

Optimization of sand plug cleaning in production wells with water-based drilling mud under low formation pressure conditions

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Abstract. The article discusses methods for cleaning sand plugs in wells. To prevent complications when flushing wells from sand plugs, the mechanisms of the effect of drilling fluid on sand plugs are considered. The main aspects of this mechanism of action are listed. A scheme of technology for cleaning a well from a sand plug during major repairs is proposed. The results of developing a new composition of a flushing solution for conducting field work are presented. The procedure and scheme for using a flushing solution with different compositions for flushing wells from sand plugs are also considered.

Keywords: sand plug in a well, flushing solutions, flushing wells; cleaning wells from plugs with drilling mud, technologies for cleaning wells from sand plugs..

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1. Introduction

The skeleton of an oil reservoir with loose rocks is destroyed in the bottomhole zone during reservoir development. In this case, liquid and gas move along the reservoir and carry sand into the well. Due to the low rate of rise of sand grains, they settle at the bottomhole and form a plug. This complicates and/or stops the access of fluid from the reservoir. Therefore, to resume operation of an oil well, the bottomhole must be cleared of sand.

In other words, sand plugs (SP) are formed as a result of sand removal in production wells. The complexity of the sand formation process depends on various factors. Analysis of known data shows that for optimal operation of wells, they are washed and cleaned from SP in various ways [1-5].

For example, according to Azneft, repair work was carried out on underground equipment of production wells at various fields in Azerbaijan this year due to the impact of sand. The estimated average height of the sand plug that formed in these wells was hundreds of meters.

It follows from the above that combating sand formation is a pressing issue. Sand plug is a sand-clay mixture contaminated with oil, asphaltene-resinous paraffins. SP has a negative impact on the environment. Therefore, preventing SP formation in oil fields and effective SP flushing are important tasks [6-19].

Thus, it has been established that a technology for removing sand-clay plugs from wells with normal formation pressures has been developed and the compositions of drilling fluids are known. However, work to remove sand and clay plugs from oil and gas wells with low reservoir pressures on depression is difficult.

When cleaning wells from sand plugs under low formation pressure conditions, it is necessary to reduce the density of the flushing reagent. In this regard, it is important to clean the well using a BR containing a surfactant. When pumping an aqueous BR containing a small amount of surfactant through the well, foam with a high degree of aeration is formed at a high speed. The ratio of the BR flow rate and the flow rate of formation gas at the bottomhole often does not correspond to the condition for foam formation at the bottomhole. If the gas content at the bottomhole exceeds 0.96, the foam is destroyed.

This can be explained by the fact that as the foam flow rises along the wellbore, the gas bubbles in the foam expand. Therefore, the gas content increases and the foam, breaking down, turns into "fog". Thus, as the foam moves from the bottomhole to the wellhead, the gas-liquid mixture can change its state of aggregation. To do this, it is necessary to specifically study the dependence of the formation gas inflow on the depression at the bottomhole in field conditions or conduct theoretical modeling. In this paper, these problems are not considered.

The aim of the work is to create an effective composition of an aqueous solution for drilling and development of wells taking into account the mechanism of action of drilling fluid (DF) on sand plugs. Such a composition should provide a high level of inhibiting and surface-active properties of DF. In addition, DF should form environmentally safe non-polar layers on the surfaces of the bottom of the drill string and rock.

2. Methodological part

The rheological properties of the prepared compositions were studied using a rotational viscometer Reotest-2 (Fig. 1 and 2). The experiments were conducted in a stabilized mode with velocity gradients of $1.8\text{--}437.4\text{ s}^{-1}$.



Figure 1. General view of the rotational viscometer Reotest 2.1.

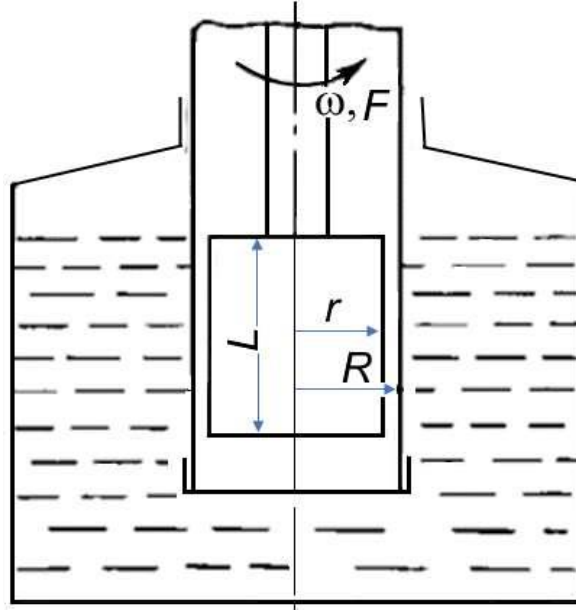


Figure 2. Scheme of the coaxial-cylindrical system Reotest 2.1.

The shear stress (τ) and shear rate (D) are determined by the known relationships:

$$\tau_{xy} = \frac{F}{A} \quad (1)$$

$$D = \frac{2\omega R^2}{R^2 - r^2} \quad (2)$$

where F is the tangential force; $A = 2\pi lr^2$ is the area on which the force acts.

In field conditions (oil wells No. 1242 and 1198 of the G.Z. Tagiev Oil and Gas Production Department), it was assumed that the pressure drop at the bottomhole was $dP = P_f - P_b$. The height of the sand plug determined the required BR flow rate for foam formation at the bottomhole. It was assumed that the gas content at the bottomhole of the wells under study was $B < 0.96$.

3. Results and discussion

Below we will consider the results of the study of the system "sand plugs - drilling fluids". Let us remind you once again that sand plugs are accumulations of sand particles that block the wellbore, limiting the flow of fluid and access to deeper zones of the oil reservoir. And drilling fluids are used to remove these plugs using a combination of mechanical, hydraulic and chemical effects.

To increase the efficiency of washing sand plugs, a cleaning compound called QTY-M has been developed. Below we consider data on the composition and study of its structural and rheological parameters.

3.1. Mechanism of the effect of drilling fluid (DF) on sand plugs in wells

DF destroys, washes away and carries away sand particles from the bottomhole zone and the wellbore. The main aspects of this mechanism of DF influence include the following.

3.1.1. Hydrodynamic effect

- Creation of a fluid flow with high speed and pressure, which washes away the sand plug.
- Turbulent flow separates sand grains from the well walls and transports them to the wellhead.
- Pulsed pressure (when using pulsating feed) destroys compacted sand deposits.

In hydraulic action (jetting and erosion), high-pressure injection of drilling fluid creates a turbulent flow that breaks up the sand plug. Shear forces and fluid velocity release sand particles from the compacted structure of the plug. And jetting or circulation can be directed to dense areas of the plug for maximum cleaning effect.

3.1.2. Physicochemical effect

- Drilling fluid containing dispersing and stabilizing additives prevents re-deposition of sand.
- The use of surface-active substances (SAS) reduces interfacial tension. This releases sand bonded to particles of clay sludge or oil.

In other words, when exposed to physico-chemical influences, surfactants reduce surface tension and help separate oil-bound or clay-covered sand grains. In this case, dispersants and stabilizers prevent re-agglomeration of fine particles and increase the efficiency of transportation. In some cases, solvents are added to the DF to dissolve organic acids that hold the sand particles together.

3.1.3. Mechanical destruction

- The impact of liquid under pressure on the sand plug mechanically destroys its structure.
- When using mechanical means (for example, check valves, vibrators or hydro-sandblasting nozzles), the efficiency of sand removal increases.

In this case, the action of liquid jets (for example, jet nozzles or mixers) breaks up compacted sand masses. Vibration or hydraulic pulsation tools are used to break up dense sand plugs.

3.1.4. Flow and sand removal

- After the plug is destroyed, the liquid captures sand grains and carries them to the surface as it circulates.
- To achieve this, it is necessary to ensure sufficient flow rate and density of the DF so that the sand does not settle back into the wellbore.

Here we note that after displacement, sand particles are suspended in the drilling fluid. Therefore, the use of additives, such as polymers, can increase the viscosity of the fluid, improving its ability to carry

sand particles to the surface. The correct flow rate prevents sand from being re-displaced during circulation.

3.1.5. Conditions for efficiency

- Correct selection of liquid composition (viscosity, density, chemical additives).
- Optimization of the injection mode - pressure, speed, volume.
- Plug type - loose, cemented, with an admixture of clays or oil.

Thus, the main factors of efficiency are the following. The composition of the fluid must match the properties of the plug (e.g. density, viscosity, chemical additives). The injection rate and pressure must be high to break the plug without damaging the well. The tools must be selected depending on the depth of the plug and the geometry of the well. The temperature and sensitivity of the formation must be taken into account so as not to damage the formation.

3.2. Main stages of the impact of drilling mud on the sand plug

The above are schematically shown in Fig. 3 for the process of action of the drilling fluid on the sand plug.

3.3. New composition of drilling fluid and its application

Taking into account laboratory and field data, a formula for a water-based drilling fluid for sand plugs was developed, without aggressive impurities. Water (technical) was used as a solvent and transport medium.

In addition, to increase viscosity and improve sand removal, reduce surface tension, prevent aggregation of sand particles, and stabilize the gel structure, appropriate components were tested and proposed. It should be noted that these additives must be anti-corrosive to protect pipes from corrosion (in water).

In case of a tight plug in the well, a two-stage approach is used: first, a diluent or surfactant is pumped in, and then the well is flushed with a gel-like liquid. Pulse feed (hydraulic shocks) is also used for mechanical destruction.

Taking into account the above, we have developed a drilling fluid formulation for specific oil well conditions (No. 1242 and 1198 G.Z. Tagiev Oil and Gas Production Department).

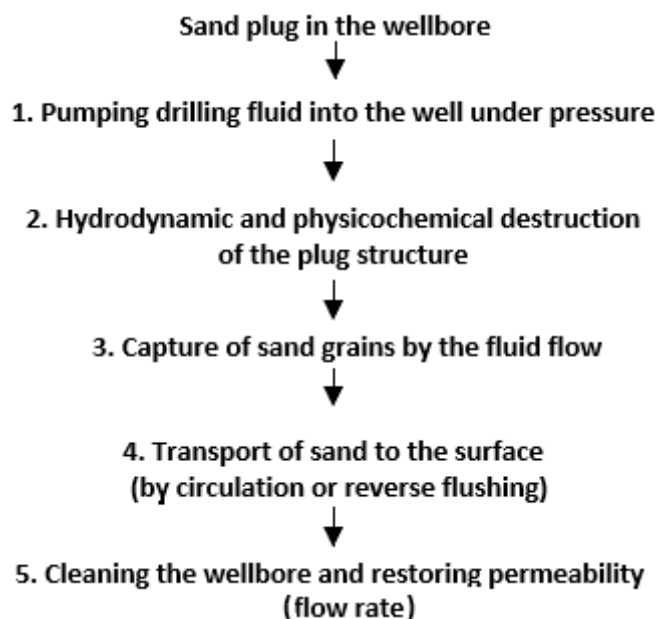


Fig. 3. Scheme of the effect of the drilling fluid on the sand plug.

The studied rheological parameters of the compositions based on an aqueous solution for washing sand plugs are given in Table 1.

Table 1. Initial data of the studied aqueous compositions for washing sand plugs

No	A l	S A S	ρ , kg/m ³	SSS _{1/10} , dPa
1	1	0.05	256	33.6/33.6
2	1.5	0.025	722	39.73/48.9
3	0.5	0.05	695	18.3/122

The compositions included optimal amounts of ingredients: structure-forming aluminum sulfate (0.5-1.5 wt.%), alcohol (0.5 wt.%) and surfactant (SAS 0.025-0.05 wt.%). An inhibitor (1-2 wt.%) and an activator (0.5 wt.%) are additionally added to the composition.

The laboratory obtained values of static shear stress (SSS) in the model "cleaning composition - pipe with sand plugs" show that the treatment increases the deformation and destruction of sand plugs.

Table 2. Composition of detergent and rheological parameters of sand plug washing

№	Composition, mass%	Velocity gradient, s^{-1}					
		1.8			437.4		
		τ_{∞} , Pa	τ_{kr} , Pa	η_{ef} , mPa·s	τ_{∞} , Pa	τ_{kr} , Pa	η_{ef} , mPa·s
1	CaO – 0.5 Al ₂ (SO ₄) ₃ – 0.5 SAM – 0.05 H ₂ O – the rest	30	30	1659	161	161	37
2	CaO – 1.5 Al ₂ (SO ₄) ₃ – 0.5 SAM – 0.05 H ₂ O – the rest	66	65	3649	113	149	26
3	CaO – 1 Al ₂ (SO ₄) ₃ – 0.5 SAM – 0.5 H ₂ O – the rest	12	12	666	66	179	15

4. Conclusions

1. The developed scheme of the drilling fluid impact on the sand plug and the developed water-based composition made it possible to compare the results of cleaning sand plugs without aggressive impurities in oil and gas wells with a low rate of sand grain rise.
2. The results of well flushing obtained taking into account the method of drilling fluid impact and sand plug elimination can be used in underground, major repairs and well development using drilling fluids in the oil and gas industry.
3. Treatment of oil reservoirs with the developed foaming liquid made it possible to establish the optimal composition of the drilling fluid when using laboratory and field methods of cleaning oil wells with dense sand plugs.
4. Taking into account the developed composition of the drilling mud, the technology of washing sand plugs was improved and refined, which was tested in oil wells No. 1198 and 1242 (NGDU named after G.Z. Tagiev) with a low rate of rise of sand grains.
5. The developed composition with cheap and easily accessible components (structure-forming aluminum sulfate, alcohol, surfactant, inhibitor and activator) and the technology of washing sand plugs in wells were also used for quantitative analysis of migration and production of hard-to-recover oil.
6. The small size and high strength of microfoam bubbles of the proposed drilling mud have a beneficial effect on the operation of drilling and centrifugal pumps, as well as on the destruction of sand plugs in the well-oil reservoir system. In this case, the quality and rheological properties of oil are improved due to the cleaning of the sand-clay plug in the wells.

7. Quantitative evaluation of rheological properties using the Rheotest 2.1 rotational viscometer and a step-by-step method of the new drilling mud impact on sand plugs yielded a positive effect both in laboratory conditions and in oil wells.

8. The sand plug cleaning method and the drilling mud flush composition have proven themselves well in cleaning and evaluating oil and gas migration, especially in late-forming reservoirs and in mature development zones with low flow rates of sand grains. The drilling mud compositions used in wells No. 1198 and 1242 (G.Z. Tagiev NGDU) increased oil production in the wells. The calculated values of the lower limits of oil recovery in the wells increased by 26% and 29%, respectively.

Conflict of interest

The authors of this work declare that they have no conflicts of interest.

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