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МОДЕЛИРОВАНИЕ ОЧИСТКИ ПРИЗАБОЙНОЙ ЗОНЫ ПЛАСТА ЗАСОЛОНЕННОГО ТЕРРИГЕННОГО КОЛЛЕКТОРА

MODELING OF THE NEAR-WELLBORE ZONE CLEANING OF A SALINE TERRIGENOUS RESERVOIR

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Аннотация. В данной работе представлены результаты моделирования очистки от бурового раствора моделей пласта $Б_5$ ботуобинского горизонта. Установлено снижение проницаемости при проведении кислотных обработок засолоненного терригенного пласта, что связано с выпадением хлорида натрия в поровом пространстве. По результатам опытов даны рекомендации по проведению кислотных обработок засолоненного терригенного коллектора.

Ключевые слова: кислотная обработка, терригенный коллектор, модель пласта, глинокислота, изопропиловый спирт.

Annotation. The results of modeling the drilling fluid cleanup of reservoir models B_5 of the Botuobinsky horizon are presented in this paper. A decrease in permeability during acid treatment of a saline terrigenous formation was determined, which is associated with the precipitation of sodium chloride in the pore space. Recommendations for acid treatment of a saline terrigenous reservoir were given based on the results of the experiments.

Keywords: acid treatment, terrigenous reservoir, reservoir model, clay acid, isopropyl alcohol.

The oil and gas fields on the territory of the Nepa-Botuoba anteclise are a major base for the oil and gas industry [1–3]. Some oil reservoirs on the territory have unique thermobaric parameters. There are 12–18 ^{o}C reservoir temperature and 10 MPa pore pressure [3]. Also, the salinity of formation water reaches 300 g/l of chloride salts [3, 4]. Drilling fluids with high salinity are used in the construction and repair of wells in these fields [5]. Cleaning of the near-wellbore zone of the well from process fluids is carried out by acid treatment. However, major acid compositions for treatment contain HCl [6]. The study of the effect of acid solutions on the permeability of a saline terrigenous reservoir is relevant.

A series of filtration experiments was carried out to estimation of acid treatment effect on permeability of terrigenous rock models. An increase or decrease of permeability were fixed in experiments. The experiments were carried out on multiprofile module system ACRS-831Z (Coretest system, USA) under thermobaric conditions (pore pressure P = 10 MPa, reservoir pressure P = 32 MPa, reservoir temperature t = 14 ^{o}C). Solutions of the composition Hydrochloric acid+Surfactant (HCl – 22 wt %, Surfactant – 3 wt %) – 1, Clay Acid+Surfactant (HCl – 22 wt %, HF – 3 wt %, Surfactant – 3 wt %) – 2 and Isopropyl alcohol+Clay Acid+Surfactant (HCl – 16 wt %, HF – 3 wt %, Surfactant – 3 wt %, Isopropyl alcohol – 20 wt %) – 3 were chosen for experiment. Core samples from the B_5 of the Botuobinsky horizon were used. Cylindrical samples had dimensions of length and diameter l = d = 3 cm, helium gas permeability in the range K = 38.31–106.73$\cdot10^{-3}$ µm^2, porosity ø = 7.08–15.23%, mineralization of formatiom water was 300 g/l (NaCl). Reservoir model was composed of 3 samples. Fluid injection rate of solutions to the reservoir model was Q = 15 cm^3/h. Drilling fluid (xanthan biopolymer – 0.35 wt %; carboxymethylcellulose (CMC) – 0.6 wt %; calcined soda (Na_2CO_3) – 0.05 wt %; defoamer – 0.02 wt %; sodium chloride – 26.4 wt %) was used as a clogging agent.

The permeability assessment test was based on the pressure difference created by fluids injected into the reservoir model at the ends of a core sample. First, a reservoir oil model was pumped through the core and oil permeability ($K_1\cdot10^{-3}$, µm^2) was determined; then drilling fluid was injected, and afterwards oil phase permeability ($K_2\cdot10^{-3}$, µm^2) was determined. The next stage involved acid treatment, followed by the determination of oil permeability of the reservoir model (K_3,$K_4\cdot10^{-3}$, µm^2). Also, the calculation of the coefficient of decrease or increase in permeability relative to the initial value of K_1: $K_3(K_4)/K_1$ was made [7].

Rock permeabilities were assessed in terms of the Darcy linear filtration law:

$$K = \frac{\mu \cdot l \cdot Q}{\Delta P \cdot F}, \tag{1}$$

where K is rock permeability, m^2 ; Q is fluid volume rate per unit time, m^3/s; µ is dynamic viscosity of the fluid, N·s/m^2 ; l is carbonate reservoir model length, m; ΔP is pressure difference at the ends of reservoir model, N/m^2; and F is filtration area, m^2.

The results of filtration experiments are presented in Table 1. Treatment of the B_5 terrigeneous reservoir models with drilling fluid led to decrease in oil permeability by 4.88–7.79 times. Also this shown in the graphs of pressure gradient changes versus injected pore volumes of solutions. He increased from initial values GradP = 5–15 atm/m to GradP = 38–45 atm/m (Fig. 1).

Table 1 – Filtration characteristics of the reaction between saline terrigenous core models and acid fluids

Acid solution	V_{pore}	K_1, µm$^2\cdot10^{-3}$	K_2, µm$^2\cdot10^{-3}$	K after first acid injection, µm$^2\cdot10^{-3}$	K after fresh water injection, µm$^2\cdot10^{-3}$	K_3 (K_4), µm$^2\cdot10^{-3}$	$K_3(K_4)/K_1$, times
1	9.4	66.80	8.57	< 0.1	6.64	19.88	low 3.36
2	9.2	18.29	3.75	< 0.2	2.40	15.48	low 1.18
3	9.4	37.27	8.25	< 0.4	4.65	46.53	high 1.25

Filtering the first volumes of acid solutions led to significant decrease in permeability. Pore space clogging is explained by the contact of acid solutions with abnormally highly mineralized water. Additional Cl^- ions lead to the precipitation of sodium chloride, when HCl interacting with a supersaturated mineralized water (the solubility of NaCl at 20 °C is 26.4 % or 311 g/l). This sharp increases the pressure gradient along the length of the reservoir model. The sharply increasing pressure gradient does not allow to measure the permeability of the rock with oil. However, fresh water injection (V = 4 V_{pore}) dissolves the NaCl crystals and increases the permeability of the reservoir. Subsequent injections of acid solutions do not lead to reservoir clogging. The injection of Hydrochloric acid+Surfactant acid solution increases the permeability in relation to clogging with drilling fluid by 2.32 times. However, decrease in permeability relative to the initial values by 3.36 times was noted. Clay Acid+Surfactant increases the permeability in relation to clogging with drilling fluid by 4.13 times, but decrease in permeability relative to the initial values by 1.18 times was fixed. Isopropyl alcohol+Clay Acid+Surfactant increases the permeability in relation to clogging with drilling fluid by 5.64 times and increases in permeability relative to the initial values by 1.25 times.

Visual analysis of the core was carried out after filtration experiments (fig. 2). The injection of acid solutions in the reservoir model does not lead to the formation of macroscopic filtration channels. Presumably, microscopic channels are formed during the injection of an acid solution Isopropyl alcohol+Clay Acid+Surfactant. Traces of NaCl were found on some samples, which is consistent with the increase in pressure gradient during injection.

Thus, based on laboratory experiments, the following recommendations were made. Sequential injection of 3–4 m^3 of fresh water buffer into the reservoir, then injection of 6–10 m^3 of acid solution and fresh water injection buffer in the tubing volume is the recommended option for acid treatment of a saline terrigenous reservoir. If there is no initial water injectivity of injection wells, then the combination of acid treatments with jet fracturing in the formation zone near the well (mini-fracturing) should also be carried out with fresh water buffers.

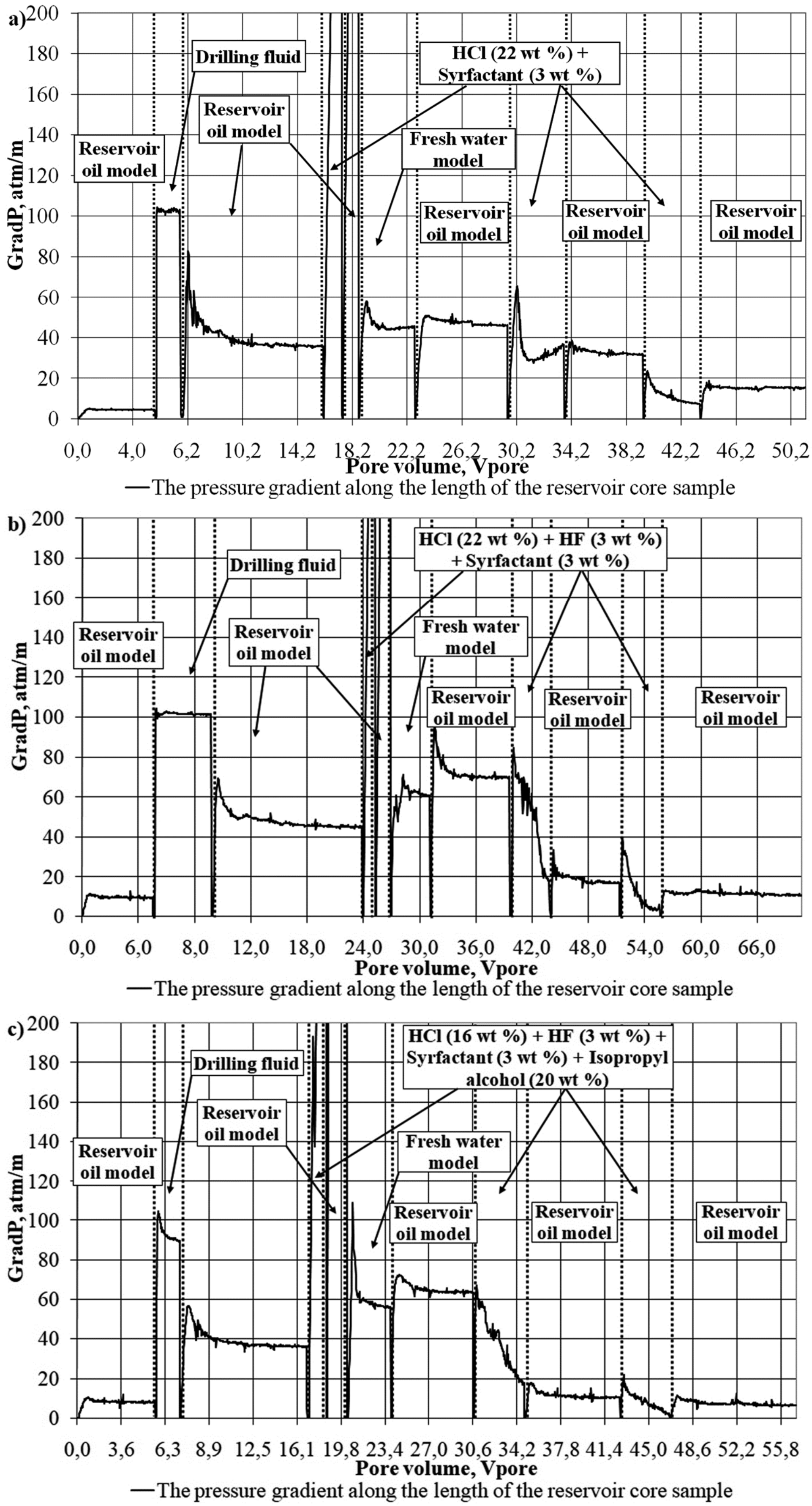

Figure 1 – Pressure gradients at the ends of the reservoir core sample upon the injection of oil, drilling fluid, and (a) Hydrochloric acid+Surfactant, (b) Clay Acid+Surfactant and (c) Isopropyl alcohol+Clay Acid+Surfactant

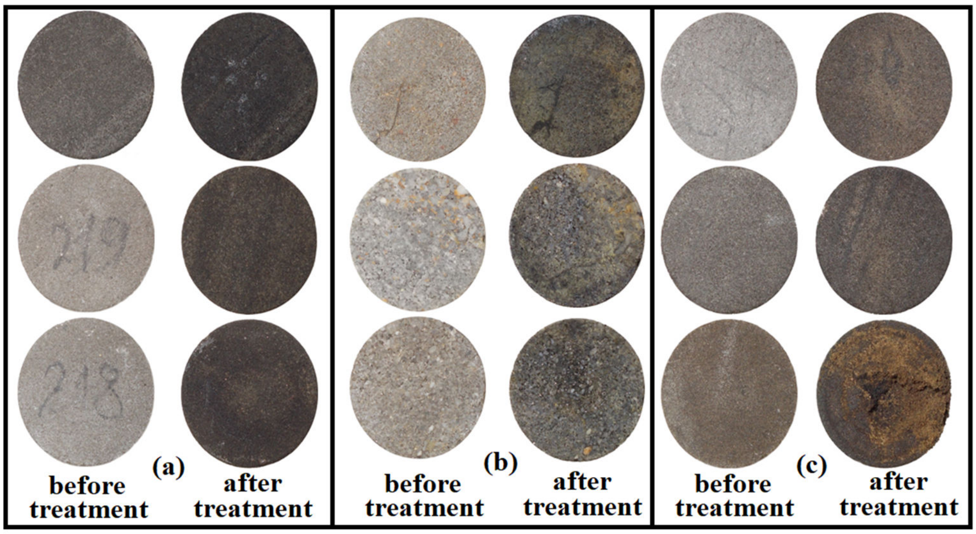

Figure 2 – End surface of terrigenous core models before and after the rock was treated with (a) Hydrochloric acid+Surfactant, (b) Clay Acid+Surfactant and (c) Isopropyl alcohol+Clay Acid+Surfactant

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