observed. Therefore, to reduce wear of interacting surfaces in the friction unit, it is advisable to use tribopolymers or polymer-forming materials as components of the drilling fluid. To improve the lubricating properties of the drilling fluid, various waste products from oil refineries, oil and fat processing plants, and others are introduced into it [4-5]. From these, lubricating additives for drilling fluids are developed and added directly to the drilling fluid (gossypol resin, cottonseed oil soapstock, hydrogenated fat soapstock, tar mixtures, fatty acids, oil sludge, etc.).

Furthermore, the accumulation of waste from the main production process, which contains lubricants in its composition, necessitates their application in areas where there is a need for it [6-7].

When selecting these main production waste materials, it is necessary to study their chemical composition and viscosity, which affect their performance characteristics [8-9].

Lubricants with high and medium viscosity form a thick lubricating film, which subsequently leads to reduced wear under identical conditions [10-11].

It has been established that high-viscosity lubricants possess the best anti-wear properties.

In abrasive environments, lubricating additives prepared from high-viscosity lubricants have shown high effectiveness. As is known, oxidative stability manifests in the friction zone at high temperatures. The composition of its base has the greatest influence on the lubricating additive.

Based on the decomposition temperature, oxidation resistance, and base of the lubricating additive, the application temperature and service life of the lubricating additive are determined [12-13], as oxidation leads to the formation of oxygen-containing surfactants. The oxidation of the lubricating additive depends on the composition of the base, its anti-wear properties, and its antioxidant stability. Oxidation-resistant lubricating additives are obtained by incorporating a large quantity of antioxidant additives into the base of lubricating additives. However, their content is limited due to their impact on the structure of the drilling fluid.

The stability of the lubricant base affects the effectiveness of antioxidants. The susceptibility of lubricants to antioxidants influences the chemical composition of their base.

The introduction of amines into lubricant additives does not significantly affect stability [1-3, 14-15]. Phenol-containing compounds contribute to the deterioration of lubricating additives' stability against oxidation [16-17] highlight the geological complication arising from drilling fluid loss into the formation, which is caused by the disruption of equilibrium between hydrostatic and formation pressure. The authors substantiate the need to select inhibited and stabilized drilling fluid systems capable of maintaining filtration stability and preventing wellbore wall deterioration.

**EXPERIMENTAL RESEARCH**

Research [18-19] has demonstrated that introducing polymer and ionic reagents into the drilling fluid system allows for targeted modification of its rheological properties, particularly increasing viscosity and structural-mechanical strength. This contributes to the creation of a stable filtration barrier, reducing the risk of fluid loss and ensuring wellbore stability.

Studies [5-20] focus on evaluating pore pressure using the normal clay compaction curve method. This approach enables more accurate prediction of fluid loss conditions and, consequently, optimization of drilling fluid composition to prevent them. Publication [7-8] investigates the influence of chemical additives on clay rock stability and filtration kinetics. Our research on the application of highly effective inhibitors and stabilizers leads to the conclusion that fluid loss is reduced and filter cake thickness is minimized, thereby helping to prevent swelling and erosion of clay formations. Work [15-20] examines the effect of various chemical additives on the viscosity and filtration characteristics of drilling fluids. The authors established that the introduction of reagents significantly increases fluid viscosity, contributing to the formation of a stable filtration barrier and reducing the likelihood of drilling fluid loss in productive formations.

A significant contribution to the optimization of flushing systems is made by the work [18-20], which examines flushing fluids intended for well workover operations. The authors have proven that a well-chosen inhibited composition allows for preserving the integrity of the wellbore walls, which, while reducing the risk of collapse, contributes to the loss of core material.

The issue of preventing drilling fluid losses in formations has been considered [18], where the authors draw attention to the need to balance hydrostatic and formation pressure, as well as to select compositions of drilling fluids with increased inhibitory capacity. Such solutions exhibit stability even in aggressive chemical environments and at high temperatures. The authors conducted research to elucidate [17-20] and developed a theoretical model for preventing drill pipe sticking based on wave dynamics, which opens up new possibilities in ensuring the reliability of drilling tools in unstable formations. They also studied the lubricating properties of flushing fluids used in well workover operations. Their results indicate the importance of tribological parameters that directly affect the reduction of wear on drilling equipment and the stability of the drill string.

In the collection of works [18], methods for calculating pore pressure using the normal clay compaction method were analyzed. The accuracy of pressure assessment allows for correct prediction of the onset of complications and timely adjustment of the density and other parameters of the drilling fluid. A number of authors [15,11] also note that the introduction of synergistic additives significantly reduces the filtration capacity of the solution, decreases fluid loss, and minimizes the swelling of clay rocks.

Research on the calculation and modeling of drilling fluid preparation based on local raw materials remains relevant [10-15], as well as the influence of well depth and flushing conditions on the stability of borehole walls and drilling efficiency [11-12].

In the context of well workover operations aimed at restoring and increasing oil and gas production, special attention is paid to the selection and application of drilling fluids [14]. These technological compositions play a key role not only in ensuring the effective removal of rock cuttings but also in preserving the reservoir properties of productive formations. The success of subsequent well development and production operations directly depends on the characteristics of the drilling fluid. Drilling fluids have a comprehensive effect on the entire wellbore: they stabilize the walls, prevent swelling and erosion of clay rocks [7-12], reduce the filtration coefficient, and ensure the protection of drilling equipment from wear. Depending on the duration of oil or gas field exploitation, the reservoir pressure decreases as the product is extracted from the formation. When drilling wells, the density of the drilling fluid used in subsequent wells can lead to gas kicks (if the field is gas-bearing). Based on this, after some time or during complex workover operations, it is necessary to use composite multifunctional lightweight drilling fluids when drilling a productive formation with a sidetrack.

**RESEARCH RESULTS**

Additionally, the decrease in reservoir pressure during production leads to the drainage of formation pores. As a result, the pores of the productive formation are contaminated with clay drilling fluid particles due to the impact of drilling on the overbalance created by the drilling fluid column [19]. Analysis of experimental data indicates a significant influence of the KMO concentration on the rheological and filtration properties of the drilling fluid prepared based on bentonite clay (Table 1).

**Table 1.** Influence of the composite multifunctional thinner on the parameters of drilling fluids at a temperature of 20°C (room temperature)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **№** | **Bentonite** | **KMS**  **%** | **KMO**  **%** | **ρ,**  **kg/m3** | **Т500,**  **s** | **V, sm3/30min** | **рН** | **Corks**  **Т, mm** |
| 1 | Stock solution: 1000 ml water +bentonite 10%+Na OH 2%+Na2CO3 | 0,1 | 0,2 | 1150 | 18 | 38 | 8,0 | 4,5 |
| 2 | Stock solution: №1 | 0,2 | 0,3 | 1150 | 28 | 36 | 8,0 | 4,5 |
| 3 | Stock solution: №1 | 0,4 | 0,6 | 1100 | 47 | 32 | 9,0 | 4.5 |
| 4 | Stock solution: №1 | 0,6 | 1,2 | 1050 | 69 | 26 | 9,0 | 3.5 |
| 5 | Stock solution: №1 | 0,8 | 1,8 | 1000 | 97 | 23 | 9,5 | 3.0 |
| 6 | Stock solution: №1 | 1,0 | 2,4 | 960 | 118 | 20.0 | 9,5 | 2.5 |
| 7 | Stock solution: №1 | 1,2 | 3,0 | 900 | 143 | 17.0 | 10,0 | 2.0 |
| 8 | Stock solution: №1 | 1,4 | 3,6 | 850 | 178 | 12.0 | 10,0 | 1,5 |
| 9 | Stock solution: №1 | 1,6 | 4,2 | 810 | 235 | 9.0 | 10,5 | 1,0 |
| 10 | Stock solution: №1 | 1,8 | 4,8 | 770 | 283 | 6.0 | 10,5 | 1.0 |
| 11 | Stock solution: №1 | 2,0 | 5,4 | 740 | 347 | 3 | 11,0 | 0,8 |
| 12 | Stock solution: №1 | 2,0 | 6,0 | 700 | 400 | 2 | 11,0 | 0,5 |

Analysis of the table data indicates that as the content of the composite multifunctional thinner (CMO) increases from 0.2% to 6.0%, a consistent change in the rheological and filtration properties of the drilling fluid is observed. The system density decreases from 1150 to 700 kg/, which is apparently caused by the displacement of a portion of the solid phase due to the dispersing effect of the modifier [20]. Meanwhile, the apparent viscosity of the solution increases from 17 to 400 seconds, which indicates the formation of a spatially structured network and an enhancement of the system's structural and mechanical stability. Additionally, a significant reduction in filtration fluid loss is observed - from 38 to 2 c per 30 minutes, which indicates an increase in the colloidal stability of the solution and a decrease in the permeability of the formed filter cake.

Figure 1 shows the dependence of density and fluid loss of drilling fluids on the concentration of the composite multifunctional lightening agent.

**FIGURE. 1.** Effect of composite multifunctional thinner content on the density and filtration of drilling fluid at a temperature of 20°C

Figure 1 shows the effect of the KMO reagent content in lightweight drilling fluids on two key parameters - density and filtration at a temperature of 20 °C.

As the concentration of CMO increases, a moderate decrease in the drilling fluid density is observed [20]. This is attributed to the reagent's inherently low density, which, when introduced, alters the ratio between the dispersed and liquid phases of the system. Despite this reduction in density, the values remain within the technologically acceptable range, maintaining the necessary stability of the fluid's rheological properties.

The most significant effect of using CMO is the reduction of filtration losses. As the reagent content increases, the filtrate volume decreases substantially, indicating an improvement in the colloidal stability of the system and the formation of a low-permeability filter cake.

**CONCLUSION**

The results of the conducted analysis and experimental research confirm the high effectiveness of using composite-multifunctional lightweight drilling fluids (CMO) in well workover operations [7,8], especially under conditions of reduced reservoir pressure. The introduction of CMO into the fluid composition allows not only to decrease its density to a safe level, minimizing the risk of formation damage and contamination of the productive zone, but also to significantly improve the rheological and filtration properties of the system.

As the concentration of KMO increases, a rise in the conditional viscosity of the solution and a decrease in fluid loss are observed, indicating the formation of a stable structural network and a low-permeability filter cake [17,19,20]. This contributes to reducing solution losses, protecting the wellbore walls, and preserving the reservoir properties of the rock. Thus, the use of KMO is an effective technological solution that ensures the reliability, safety, and economic viability of well workover operations. The results can be used to optimize drilling fluid systems for sidetracking and production restoration in mature fields.

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