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Selection of acid compositions in well construction in difficult geological conditions

M V Mishchenko[1] and M R Kamartdinov[2]

[1, 2] Tomsk Polytechnic University, 30 Lenin Avenue, Tomsk, 634050, Russia

E-mail: [1] MishenkoMV@hw.tpu.ru, [2] KamartdinovMR@hw.tpu.ru

Abstract. Within the scope of the current work we have presented an approach towards selecting and substantiation of acid composition in accordance with petrophysical characteristics of formations for acid treatment of bottom-hole formation zones. Article presents the results of lab tests of selected acid compositions, in conditions, which model thermobaric conditions of a payzone, combined with an evaluation of hydraulic permeability change, and this, in its turn, should allow us to evaluate the quality of impact of the acid composition recipe on the reservoir formation.

1. Introduction

Processing bottom-hole formation zone with acid compositions is a relatively inexpensive, effective and commonly used methods to increase the permeability of the bottom-hole zone [5]. The method is based on the effects of water-based solution of acid reacting with minerals, forming the reservoir rock, and introduced solid minerals, blocking the bottom-hole zone. Therefore, one must use acid compositions containing chemical additives that meet specific geological and physical conditions and provide optimum depth of penetration of the active reagent. This approach can increase the effectiveness of the acid treatment and avoid the negative consequences, in particular, the formation of stable emulsions, insoluble precipitates causing secondary mudding of bottom-hole formation zone [3, 6, 7, 8]. Well acidizing with sandstone reservoirs, in most cases does not require influence on the reservoir matrix. It is enough to remove colmatants of technogenic origin or carbonate component of reservoir. One of the common ways to treat well bottom-hole zone is the use of hydrochloric acid [4, 7].

2. Preparation and laboratory work

To select the most effective acid composition, the following laboratory tests were performed: samples preparation, study of porosity and permeability coefficients, determination of their mineralogical composition, definition of the impact of acidic compounds on the rock.

Preparation of samples for the study was conducted in accordance with GOST 26450.0-85 whereby core material samples were subjected to extraction with alcohol-benzene mixture (in the ratio 3:1), washed in distilled water and dried to constant weight [1]. Upon preparatory phase completion, porosity and permeability coefficients were studied [2].

To determine the mineralogical composition and quantitative relations of minerals in the rock, X-ray diffraction (XRD) method was used. Of all methods of determining the mineral composition of rocks, X-ray analysis is the most informative. For clay minerals XRD is the only reliable diagnostic tool. The quantitative mineral content in the sample was established against basal diagnostic reflections in the diffraction patterns obtained under strictly constant conditions of sample survey [9]. Based on this analysis, compositions for acidizing were proposed.

For greater effect of acid treatment, it is proposed to use mud acid (a mixture of hydrochloric and hydrofluoric acids in different proportions), which, in turn, will optimally recover reservoir permeability and porosity properties (PPP).

Laboratory testing of acid compositions. For laboratory analysis, core material composition was taken, the main parameters of which are presented in Table 1.

Table 1. Core material for laboratory analysis.

Suite/Formation	Interval	Lithological composition
Dolganskaya ($K_{1–2}$ dl)	1090.0–1096.9	Uneven interbedding of siltstones sandy, clayey, quartz-feldspar, micaceous and clays dark grey, silty, micaceous.
Malokhetskaya (K1mh)	2269.8–2266.2	Sandstone, silty clayey
	2270.7–2267.1	Sandstone, silty clayey
	2275.4–2273.5	Sandstone, silty clayey
Suhodudinskaya (K1cd)	2504.0–2509.6	Sandstone, silty clayey, weakly micaceous
	2815.0–2826.2	Sandstone, silty clayey
	2816.4–2815.1	Sandstone, silty clayey
	2957.7–2970.7	Siltstones sandy, clayey, micaceous; Sandstone, silty clayey

In the samples, general mineralogical composition was determined. The results are shown in Table 2. In determining the mineral composition of the rocks the total content of all minerals and cement was assumed to be 100%.

Table 2. Mineral composition of rocks according to the XRD.

Suite/Formation	Mineral composition							Total, %
	Calcite	Kaolinite	Quartz	Quartz-feldspar	Muscovite / Illit	Plagioclase	Chlorite	
Dolganskaya	0.0	3.0	28.8	5.6	21.3	31.6	9.7	100
Malokhetskaya	0.0	3.0	30.0	7.6	18.3	30.6	10.5	100
Suhodudinskaya	0.0	1.1	44.9	8.4	4.2	37.5	3.9	100

X-ray diffractograms of core samples are shown in Figure 1-3. On disintegrated rock samples, interaction of acidic compounds (HCl 10%) with different groups of minerals that make up the sample was studied. For each sample six batches of five different test compounds were prepared. Batches were filled with 30 ml of acid solution, mixed and placed in an oven for 4 hours at reservoir temperature. After a predetermined time, precipitates were transferred onto pre-dried filters, washed with distilled water until neutral state, dried to a constant weight. Weight loss was determined by the difference in the sample weights after interaction with the test compositions. The results are shown in Table 3.

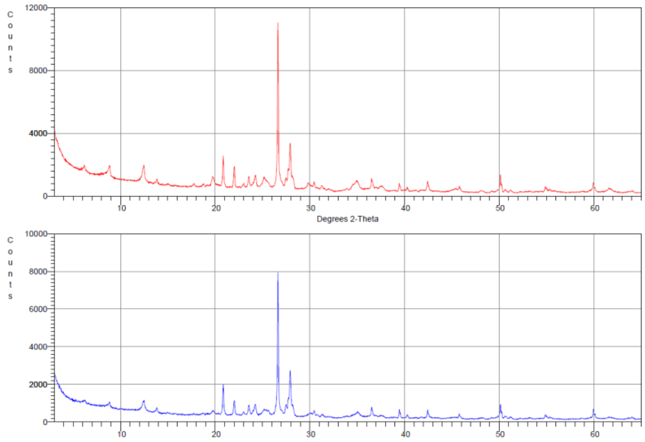

Figure 1. X-ray diffraction patterns before treatment with acid compositions, Dolganskay formation.

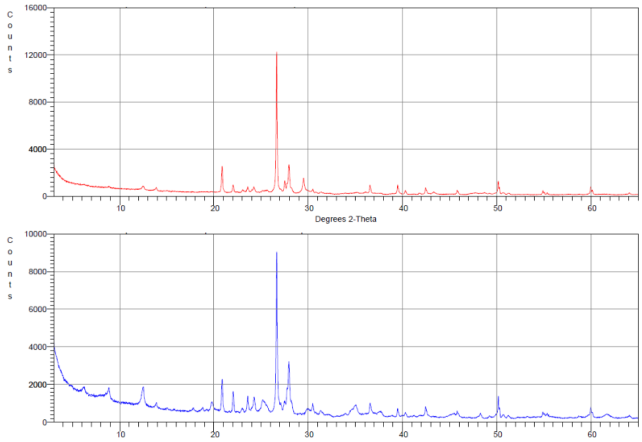

Figure 2. X-ray diffraction patterns before treatment with acid compositions, Malohetskaya formation

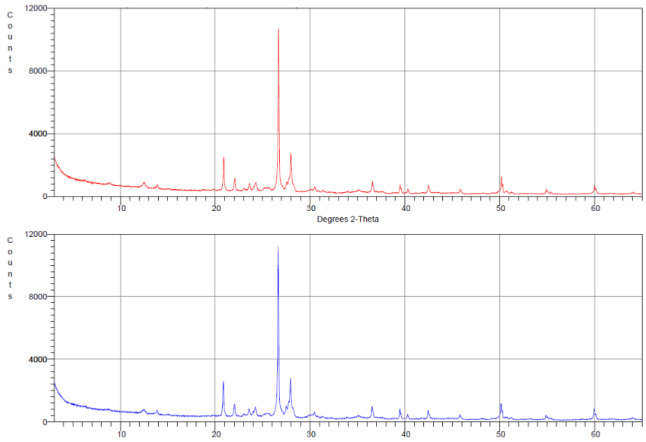

Figure 3. X-ray diffraction before treatment with acid compositions, Suhodudinskaya formation

Table 3. Weight loss after crushed rock samples acidizing.

Suit	Weight before acidizing, gr.	Weight after acidizing, gr.	Weight change, %
Dolganskaya	7.221	7.215	1.05
Malokhetskaya	9.510	9.485	0.58
Suhodudinskaya	5.413	5.330	1.53

For sand reservoirs, this weight change after acid treatment was minor. The biggest change in weight (approximately 1.5%) showed the sample of Suhodudinskaya suite. It can be explained by the highest clay content among selected test samples.

The study results of the mineral composition change of pelitic fraction in the samples after exposure to 10% HCl acid solution are shown in Table 4.

Table 4 .Mineral composition change of pelitic fraction in the samples.

Suit	Mineral composition change, %						
	Calcite	Kaolinite	Quartz	Quartz-feldspar	Muscovite / Illit	Plagioclase	Chlorite
Dolganskaya	+0.1	+0.2	+1.2	-2.6	-6.8	-4.2	+0.5
Malokhetskaya	-0.2	+0.0	-2.3	+0.6	-8.5	-7.4	+1.9
Suhodudinskaya	-0.1	-0.4	+1.9	+1.4	-7.0	-6.2	-2.1

As the table shows, the major quantitative changes when exposed to acid treatment take place in illite and plagioclase. Changes in the content of other components of pelitic fraction are logically associated with statistical error in measurement.

In accordance with the method, filtration experiments simulating acid effect on the bottom-hole zone were performed. The compositions most often used in Western Siberia were chosen as the acid ones (see Table 5). For basic acid composition, 10% HCl solution was used.

Table 5. Acid compositions used in filtration experiments.

No.	Acid composition	Producer
1	HCl (10% solution)	
2	Himeko TK-2 KM	ZAO «HIMEKO-GANG»:
3	Modified composition of hydrochloric acid	AO «POLIEKS»
4	FLAKSOKOR 210	ZAO "Petrohim"
5	Petrohim-KGS	GC "Mirrico" basic solution

Figure 4 shows the behavior of the differential pressure from the flow of the pumped liquid (kerosene) at various stages of the experiment - before and after the injection of drilling mud, after acid exposure. Figure 5 shows a photograph of a core sample with the mud cake after the acid treatment.

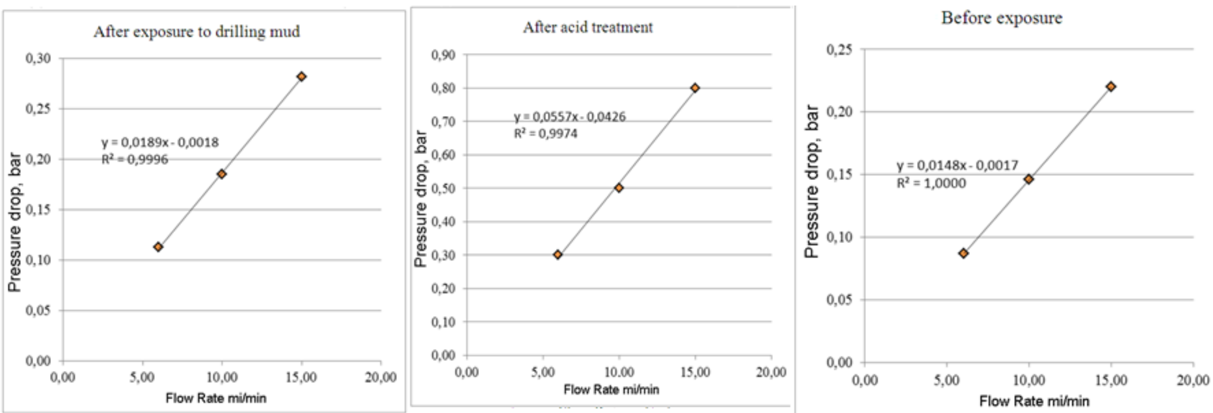

Figure 4. Dependence of the differential pressure across the sample from fluid flow.

Results of filtration experiments, which determine the permeability recovery coefficient (K_{recov}) after exposure to drilling mud and subsequent treatment with acid compositions, are shown in Table. 6.

As seen from Table, 10% HCl effect does not improve the recovery coefficient. In general deterioration of permeability by oil after 10% HCl acid impact on the core can be explained by two different processes: a positive effect on the permeability of the core by removing residues of colmatant is offset by negative influence of the water-based phase of the acid solution entering the pore space. The sharp decrease in permeability of the core sampled from producing horizons after the impact of technological water-based fluids has repeatedly been noted earlier by other researchers.

Figure 5. Photograph of a core sample with the mud cake after the acid treatment.

Table 6. Results of filtration experiments to determine the effectiveness of acid treatments.

Suit	Drilling mud type	Acid composition	K_{recov}, after mud cake collapse, %	K_{recov}, after acid treatment, %
Malohetskaya	Basic	HCl (10 % solution)	48.26	26.57
Malohetskaya	Polymer+KCl	Himeko TK-2 KM	92.60	86.67
Nizhnehetskaya	OBM	Modified composition of hydrochloric acid	82.61	96.70
Nizhnehetskaya	Basic	HCl (10 % solution)	46.24	24.06
Suhodudinskaya	OBM	FLAKSOKOR 210	53.15	25.81
Nizhnehetskaya	Basic	Petrohim-KGS	49.26	93.32

4. Conclusion

The conducted tests on acid treatment of various compositions based on HCl showed little impact on the rock of formations under consideration (the change in weight of the sample after the acid treatment is not more than 1.5%, minor changes in the mineral composition based on results of XRD). Meanwhile, the acidic compounds actively interact with colmatant of the considered drilling muds.

Conducted filtration experiments, simulating acid treatment of bottom-hole zone after exposure to drilling mud, showed mixed effects from exposure to different acidic compounds in the mud cake. Direct measurements of permeability before and after acid treatment, as well as photos of the surface of the sample with a mud cake, show high activity of acid composition and destruction of the mud cake. Meanwhile, the experimental results show that in most cases washing off the mud cake is more efficient than the acid treatment without washing off. Furthermore, the use of acid solutions (10% HCl, water-based) leads to a significant reduction of permeability due to increased saturation of the pore space with water-based acid compositions, preventing filtration of oil (kerosene).

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