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IMPROVEMENT OF ACID TREATMENT ON BOTTOMHOLE ZONE

Kh. M. Ibrahimov, A. A. Hajiyev*, A. F. Akbarova, F. K. Kazimov

«OilGasScientificResearchProject» Institute, SOCAR, Baku, Azerbaijan

ABSTRACT

The article focuses on optimizing acid treatments for the wellbore zone, considering the geological and lithological characteristics of the formation. The geological and lithological characteristics of the deposits in the OGPDs of the «Azneft» PU were investigated, and the selection of acids was justified depending on the lithological composition of the deposits. By conducting laboratory studies, the effect of acid compositions on cuttings samples taken from different horizons was studied, the optimal acid composition and volume were selected, and the mutual effect of their compositions with formation fluids was determined. The study of the effect of acid compositions on cuttings samples taken from the 600-640 m depth of the GA horizon of the «Absheronneft» OGPD showed that compositions with a low content of hydrofluoric acid in the composition had a better effect on the decomposition of cuttings. Thus, since the samples were decomposed and dispersed when affected by these compositions, the penetration of the acid into the rock sample was facilitated and the mass loss was higher. The research also indicated that compositions containing organic acids were particularly effective in breaking down the rock samples. The presence of organic acids appears to enhance the dissolution and disintegration of the rock, making them a promising choice for acid treatments. Laboratory experiments conducted on drilling cuttings from the Pirallahı field of «Absheronneft» OGPD have shown that the best permeability recovery is achieved with a solvent mixture consisting of 6% HCl and 2% HF, resulting in a 37% recovery.

KEYWORDS:
acid treatment of the bottomhole zone;
wellbore zone;
chemical solvent compositions;
improving fluid filtration;
restoring permeability.

e-mail: aliabas.haciyev@socar.az

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İntroduction

Since most of Azerbaijan's oil fields are in the final stage of development, the production from wells in these fields is rapidly declining. To prevent this, it is important not only to develop new methods for treating the bottomhole zone but also to improve existing methods and adapt them to the real reservoir conditions [1-7].

The lithological heterogeneity of the formations, long-term exploitation, particularly the exposure of the near-wellbore area to intense physicochemical impacts, the gradual reduction of light fractions in the reservoir oil, the gradual decline in pressure and temperature, and other factors lead to changes in the lithological composition of the productive layers. Additionally, due to the influence of water influx from other horizons, changes occur in the mineralogical composition of the rocks. In such cases, the physicochemical properties of the formation are constantly altered, requiring new research and chemical solvent compositions for cleaning contamination [8-15].

Acid treatment of the bottomhole zone is one of the most effective and commonly used chemical methods. When selecting acid formulations for the bottomhole zone, the factors mentioned above must be considered [16-20].

The method of acidizing the bottomhole zone to increase well productivity has been known since the late 19th century. Hydrochloric (HCl) acid is generally useful in increasing oil production; it is also used extensively in carbonate acidizing and is beneficial in removing dolomite and limestone from reservoirs. Combinations of hydrofluoric acid (HF) and HCl are used in certain applications to accelerate the dissolution of sandstones and other silicates found in reservoir rocks. By removing or avoiding the formation damage, well stimulation aims to reduce the amount of debris produced and finally clean up the gravel packs [21-23].

Despite its common use, there has been relatively limited research on the long-term effects of acidizing on the physical characteristics of the reservoir, including porosity, permeability, and recovery factors [24-26].

Some studies have investigated the impact of HCl treatment on formation porosity and spontaneous inhibition (the formation's natural resistance to further damage). These studies have been complex and limited by the use of specific parameters, such as the decipherability of formations and crack distributions.

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The purpose and main objectives of the study

The essence of acid treatment in the bottomhole zone (BHZ) is to clean contamination from the channels and micro-fractures in this zone, thereby expanding its volume, improving permeability, and intensifying the fluid flow from the formation to the well.

Acid treatment of the bottomhole zone (BHZ) is performed for various purposes [22-25]:

- Development of production and injection wells;
- Increasing (intensifying) the production of production wells and the injectivity of injection wells;
- Cleaning sediments formed in the BHZ due to various reasons;
- Cleaning the contaminated filter zone resulting from operations performed in wells.

Novelty of the work

The innovation of this method lies in the fact that, for the first time, acid compositions have been carefully selected in optimal proportions to match the geological and lithological characteristics of each Azerbaijani field, offering a more effective solution than previous general treatments.

The acid treatment strategy for wellbore zones is selected based on several factors, such as the chemical and mineral composition of the rocks, the filtration properties, the chemical makeup of formation fluids, rock permeability, and formation temperature. Previous acid treatments did not effectively penetrate the formation. In some cases, the acid reacted only with the wellbore zone, creating a gel-like substance on the rock surface that further reduced permeability and failed to achieve the desired results. However, the newly developed approach uses acid compositions specifically tailored to the unique conditions of each field in Azerbaijan. These compositions, optimized based on extensive theoretical and experimental research, dissolve particles deposited in the rock pores and from drilling fluids that could not be cleared during drilling. As a result, the acid treatment is able to penetrate deeper into the formation, improving fluid filtration and restoring permeability.

Mechanism of process

The mechanism of acid treatment using hydrochloric, acetic, or formic acid solutions is based on their ability to dissolve the limestone, dolomite, dolomitized limestone in the productive layers, or carbonate minerals and cementing components in sandstone formations. Since the fields under the management of «Azneft» Production Union are composed of lithologically heterogeneous rocks, the selection of appropriate acid formulations for bottomhole zone treatment should be based on the mineralogical composition of the rocks forming the BHZ. For instance, in wells operating in terrigenous reservoirs, it is advisable to use a combination of hydrochloric (HCl) and hydrofluoric (HF) acids.

Since terrigenous reservoirs contain a low amount of carbonates, acid treatment should be conducted in two stages: first, hydrochloric acid should be injected, followed by hydrofluoric acid. This approach prevents the precipitation of calcium fluoride (CaF_2), silica gel, and other substances in the formation's pores resulting from the action of hydrofluoric acid.

In addition to hydrochloric acid, relatively weaker organic acids are also used. Since the reaction of organic acids with minerals is slower, it allows for a longer-lasting reaction and deeper penetration of the acid into the formation.

The method of acid stimulation is applied in both injection and production wells. Acid treatment of the bottomhole zone of injection wells improves their injectivity.

To intensify oil well production and improve the injectivity of injection wells, strong inorganic acids (such as hydrochloric, hydrofluoric, sulfamic, sulfuric, nitric, etc.) and weak organic acids (such as acetic, acetic anhydride, citric, formic, etc.) are often used.

Based on permeability values, research has been conducted on the selection of acids and determining their volume for the preflush and main treatment of rocks [3], and the results are presented in table 1.

Table 1

Recommended acid compositions for pre- and main treatment depending on rock permeability

Mineral Composition	> 100 mD		20-100 mD		< 20 mD	
	Preflush	Main Treatment	Preflush	Main Treatment	Preflush	Main Treatment
< 10 % Silt and < 10 % Clay	15.0% HCl	12.0% HCl+3.0% HF	10.0% HCl	8.0% HCl+2% HF	7.5% HCl	6% HCl+1.5% HF
> 10 % Silt and > 10 % Clay	10.0% HCl	13.5% HCl+1.5% H	7.5% HCl	9.0% HCl+1% HF	5.0% HCl	4.5% HCl+1.0% HF
> 10% Silt and < 10 % Clay	10.0% HCl	12.0% HCl+2.0% HF	7.5% HCl	9.0% HCl+1.5% HF	5.0% HCl	6.0% HCl+1.0% HF
> 10% Silt and > 10 % Clay	10.0% HCl	12.0% HCl+2.0% HF	7.5% HCl	9.0% HCl+1.5% HF	5.0% HCl	6.0% HCl+1.0% HF

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Methodology

Laboratory studies have been conducted using drilling cuttings samples to determine the efficiency of acid treatment in Azerbaijan's oil fields (Pirallahi and Guneshli). For this purpose, the effects of various concentrations of acid mixtures on drilling cuttings samples taken from different depths during drilling were studied. The research was conducted as follows:

First, a drilling cuttings sample is weighed and poured into a flask, after which a solvent (acid or acid mixture) is added to the sample. After mixing the drilling cuttings sample with the solvent, the flask is sealed and left for 24 hours. After 24 hours, the cuttings-acid mixture in the flask is filtered through filter paper, and the residue left on the paper is dried and then weighed again. The mass loss of the drilling cuttings due to the reaction is calculated as follows:

$$\Delta = \frac{m_1 - m_2}{m_1} \cdot 100\ \%$$

Here, Δ – the mass loss, %; m_1 – the mass of the cuttings sample before the reaction, g; m_2 – the mass of the drilling cuttings sample after the reaction, g.

Experimental studies were conducted using a linear reservoir model to investigate the effect of drilling cuttings on the permeability of bottomhole zones [27]. For this purpose, the reservoir model was filled with quartz sand, and its permeability to water was measured (1.92 mkm^2). Subsequently, 10 g of quartz sand was removed from the inlet section of the model and replaced with an equivalent amount of drilling cuttings. In this scenario, the permeability to water was reduced to 0.65 mkm^2 in the medium containing cuttings from the Pirallahı field and to 0.92 mD for the medium with cuttings from the Gunashli field. Afterward, 20 ml of a solvent (acid or acid mixture) was injected into the model from the inlet, and both ends of the model were sealed for 24 hours. Once the 24-hour period had passed, water was reintroduced from the inlet, and the permeability was reassessed, allowing for the determination of how much the permeability had been restored after the application of the solvent.

Discussion

The effect of acid compositions on a drilling cuttings sample taken from a depth of 600-640 meters from the Pre-Kirmaky horizon of well No. 1297 at the «Absheronneft» OGPD was studied, and the results are presented in figure 1.

It is observed from the figure that when using compositions with a fluoride acid (HF) concentration higher than 4% (compositions 1, 2, 3, 6, 7, 8, 11, 12, 13, 17, 20), the mass loss of the drilling cuttings samples was very low. This is due to the fact that when the compositions react with the cuttings, the HF in the composition reacts with the components of the cuttings to form a gel-like substance (as shown in fig. 2, samples b and c).

The gel-like substance insulates the surface of the sample, making it difficult for the acid to further penetrate the rock. Therefore, it is not advisable to use

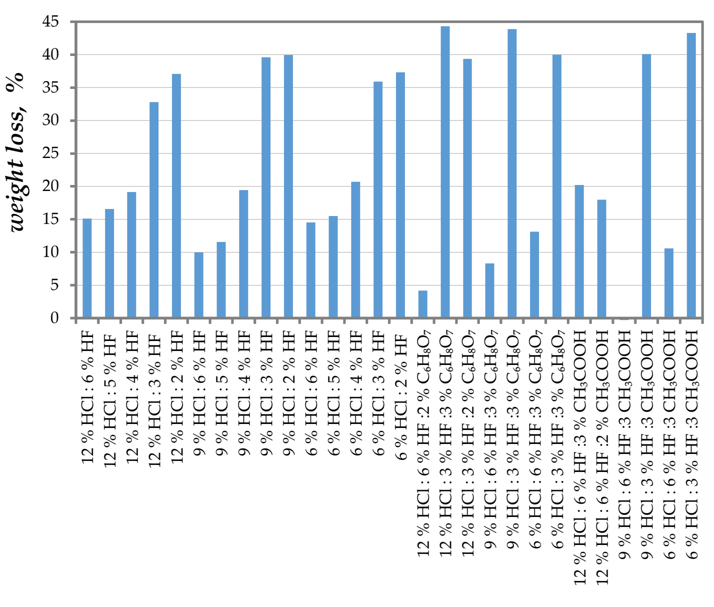

Fig. 1. The effect of acid compositions on the drilling cuttings sample from the Pre-Kirmaky horizon at a depth of 600-640 m in well No. 1297 of «Abşeronneft» OGPD

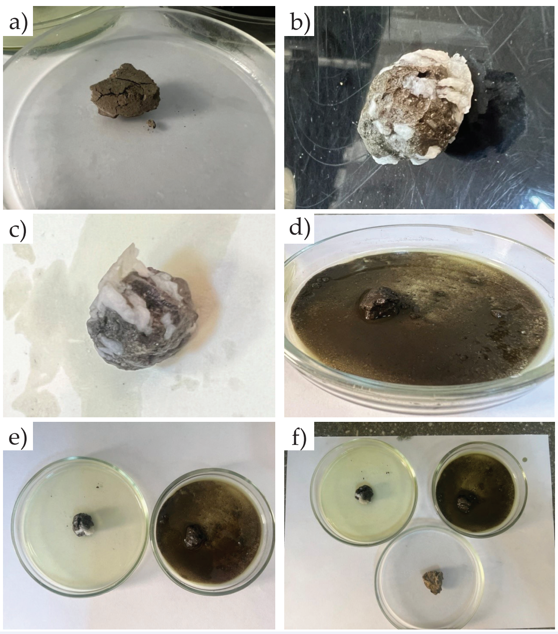

Fig. 2. Rock sample before and after acid treatment: a - before treatment, b, c, d, e, and f - after treatment

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compositions with high concentrations of fluoride acid for acid treatment in such formations to achieve high permeability. Moreover, the use of such compositions may lead to additional complications.

The compositions with a low concentration of fluoride acid had a better effect on the disintegration of the cuttings. When these compositions were applied, the samples disintegrated and dispersed, making it easier for the acid to penetrate the rock sample (fig. 2d), resulting in a higher mass loss. The ability to effectively disintegrate the rock samples was observed in compositions that included organic acids (28, 19, 21, 23). When these compositions were applied to the rock samples, there was a mass loss of up to 45%. Therefore, for creating high permeability in such rocks, it is more appropriate to use compositions with a low concentration of fluoride acid that include organic acids. The difference can be clearly seen in figure 2e.

In subsequent studies, the effects of various concentrations of acid mixtures on drilling cuttings obtained from the Pre-Kirmaky horizon of «Abşeronneft» at a depth of 820-840 m from well No.1278 have been investigated. The results obtained are presented in table 2. As seen in the table, the highest mass loss (18.4%) occurs with a mixture of 6% HCl and 2% HF, while the lowest mass loss (9.81%) occurs with a 12% HCl solution. In all experiments, a 5 g drilling cuttings sample and 10 ml of solvent (acid or acid mixture) were used. When the concentration of hydrochloric acid is high, it reacts with the components of the rock samples to form a gel-like substance, which causes an increase in mass.

Research was also conducted on the effects of various acid mixtures on drilling cuttings taken from the depths of 2476-2477 m from well No.341 (Platform 10) of «28 May» in the Gunashli field, with the results presented in table 3. As indicated in the table, the highest mass loss (17.2%) of the drilling cuttings occurs with a mixture of 6% HCl, 3% HF, and 3% CH_3COOH, while the lowest mass loss (4.8%) occurs with a 12% HCl solution.

The first series of experiments were conducted using drilling cuttings from the Pirallahı field of the «Abşeronneft» OGPD. The results obtained are presented in table 4. As can be seen from the table, the best result was achieved when a mixture of 6% HCl+2% HF was injected into the model as the solvent (experiment №3). In this case, the permeability recovery of the model reached 37%. The lowest result was observed when a 12% HCl solution was used as the solvent (experiment №2), where the permeability recovery of the model was only 15.4%.

In the next series of experiments, drilling cuttings from rig 341 at a depth of 2476-2477 meters from the Gunashli field of «28 May» OGPD were tested.

Similar to the previous series of experiments, a linear reservoir model filled with quartz sand – with an initial permeability of 1.92 mkm^2 to water – was used. From the inlet section of the model, 10 grams of

Table 2

The effects of various acid mixtures on drilling cuttings obtained from well No. 1278 of «Absheronneft»

Experiment №	Amount of drilling cuttings sample, g	Amount of solvent, (10 ml)	Amount of remaining drilling cuttings after the reaction, g	Mass loss, %
1	5	18% HCl	8.812	11.88
2	5	12% HCl	9.019	9.81
3	5	6% HCl+2% HF	4.08	18.4
4	5	6% HCl+3% HF+3% $C_6H_8O_7$	4.142	17.16
5	5	6% HCl+3 %HF+3% CH_3COOH	4.43	11.4

Table 3

The effect of various acid mixtures on the drilling cuttings sampled from the 341st well of the Gunashli field operated by the «28 May» OGPD

Experiment №	Amount of drilling cuttings sample, g	Amount of solvent, (10 ml)	Amount of remaining drilling cuttings after the reaction, g	Mass loss, %
1	5	18% HCl	4.690	6.2
2	5	12% HCl	4.760	4.8
3	5	6% HCl+2% HF	4.497	10.06
4	5	6% HCl+3% HF+3% $C_6H_8O_7$	4.691	6.18
5	5	6% HCl+3% HF+3% CH_3COOH	4.140	17.2

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Table 4

Experimental results on restoring the permeability of the porous medium by treating the drilling cuttings samples from the «Absheronneft» OGPD with acid

Experiment №	The amount of drilling cuttings added to the porous medium of the model, g.	The amount of solvent injected into the model, (20 ml)	Permeability of the porous medium after the reaction, mkm²	Permeability recovery, %
1	10	18% HCl	0.82	26
2	10	12% HCl	0.75	15.4
3	10	6% HCl+2% HF	0.891	37
4	10	6% HCl+3% HF+3% $C_6H_8O_7$	0.85	30
5	10	6% HCl+3% HF+3% CH_3COOH	0.807	22.3

Table 5

Experimental results on restoring the permeability of the porous medium by treating the drilling cuttings samples from the «28 May» OGPD with acid

Experiment №	The amount of drilling cuttings added to the porous medium of the model, g.	The amount of solvent injected into the model, (20 ml)	Permeability of the porous medium after the reaction, mkm²	Permeability recovery, %
1	10	18 % HCl	1.018	10.65
2	10	12% HCl	0.98	6.52
3	10	6% HCl+2% HF	1.06	15.2
4	10	6% HCl+3% HF+3% $C_6H_8O_7$	1.012	10
5	10	6% HCl+3% HF+3% CH_3COOH	1.11	20.65

quartz sand were removed and replaced with an equal amount of drilling cuttings from the Gunashli field. In this case, the model's permeability to water decreased to 0.92 mkm^2. Then, 20 ml of solvent (acid or acid mixture) was injected into the model, and both ends were sealed for 24 hours. After this period, water was reintroduced from the inlet, and the permeability was reassessed to determine how much permeability had been restored following the solvent injection.

The results obtained are presented in table 5. As shown in the table, the best result was achieved when a mixture of 6% HCl+3% HF+3% CH_3COOH was injected as the solvent (experiment №5). In this case, the permeability recovery of the model was 20.65%. The lowest result was observed when a 12% HCl solution was used as the solvent (experiment №2), where the permeability recovery was only 6.52%.

When designing acid treatment operations in the reservoir's bottomhole zone, the following considerations should be addressed:

- justification for the selection of wells to be treated,
- determination of the recipe and volume of acid solutions,
- flow rate and pressure of the fluid to be injected into the reservoir,
- identification of the displacement fluid,
- duration of the treatment solution's stay in the reservoir,
- determination of the method for cleaning the bottomhole zone from reaction products.

The justification for selecting the well where the stimulation treatment will be conducted is essential. The most accurate results for this issue can be obtained from geophysical and hydrodynamic studies of the wells.

Conclusions

1. Based on the results obtained from the conducted laboratory studies, the following has been established:
2. From the drilling cuttings collected at a depth of 820-840 m from well 1278, operating in the Pre-Kirmaky horizon of «Absheronneft» OGPD, the greatest mass loss (18.4%) occurs as a result of the interaction of the cuttings with a mixture of 6% HCl and 2% HF acid, while the least mass loss (9.81%) occurs with a 12% HCl solution.

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3. From the drilling cuttings collected at a depth of 2476-2477 m from Rig 10, well №341 of the «28 May» OGPD in the Gunashli field, the greatest mass loss (17.2%) occurs with a mixture of 6% HCl, 3% HF, and 3% CH_3COOH, while the least mass loss (4.8%) occurs with a 12% HCl solution.
4. The laboratory-experimental studies conducted in a linear layer model have determined that the best result when applying solvents to the drilling cuttings from the Pirallahı field of «Absheronneft» OGPD is obtained from the application of a mixture of 6% HCl and 2% HF. In this case, the recovery of the model's permeability is 37%. The lowest result is obtained from the application of a 12% HCl solution, where the recovery of the model's permeability is 15.4%.
5. When applying solvents to the drilling cuttings from the Gunashli field of «28 May» OGPD, the best result is obtained from the application of a mixture of 6% HCl, 3% HF, and 3% CH_3COOH, where the recovery of the model's permeability is 20.65%. The lowest result is obtained from the application of a 12% HCl solution, where the recovery of the model's permeability is 6.52%.
6. In the preparation of the acid treatment project, the issues to be considered have been substantiated.

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