Preservation of the filtration capacity of the formation by increasing the strength of the crust and colmatating ability of the drilling fluid

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Abstract. The insufficient density and low strength of the mudcake does not ensure the complete cessation of drilling fluid penetration into the reservoir capillary volume. At the same time, the penetrating components of the solutions, upon contact with the formation components, lead to clogging of the capillary volume due to physicochemical processes. The experiments were carried out on cores made from carbonate rocks of a similar composition of the productive formation and on artificial cores made from carbonate rocks, 30 mm in diameter and 40 mm long. The initial gas permeability of artificial samples was approximately the same (3.6-3.7 m). According to the results, the high strength of the colmatation barrier created by WC-Y736-A polyethylene powder and the low strength of the bonfire-kenaf and cotton cellulose. The resulting deep clogging of the pores and sufficient strength of the polyethylene colmatation barrier was achieved due to their high degree of swelling and physico-chemical effect of the colmatant with the rock.

Keywords: crust, filtration, formation, colmatation, mudcake, rocks, drilling fluid, Uzbekistan

1. Introduction

One of the reliable ways leading to the preservation of the natural permeability of the formation is the clogging of the pore space of the formation with a strong impermeable crust. However, the insufficient density and low strength of the mudcake does not ensure a complete cessation of drilling fluid penetration into the reservoir capillary volume. At the same time, the penetrating components of the solutions, upon contact with the formation components, lead to clogging of the capillary volume due to physicochemical processes [1, 2]. Therefore, researchers working in the oil and gas industries are faced with the task of improving the strength of the clay cake formed on the wellbore wall in the bottomhole zone of the well and the clogging ability of flushing solutions used to open the productive formation.

In practice, this issue was solved by adding such fillers as crumb rubber, waste from chemical and woodworking plants to the composition of the drilling fluid. However, the use of these fillers eliminated only catastrophic losses of solutions in highly fractured and fault zones of the section [3, 4].

In the study area, productive formations in most of the fields in Uzbekistan have high permeability and fracturing. Drilling practice has shown that the use of these fillers during the opening of productive horizons does not always ensure a complete cessation of the penetration of the solution filtrate into the pores of the formation due to the weak clogging ability [5, 6].
Considering the above, we have studied the bridging ability of a number of widely used fillers in the conditions of Uzbekistan. For example, hydrolyzed cotton cellulose (HC), diacetylcellulose (DAC), triacetylcellulose (TAC), asbestos, kostra-kenaf, marble powder, as well as a powdered mass layer - WC-Y736-A polyethylene produced by the Shurtan gas chemical plant, Uzbekistan [7].

The studies were carried out on cores made from carbonate rocks of a similar composition of the productive formation and on artificial cores made from carbonate rocks, 30 mm in diameter and 40 mm long. The initial gas permeability of artificial samples was approximately the same (3.6-3.7 mD).

2. Methods

In this research, the bridging ability of a number of widely used fillers in the conditions of Uzbekistan was studied. Noteworthy, hydrolyzed cotton cellulose (HC), diacetyl cellulose (DAC), triacetyl cellulose (TAC), asbestos, kostra-kenaf, marble powder, as well as a powdered mass layer-WC-Y736-A polyethylene produced by the Shurtan gas chemical plant located in Uzbekistan [8].

The experiments were carried out on cores made from carbonate rocks of a similar composition of the productive formation and on artificial cores made from carbonate rocks, 30 mm in diameter and 40 mm long. The initial gas permeability of artificial samples was approximately the same (3.6-3.7 m). To determine the clogging ability of each filler, a control solution of bentonite was prepared, and to compare the clogging ability of fillers, the same amount (0.5%) of fillers was added to the initial solution [6, 7]. The studies of the bridging ability of fillers were carried out on a laboratory setup shown in Figure 1. The installation was designed in the scientific center “Combating complications in drilling wells” where the authors actively participated in the process [1, 2].

![Figure 1. Laboratory installation for determining the clogging ability of solutions.](image-url)
3. Results and discussions

According to the research results, powdered plastic-WC-Y736-A grade polyethylene and marble flour had the best bridging abilities. With the addition of cotton cellulose, asbestos and kostra-kenor, the filtration rate decreases by about 15% compared to the original (Table 1). Fillers do not affect other indicators of the solution. The next stage of the study was devoted to the study of the degree of swelling of coltmatants over time under the influence of the solution filtrate.

Table 1. The effect of fillers on the properties of drilling fluids and the filtration characteristics of samples.

| # | Solution name | Solution parameters | The amount of liquid filtered through the samples, cm³ over time (min) |
|---|---------------|---------------------|---------------------------------------------------------------|
|   |               | ρ kg/m³ | T 500 sec | V cm³/m³ | SNA mg/cm² | 5 | 10 | 15 | 20 | 25 | 30 |
| 1 | Initial bentonite solution | 1040 | 6.2 | 18 | 21/26 | 11.6 | 12.3 | 13.4 | 14.6 | 15.4 | 16 |
| 2 | With the addition of 3 g/l bonfire-kenaf | 1040 | 6.9 | 15.4 | 32/39 | 6.5 | 6.9 | 7.3 | 7.8 | 8.1 | 8.3 |
| 3 | With the addition of 3 g/l AC | 1030 | 7.5 | 15.0 | 30/36 | 5.9 | 6.4 | 6.9 | 7.3 | 7.9 | 8.2 |
| 4 | With the addition of 3 g/l TAC | 1030 | 7.3 | 16.1 | 46/52 | 6.4 | 6.9 | 7.4 | 7.8 | 8.2 | 8.6 |
| 5 | With the addition of 3 g/l of asbestos | 1040 | 8.2 | 15.4 | 34/39 | 6.2 | 6.7 | 7.4 | 7.8 | 8.2 | 8.7 |
| 6 | With the addition of 3 g/l HC | 1050 | 8.4 | 15.2 | 26/33 | 4.2 | 4.6 | 5.6 | 6.1 | 6.6 | 6.9 |
| 7 | With the addition of 3 g/l marble powder | 1030 | 6.0 | 10 | 26/35 | 4.0 | 4.7 | 4.9 | 5.0 | 5.2 | 5.3 |

During the experiment, the fillers were crushed to the same (average) fraction. To model the drilling mud filtrate, chalk mud filtrates of a stabilized 0.5% (by volume) polymeric reagent Carbo-PAC, which is widely used in productive formations in the country, was used in this research. The fillers were individually placed in glassware and the studied filtrate was poured. The resulting paste-like mass was placed in a device-determinant of the swelling of the representations in Figure 2. The temperature during the experiment was maintained at 20-22°C.

![Figure 2](image-url)
Table 2 indicated that in descending order, the swelling index of the fillers was arranged as following as % polyethylene WC-Y736-A, asbestos, marble flour, kostra-kenaf, cotton cellulose (CC). It was reported that in those two cases where the maximum swelling of the fillers was only 1.35 and 1.20%, colmatation barriers apparently formed here due to mechanical clogging of pores, and in other cases, physicochemical processes also took place.

| #  | Name of fillers       | Swelling index (in %) over time (days) |
|----|-----------------------|---------------------------------------|
| 1  | Kostra-kenaf          | 0.75 1.15 1.25 1.30 1.35               |
| 2  | Cotton cellulose (CC) | 0.60 1.00 1.15 1.20 1.20               |
| 3  | Asbestos              | 1.00 1.30 1.65 1.75 1.80               |
| 4  | Marble flour          | 0.85 1.20 1.50 1.60 1.65               |
| 5  | Polyethylene WC-Y736-A| 1.05 1.60 1.95 2.15 2.225              |

Futhermore, the strength of the clogging barrier for core formation was researched. Accordingly, Colmatants were injected into artificial core samples under pressure of 2.0 MPa with a filtrate of chalk solutions for 30 minutes. The strength of the colmatation was assessed by the gas permeability of the samples before, after colmatation and removed from the clogging zone of the 5 mm core layer (Table 2).

According to the results, the high strength of the colmatation barrier created by WC-Y736-A polyethylene powder and the low strength of the bonfire-kenaf and cotton cellulose (Table 3). The resulting deep clogging of the pores and sufficient strength of the polyethylene colmatation barrier was achieved due to their high degree of swelling and physico-chemical effect of the colmatant with the rock. It should be noted that plasticine powder, as a result of interaction with the filtrate of drilling fluids, creates a strong impermeable screen in all permeable zones of the open trunk in a short time, thereby suspending the penetration of the solid and liquid phases of the drilling fluid into productive formations (Table 3).

| #   | Name of the colmatant       | Absolute gas permeability of mD samples |
|-----|------------------------------|----------------------------------------|
|     |                              | Original | After colmatation (K1) | After removing the 5 mm barrier (K2) | K=K1/K2 |
| 1   | Polyethylene WC-Y736-A       | 8.7      | 0.27                  | 0.17                             | 1.0     |
| 2   | Asbestos                     | 8.4      | 1.79                  | 2.17                             | 1.21    |
| 3   | Marble flour                 | 8.9      | 2.08                  | 3.50                             | 1.68    |
| 4   | Kostra-kenaf                 | 8.0      | 2.77                  | 7.87                             | 2.84    |
| 5   | Cotton Pulp (HC)            | 8.6      | 3.11                  | 7.95                             | 2.55    |

Another experiment done during this study was devoted to the study of the degree of restoration of the natural filtration capacity of productive layers after the creation of colmatation barriers with the help of colmatants. During the experiments, artificial cores from carbonate rocks were used. The initial qualities of the filtered liquids of the artificial samples were approximately the same – 100-110 cm³ in 30 minutes. The amount of colmatants in the liquid phase was 1.0% of the volume of the solution. Saturation of colmatants into artificial core samples was carried out with a filtrate of a chalk solution stabilized with 0.5% carbonic acid reagent. The saturation pressure was 2.0 MPa and was left for three weeks for the expiration of the swelling process of colmatants. After the set time, the amount of filtered liquid was measured through the colmatation zone for 30 minutes. Moreover, the degree of decolmatation, a chalk solution filtrate with an excess pressure of 2.0 MPa was sent through the samples from the other end for 30 minutes. The difference in the amount of liquid phase filtered out within 30 minutes after
colmatation and during decolmatation will help us to determine the degree of restoration of the filtration capacity of the productive reservoir.

It can be assumed that under production conditions, fillers such as bonfire-kenaf and cotton cellulose restore the natural filtration characteristic to the maximum extent as a result of reducing excess pressure on the formation, since the weakly formed, little durable colmatation barrier was formed as a result of only mechanical clogging of the pores of the core material. These colmatants were easily destroyed when exposed to pressure from the reservoir and cleans the pores of the formation from impurities of colmatants. Another problem arises with those colmatants whose core recoverability is at a low level, although in terms of the strength of the colmatation barrier, swelling and filtration parameters, they are much superior to bonfire-kenaf and cotton cellulose (Table 4).

Table 4. Recoverability of filtration abilities of the core sample after colmatation of the pore channel with colmatants.

| #  | Name of the colmatant    | The amount of filtered liquid phase for 30 minutes cm$^3$ | Recoverability in % F=F2/F1*100% |
|----|--------------------------|-----------------------------------------------------------|----------------------------------|
| 1  | Kostra-kenaf             | Source F2 110, After colmatation 27, After decolmatation (F2) 100 | 90.0                             |
| 2  | Cotton cellulose (CC)    | 105, 30, 97                                               | 92.3                             |
| 3  | Asbestos                 | 100, 10, 70                                               | 70.0                             |
| 4  | Marble flour             | 108, 13, 77                                               | 71.2                             |
| 5  | Polyethylene WC-Y736-A   | 110, 2, 68                                                | 61.1                             |

Apparentl, physicochemical phenomena played an important role here in the process of colmatation, which created additional resistance in the process of decolmatation. It should be noted that all three colmatants (asbestos, marble flour and polyethylene) were easily dissolved upon contact with hydrochloric acid (HCl) thereby restoring 100% filtration channels of the productive reservoir (Table 4). Thus, as a result of the conducted research, it was established that not all colmatants can create a strong non-permeable barrier in the productive reservoir. It was found that fillers of the WC-Y736-A type to a certain extent suspend the amount of filtrate solutions penetrated into the layers, which showed increase in the strength and density of the structure, as well as improving the reinforcing ability of WC-Y736-A, as well as the crust.

4. Conclusions
1. It was reported that in those two cases where the maximum swelling of the fillers was only 1.35 and 1.20%, colmatation barriers apparently formed here due to mechanical clogging of pores, and in other cases, physicochemical processes also took place.
2. Furthermore, in those two cases where the maximum swelling of the fillers was only 1.35 and 1.20%, colmatation barriers apparently formed here due to mechanical clogging of pores, and in other cases, physicochemical processes also took place.
3. As a result of interaction with the filtrate of drilling fluids, plasticine powder created a strong impermeable screen in all permeable zones of the open trunk in a short time, thereby suspending the penetration of the solid and liquid phases of the drilling fluid into productive formations.

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