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ВЗАИМОДЕЙСТВИЕ КИСЛОТНЫХ РАСТВОРОВ С МОДЕЛЯМИ ПЛАСТА ЮС$_2$ В ТЕРМОБАРИЧЕСКИХ УСЛОВИЯХ

INTERACTION OF ACID SOLUTIONS WITH A FORMATION JS$_2$ MODELS UNDER THERMOBARIC CONDITIONS

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Аннотация. В данной работе представлены результаты обработки моделей пласта ЮС$_2$кислотными растворами в термобарических условиях. Определены коэффициенты проницаемости моделей пласта до и после проведения кислотных обработок, проведен визуальный анализ керна. По результатам опытов рекомендован подходящий кислотный раствор для проведения кислотной обработки пласта ЮС$_2$.

Ключевые слова: пласт ЮС$_2$, кислотная обработка, модель пласта, глинокислота, изопропиловый спирт, этиленгликоль.

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Annotation. The results of treatment of a formation JS$_2$ models with solutions under thermobaric conditions are presented in this paper. The permeability coefficients of reservoir models were determined before and after acid treatments, and a visual analysis of the core were carried out. According to the results of the experiments, a suitable acid solution was recommended for treatment of the formation JS$_2$.

Keywords: formation JS$_2$, acid treatment, reservoir model, clay acid, isopropyl alcohol, ethylene glycol.

The Tyumen formation (formation JS$_2$) contains up to 4.5 billion tons of oil according to various estimate [1, 2]. JS$_2$ formation is a terrigenous reservoir. However, the reserves of the JS$_2$ formation are hard-to-recover. Low oil production rates are due to low permeability($3–5 \cdot 10^{-3}$ μm^2) and layered reservoir heterogeneity. Also, the clogging of the near-wellbore zone in the process of construction and repair of wells lead to reduce hydrodynamic connection between production wells and injection wells [3].

The main method of cleaning from clogging and increasing the permeability of the formation is acid treatment. The treatment of terrigenous reservoir is carried out by Clay acid with various additives. Clay acid with Isopropyl alcohol is used for treatment of JS$_2$ formation [4]. However, Isopropyl alcohol is a flammable liquid. Safety requirements at some oilfield facilities prohibit the storage of flammable liquids with acids in the storage of chemicals. In this regard, the selection of a non-flammable co-solvent for adding to the acid is relevant.

A series of filtration experiments was carried out to compare of acid solution. An increase in the fluid conductivity of the rock was an indicator of effectiveness. 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 = 42–44 MPa, reservoir temperature t = 82 °C). Solutions of the composition Clay Acid+Surfactant (HCl – 22 wt %, HF – 3 wt %, Surfactant – 3 wt %) [5], Isopropyl alcohol+Clay Acid+Surfactant (HCl – 16 wt % , HF – 3 wt %, Surfactant – 3 wt %, Isopropyl alcohol – 20 wt %) and Ethylene glycol +Clay Acid (HCl – 17,1 wt %, HF – 3,2 wt %, Ethylene glycol – 8 wt %, Tradename – «СНПХ-9030, марка Б») were chosen for experiment. Core samples from the JS_2 formation (fine-grained silty sandstone) were used. Cylindrical samples had dimensions of length and diameter l = d = 3 cm, helium gas permeability in the range K = 3.52–6.62$\cdot10^{-3}$ μm^2, porosity ø = 15.08-17.68 %. The reservoir model was composed of 3 samples. Fluid injection rate of solutions to the reservoir model was Q = 6 cm^3/h. Drilling fluid filtrate (polyacrylamide Survey D1 – 1.0 wt %; biopolymer Xanthan Gum – 1.0 wt %; filtration stabilizer Survey FL – 2.0 wt %; Clay powder – 8.0 wt %; NaOH – 0.1 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 filtrate 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 and increase in permeability relative to the initial value of K_1: $(1-K_3(K_4)/K_1)\cdot100\%$ and $(K_3/K_{2-1})\cdot100\%$ was made [6].

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 JS_2 reservoir models with drilling fluid filtrate led to a decrease in oil permeability by 2.3–2.6 times. Also this shown in the graphs of pressure gradient changes versus injected pore volumes of solutions. He increased from initial values GradP = 35–55 atm/m to GradP = 80–120 atm/m (Fig. 1).

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

Acid solution	V_{pore}	K_1, μm$^2\cdot10^{-3}$	K_2, μm$^2\cdot10^{-3}$	K_3 (K_4), μm$^2\cdot10^{-3}$	$K_4(K_3)/K_1$-$K_1/K_4(K_3)$
Clay Acid+Surfactant [5]	7,2	2,61	1,09	>920	>380
Isopropyl alcohol+Clay Acid+Surfactant	3,3	1,65	0,63	>1590	>610
Ethylene glycol+Clay Acid	7,7	2,62	1,04	>960	>420

Filtering the first volume of Clay Acid+Surfactant led to an increase in permeability with K = 1.09$\cdot10^{-3}$ μm^2 up to K = 3.13$\cdot10^{-3}$ μm^2 [4]. Injection of the second volume acid solution led to significant (K > 1000$\cdot10^{-3}$ μm^2) increase in rock permeability. This is explained by the dissolution of the aluminosilicate framework of the rock by hydrofluoric acid and the formation dissolution channel. Injection of an acid solution of Isopropyl alcohol+Clay Acid+ Surfactant into the reservoir model also led to a significant (K > 1000$\cdot10^{-3}$ μm^2) increase rock permeability. Smallest volume of solution V = 3.3 V_{pore} was spent on this treatment. Injection the second volume of acid solution was not required. Filtering of solution with non-flammable co-solvent looks like injection of Clay Acid+Surfactant, but volume of solution was V = 7.7 V_{pore}.

Visual analysis of the core was carried out after filtration experiments (fig. 2). Formation of highly permeable dissolution channels in all models was confirmed. The formation of dissolution channels with a diameter of 1-3 mm was noted. High reactivity led to the destruction of the rock matrix and the removal a layer of frame grains of sandstone (quartz, feldspar) by the filtration flow from models.

Thus, in a series of experiments, it was confirmed a significant decrease of the permeability of the JS_2 reservoir models after their treatment with process fluid (drilling fluid filtrate). All acid solutions led to increase of permeability and formation of highly permeable channels of dissolution. The smallest volume of the solution is required when acidizing the reservoir model with a solution of Isopropyl alcohol+Clay Acid+Surfactant. However isopropyl alcohol is a flammable liquid. Therefore, the treatment of formation JS_2 at some oilfield facilities is recommended to be carried out with acid solution Clay Acid+Surfactant. Acid treatment of the JS_2 formation with an acid composition with non-flammable alcohol (Ethylene glycol+Clay Acid) is also an acceptable method. Besides this, the addition of various surfactants to the acid solution Ethylene glycol+Clay Acid is of interest and will be further investigated by the authors.

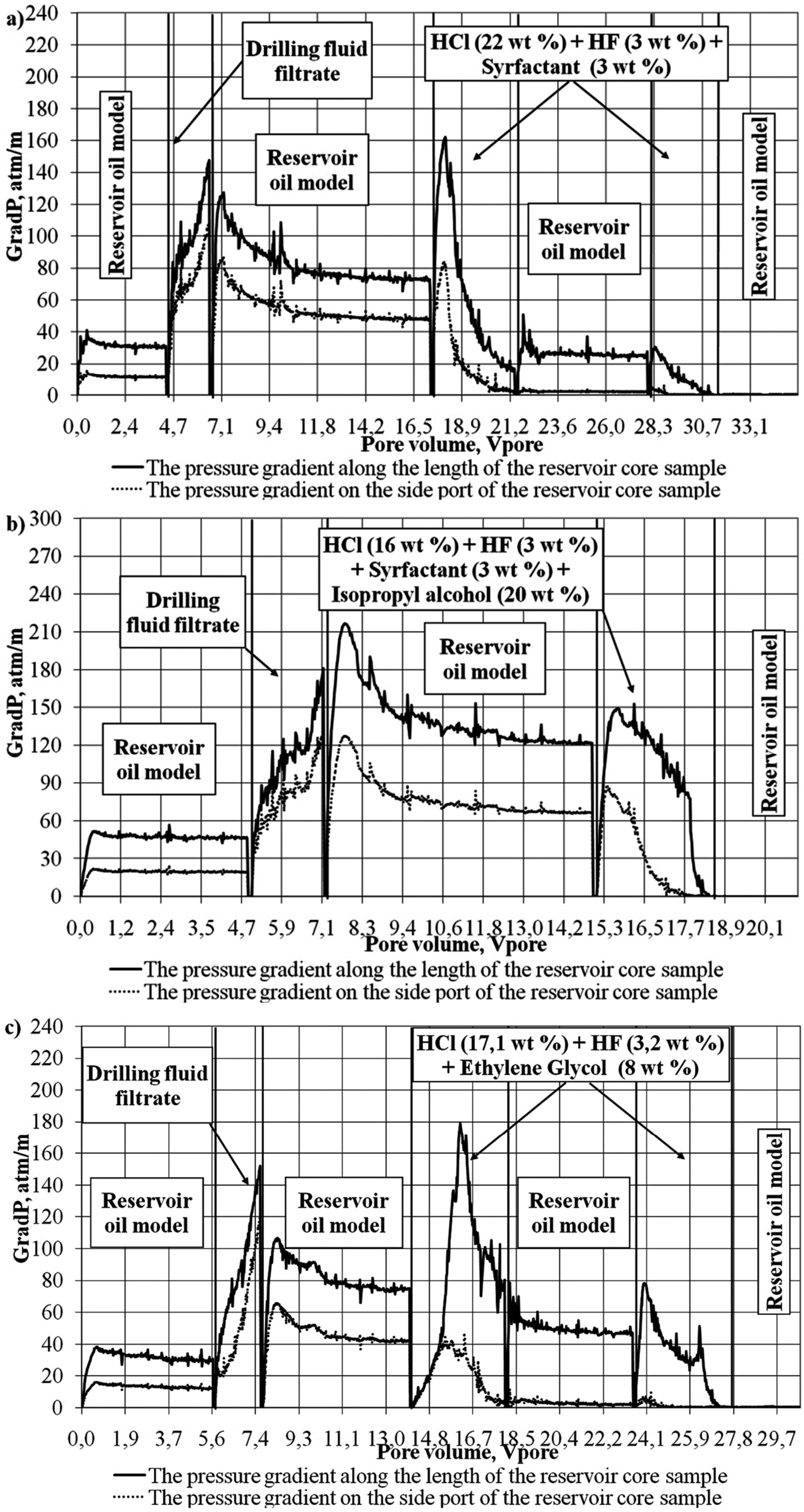

Figure 1 – Pressure gradients at the ends of the reservoir core sample upon the injection of oil, drilling fluid filtrate, and (a) Clay Acid+Surfactant [5], (b) Isopropyl alcohol+Clay Acid+Surfactant and (c) Ethylene glycol+Clay Acid

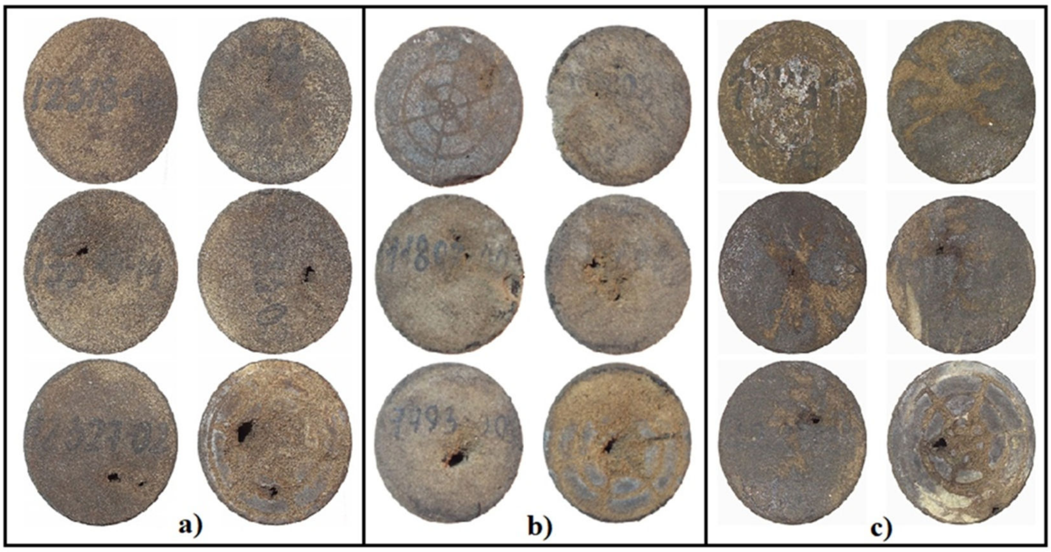

Figure 2 – End surfaces of terrigenous core models after the rock was treated with (a) Clay acid+Surfactant [5], (b) Isopropyl alcohol+Clay Acid+Surfactant and (c) Ethylene glycol+Clay Acid

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