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Research of Clayless Drilling Fluid Influence on the Rocks Destruction Efficiency

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Abstract

The paper presents the study of clayless drilling fluid influence on the efficiency of rocks destruction with increased hardness.

Researchers have shown that a decrease in drilling fluid density in turn increases rate of penetration. This indicates a need for the investigation on reduced density drilling muds, mostly based on various types of polymers. It is also an addition into drilling mud of special reagents - hardness reducers, whose action is based on "Rebinder effect“, which will enhance the efficiency of rocks destruction with increased hardness.

Studies presented in the article include development of recommendations on the mud composition: the justification of the biopolymers and polymers use as structure-forming agents; the need for surfactants and bactericides addition into the drilling fluid; selection of appropriate concentrations of the mentioned above reagents.

To evaluate the efficiency of rocks drilling with increased hardness experimental test bench was designed along with technique of test trials, which provided the ability to simulate fragmenting-chipping mode of rock cutting tool operation. While conducting experimental studies the effect of anion-active surfactants and developed composition of the drilling mud on the efficiency of rocks destruction with increased hardness was examined (diabase was used as ore sample). Ecological and economic aspects of developed clayless drilling fluid composition were also evaluated.

Performed studies confirm the efficiency of rocks destruction using a clayless drilling fluid containing hardness reducers - detergents in its composition.

Keywords: drilling mud, biopolymer, detergent, rocks destruction.

INTRODUCTION

As it is known, the durability of mineral rocks depends from the hardness of mineral grains, the bond between the mineral grains, their thickness of connection with the cement and hardness of the cement. Fine-grained rocks are more durable than coarse-grained with the same mineralogical composition. Denser, less porous and less fractured rocks possess greater durability.

The strength of the rocks in relation to various kinds of deformations is also different. Destruction of rocks during rotary drilling is usually carried out by indentation of cutters or teeth with various shapes into the borehole bottom rocks, followed by further development of rock destruction by chipping. Therefore rock hardness indentation index plays great role at rotary drilling [1].

Physical and mechanical properties of the rocks can vary with increasing of the deposition depth. This is explained by the fact that the rocks layered on greater depth are subjected to significant overall compression caused by geostatistical pressure.

It should be noted that the rock of high hardness experiences little changes of its mechanical properties under the influence of high pressures and temperatures that occur at greater depths. On the contrary, the sedimentary rocks of low hardness and density at greater depths under the influence of high pressure and temperature compressed tight so their hardness can increase by 3-4 times, changing their drillability accordingly.

It is known that a decrease in the density of the washing liquid causes increase in rate of penetration. If clay washing fluid is replaced by water solution, the drilling speed is increased by 20-30%. Even greater (2-5 times) rise of drilling speed is achieved through replacement of flushing fluid with gas [1]. This indicates a need for research into the application of low density drilling muds with various polymers basis. Adding of special reagents - hardness reducers (detergents), whose action is based on "Rebinder effect" - adsorption decrease of hardness, into the drilling mud will enhance the efficiency of rocks destruction.

METHODOLOGY: Recommendations to developed compositions of polymer clayless solutions

As mentioned above, to increase the efficiency of rocks destruction it is required to reduce drilling mud density and to add reagents - hardness reducers into the solution. Therefore, the composition belongs to the group of polymer clayless drilling fluids.

For the first time, the polymer solution was used in the mid-50s in the US. The polymer used was high molecular weight polyelectrolyte «Ben-Ex», which is a copolymer of vinyl acetate and maleic anhydrite. Later in the oil well drilling in the United States and Canada were widely used drilling fluids containing acrylic polymers, such as partially hydrolyzed PAA, GIPAN etc. In the sixties - early seventies research focused on the development of a clayless and low clay biopolymer drilling muds, which are based on linear polysaccharide - biopolymer XS [2].

The main components of the proposed solution are biopolymers (xanthan-based resins), polymers of varying molecular weight and anion-active surfactants.

It is known that a biopolymer based solution has a unique combination of properties: it reduces the viscosity while increasing shear rate and exhibits viscoelastic effects during filtration.

Development of clayless drilling fluids formulas also requires biopolymer to interact efficiently with other components.

The second equally important component of the solution is the polymer reagent. For investigation a reagent was used, based on acrylic polymers "KM-017", which is a 15-45% aqueous solution of carboxylic acid copolymer of acrylic series, their esters and salts, with molecular weight of 250 000. Unlike other analogues, increase in concentration of the reagent doesn't cause an intense rise of the drilling mud viscosity.

As a basis of the solution xanthan biopolymer "KK-Robus", acrylic polymer "KM-017" and anion-active surfactants are proposed to be used. Series of earlier conducted experiments described application of sodium linear alkyl benzene, sodium lauryl sulfate and potassium acetate [3]. It is known that biopolymers at their physical and chemical structure are microbial polysaccharides susceptible to biodegradation. Under the effect of bacteria metabolic products pH of the drilling fluids is reduced, they "rot", what impairs their technological properties. This disadvantage is eliminated when using solutions of acetic acid salts, which are bactericides and possess preservative properties. Therefore, surfactant formulation can be introduced into the developed solution, for example sodium lauryl sulfate and potassium acetate.

Previously published papers [4,5] presented investigation on the research and development of clayless composition of the solution on the basis of a biopolymer "KK-Robus", possibilities of its use at different temperatures with the assessment of structural, rheological and filtration characteristics. Further studies have been devoted to the experimental trial research.

RESULTS

1. Trial experiments of rocks destruction process during drilling and evaluation of the biopolymer solution efficiency

To evaluate the efficiency of rocks drilling and experimental relevance of the results test bench was developed along with technique of trials conducting.

While conducting experimental studies, the influence of anion-active surfactants and developed composition of the biopolymer drilling mud on drilling efficiency was examined.

Scheme of the test bench is shown at Figure 1.

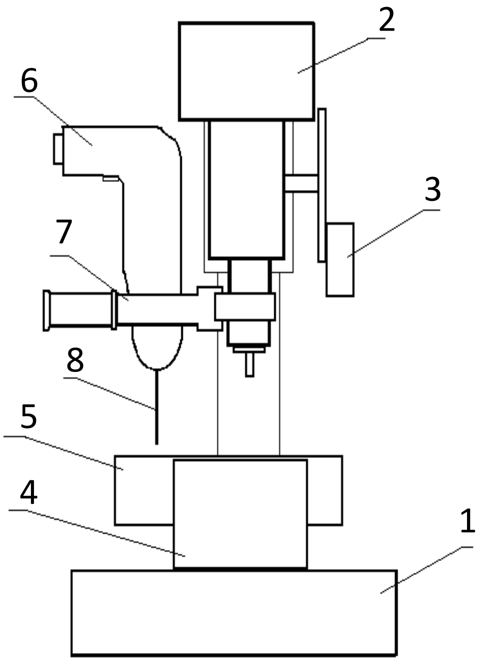

Figure 1 - The scheme and the general appearance of the test bench

1 - bed; 2 - mobile loading device; 3 - weight; 4 - screw clip; 5 - ore sample; 6 - impact rotator; 7 - clamp; 8 - rock cutting tool with rotary-impact action

The methodology of the bench trials included:

- Preparation of a fine-grained rock sample having a rectangular parallelepiped shape and polished surfaces;
- Leveling and subsequent fixation of the sample in the clamping device;
- The installation and consolidation of the axial load, impact frequency and rpm of rock cutting tool (RCT);
- Supply of the test liquids directly to the contact zone of RCT and a rock sample;
- The destruction of the rock sample in rotary-impact manner;
- Measurement of the RCT immersion depth into the sample for a fixed time.

Wherein:

- Rock sample sizes - 30 x 8 x 6 cm;
- Ore - diabase;
- Axle load - 180 N;
- Rotation frequency - 100 rpm;
- The frequency of strokes - 200 spm;
- RCT material - Solid alloy VK-8;
- The diameter of the RCT - 8 mm;
- Exposure time - 10 min.

Electric rotary-impact drill was used as main drive of the test bench, imitating fragmenting-chipping mode of RCT operation.

The load exerting on the impact drill bit 8 is created by a mobile loading device 2, the impact rotator 6, located in the clamp 7, and load 3. The weight of the mobile loading device 2 and impact rotator 6 is constant, the load can only be changed by increasing or decreasing the mass of weight 3.

Experiments were conducted at the designed test bench using the following solutions:

- Water;
- 0.1% linear alkyl benzene sulfonate (LABS) of sodium aqueous solution;
- 0.1% aqueous solution of sodium lauryl sulfate;
- Developed biopolymer drilling mud.

The results are shown in Table 1 and Figure 2.

Table 1. Results of test trials

Investigated solution	Water	LABS of sodium	Sodium lauryl sulfate	Biopolymer drilling mud
RCT immersion depth, mm	9,0	9,6	11,05	10,65

The table shows that the use of sodium LABS increases the effectiveness of the destruction on 7%, and sodium lauryl sulfate on 23%. Biopolymer solution containing a surfactant composition increases investigated parameter on 18%. At the same time other functions of drilling fluid are also maintained, e.g. hydrostatic (sludge keeping in suspended state when circulation is stopped), hydrodynamic (sludge removal and cleansing of borehole bottom), wall building properties etc.

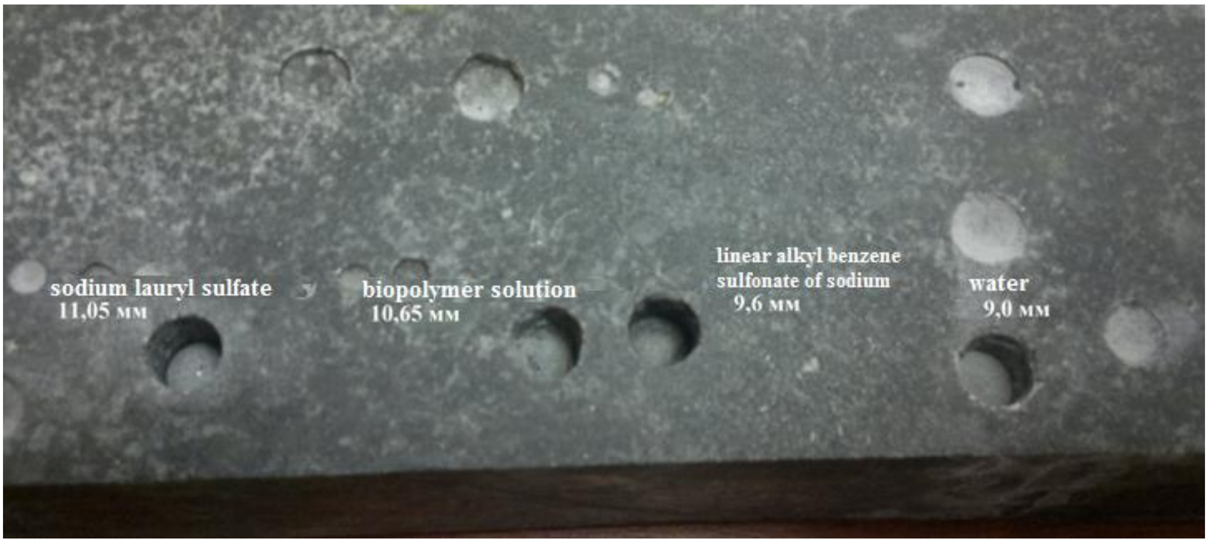

Figure 2 - The results of experimental test trials

The results of experimental test trials stand in agreement with the results obtained in the study of these solutions by the method of quantifying assessment of washing liquid softening action on drilled rocks, presented in [3].

2. Ecological and economic evaluation of the developed biopolymer drilling mud

It is known that drilling is accompanied by the use of different materials, including chemicals of varying hazard level, significant volumes of water consumption and the formation of production and processing wastes, representing a danger for the flora and fauna. The main objects of contamination during drilling are geological environment, hydro- and lithosphere. They are contaminated as a result of imperfections and inconsistencies of individual technological processes with environmental protection requirements, as well as due to the ingress of chemicals, petroleum products and production and processing wastes of drilling, comprised by drilling wastewater, waste drilling mud and drill cuttings.

Currently much attention is also paid to reduction or elimination of the environmental risks associated with the human impact on the environment. Modern technologies used in production and drilling in particular, need to minimize the possibility of pollution of atmosphere, soil, surface water and ground water. With the development of the oil and gas industry pollution by organic substances, the most common of which are oil and oil products, is becoming more global. However, increased use of surfactants at home and in industry should also be noted. Water containing a surfactant has a detrimental effect on the environment and toxic impact on the human body, causing carcinogenic, mutagenic and allergenic effects. One of the most important factors, indicating environmental safety, is biodegradability of substances.

Since the composition of solution contains surfactants, it is necessary to assess their environmental safety. All surfactants are divided into three generations in the degree of degradability: the first generation (hard) - non-biodegradable or biodegradable to less than 80%; the second (intermediate) – biodegradable to more than 80% (80-90%), only until organic compounds; the third (soft) - compounds fully biochemically degradable to water, carbon dioxide, sodium sulfate [6].

At well drilling various types of surfactants are widely used, most of them belong to III and IV classes of hazard (moderately hazardous and low-hazard substances). Therefore, when working with a surfactant it is necessary to use personal protective equipment.

In this paper, main components of developed drilling mud are: biopolymer "KK Robus", acryl polymer "KM-017" and the composition of anion-active surfactants (sodium lauryl sulfate and potassium acetate).

Biopolymer "KK Robus" - dry mixture, which is fire- and explosion safe, non-toxic, biologically harmless, does not emit harmful products during storage and usage, belongs to IV class of hazard. "KM-017" is an acryl series copolymer of carboxylic acids, their esters and salts. Reagent belongs to IV hazard class [7]. Sodium lauryl sulfate and potassium acetate are hazard class III and IV respectively [8].

Thus, developed composition of the biopolymer solution is a low-hazard substance from the environmental point of view.

In order to assess the cost-effectiveness of the proposed composition, calculation of 1 m^3 clayless drilling mud preparation is presented. Table 3 shows formulations and costs of common clayless fluid compositions (due to 2015).

Table 3 - Formulations and costs of clayless solutions

Mud composition	Concentration, kg/m^3	Cost, USD.	
		1 kg of reagent	1 m^3 of solution
Proposed solution			
«KK Robus»	4	4.5	18
«KM-017»	50	1.25	62.5
Sodium lauryl sulfate	0,5	1.66	0.83
Potassium acetate	0,5	1	0.5
Sodium hydrate	1	0.48	0.48
Overall:			82.31
Barroid solution			
Barazan	3,5	9.33	32.66
Dextrid	15	1.5	22.5
KOH	1,5	0.95	1.43
KCL	40	1.33	53.2
Overall:			109.79
M-I SWACO solution			
Flo-Pro	20	5	100
KCl	30	1.33	39.9
Overall:			139.9

Table 3 shows that the cost of widespread clayless solutions is 33 - 70% higher than the cost of the developed composition, based on the biopolymer "KK Robus" and polymer "KM-017".

CONCLUSION

Conducted test trials confirm high efficiency of rocks destruction with application of biopolymer solutions containing hardness reducers - detergents in its composition. Also, developed composition of the biopolymer solution on the basis of a biopolymer "KK Robus" and acryl polymer "KM-017" is seen as low-hazard substance from an environmental point of view.

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