Research in the effectiveness of acid treatments productive formations on oil fields in Western Siberia

A S Akopov¹, A P Yanukyan², I I Kushch³, S A Kaverzin¹, S B Beketov¹

¹North Caucasus Federal University, Stavropol, Pushkina str., 1, 355017, Russia
²Branch of the Tyumen Industrial University, Surgut, Entuziastov str., 38, 628404, Russia
³Gazprom Dobycha Yamburg LLC, Novy Urengoy, Geologorazvedchikov str., 9, 629306, Russia

E-mail skaverzin@ncfu.ru

Abstract. The Article studies the efficiency of acid bottom-hole formations treatment dependence in productive zones of the Sangopai formation from various technological parameters. The correlation dependencies of the average production rate of oil before and after acid treatment in addition to the analysis of acid treatment influence on the injection wells infectivity are presented. The purpose of this research is to determine the most optimal technological parameters of bottom-hole formation zone acid treatment.

Keywords: a flow rate, the working acid solution, productivity coefficient, injection capacity of well

1. Introduction

The most used method to affect the bottom-hole formation zone in order to increase or restore the productivity of production wells is well acidizing, in practical stimulation technologies production over the world.

The main task of the acid well treatment is to recover reservoir properties in the bottom-hole formation zone that have been devastated, transfer the solution, and take out the solid natural particles and the ones with technologic origin into the wellbore. As well as expanding the fluid-conducting canals and creating new ones along the entire perforated capacity of the formation in order to improve the filtration properties of the bottom-hole zone. The main used reagents acids interaction include hydrochloric (hydrochloric HCl), hydrofluoric (hydrofluoric HF) acid. The development of well and inflow stimulation implies the use of other acids and their mixtures such as acetic (CH₃COOH), sulfamic (NH₂SO₃H), sulfuric (H₂SO₄), clay acid (HCl + HF), etc. [1, 2].
Acidizing the bottom-hole formation zone is one of the major ways of production rate magnification of the wells that drain the productive strata of the Sangopai formation. Furthermore, acidizing is very effective in restoring the injection wells productivity.

2. The Problem Statement
The capacity of the Sangopai formation within the five Western Siberian deposits under consideration varies from 4.2 to 15 m. The composition, the color of the rocks, and the complex of organic remains are considered as a confirmation that sedimentary rock formation was formed in a low-lying basin. The formation is composed of light gray sandstones and mudstones and siltstones. The clay zones formation of productive strata that represented by packs of dark gray compacted clays are very common, while the finely elutriated clays are predominantly originated from alluvia [3].

The Sangopai formation composed of dense micaceous mudstone has uneven fracture. While the sandstones are cross-bedded, fine, and medium-grained; in addition, alluvial deposits on the vegetative layering flat and carbonaceous detritus characterize them. On the other hand, they often contain clayey siderite areas.

Heterogeneity sharp fractures, various granulometric composition, and clay bridges present in Sangopai formation productive strata create difficulties in oil production [4]. For example, the injection wells that revealed formation layers are characterized by constantly fading injectivity. Besides, wells injectivity declines sharply in clay zones, which requires various geological and technical measures [5]. The development of self-flowing injection wells of Sangopai formation showed its low efficiency and the inability of hydraulic fracturing all the time (due to the series of geological requirements for hydraulic fracturing of candidate wells), as well as from the economic feasibility point of view [6]. Moreover, the productive stratum of Sangopai formation is characterized by impressive filtration and storage' properties, the permeability reaches 600-650 μm2, while the porosity is about 20-23%. According to experiments in these geological conditions, it is not expedient to use hydraulic fracturing. Considering what we mentioned before, Sangopai formation geological conditions, acidizing the bottom-hole formation zone is the most effective way to restore the injection wells injectivity and producing wells productivity [7].

3. Study of acidizing effectiveness
After years of industrial experiences in the development of Sangopai formation productive stratum, we have found acidizing is characterized by efficiency [8]. As an example, Figure 1 shows the results of hydrochloric acid treatment (HAT) of 10 wells of AC group that consist of five fields in Western Siberia. In all acidizing operations, the same working acid composition was used (the acid concentration ranged from 12 to 16%) [9].

The multiplicity of the increasing production rate after HAT

The conventional well numbers

Figure 1. The results of acidizing wells of the AC group on some fields in Western Siberia
It should be noted that similar results of acidizing have been gotten on most of the Surgut arch fields in the wells, where AS group’s development facilities work, (the results characterized by a very large scatter)[10].

In order to reveal the factors that determine the acidizing efficiency within the framework of this research, a correlation dependence analysis of the average oil production’s rate has been performed, before CAT (clay acid treatment) and an additional production from CAT. The results are shown in Figure 2.

We used the acidizing results in AC group productive formations on five fields of the Surgut arch as data for the analysis. In the analysis, acid treatments with an identical composition of the working acid solution were selected. All the analyzed CATs were carried out according to the standard technology [11]. The sample includes the results for 60 observations.

Additional oil production

![Figure 2. The correlation dependence of the average oil production’s rate before CAT and additional oil production from CAT](image)

Clearly, we can find in figure 2, that the well flow rate before HAT / CAT substantially determines the additional oil production from acid treatments [12].

Based on the result of this research, the conclusion we can make that the acidizing on the injection wells fund are characterized by an analog dependence, whenever the injectivity of the well before acidizing is getting greater, the effect is getting higher (see Figure 3).
Injectivity after CAT

Figure 3. Correlation dependence of injection wells injectivity before CAT and injectivity of wells after CAT

According to the research about the correlation relationship between the concentration of hydrofluoric acid in the working solution and the acid treatment efficiency on the producing wells fund that operate the Sangopai deposits: there is no relationship between these parameters [13].

The Additional oil production

Figure 4. The correlation between the acid concentration in the working solution and the acid treatments effectiveness

Studying the relationship between the hydrofluoric acid concentration, and the acid treatments effectiveness on the injection wells fund, led to analogic results.
The growth in injectivity

By summing the interim result, the conclusion we got is an acid concentration growth does not lead to an increase in the acid treatment efficiency at the development sites associated with the Sangopai formation. That can be explained by the fact that the increasing in the formation sweep by the acid effect does not occur, even if the acid concentration increased in the working solution [14]. Considering the high degree of reserves depletion, the acidizing efficiency does not change significantly [15].

The correlation analysis showed that there is a close correlation connection between the injection wells injectivity before the acidizing and after it. Moreover, whenever the concentration of the surface active substances (surfactants) is getting higher in a working acidic solution, then the correlation is getting weaker [16]. Thus, in a situation where there are no surfactants in the acid solution, so the linear correlation coefficient was 0.983, and with 5% surfactant concentration - 0.922.

The hydrofluoric acid concentration

Figure 5. The correlation between the acid concentration in the working solution and the growth in injectivity after HAT / CAT

The injectivity before CAT + surfactant

Figure 6. The correlation between the injection wells injectivity before and after acidizing with the addition of the surfactants
The result of analyzing the correlation can be explained by taking into account, the significant micro-heterogeneous of Sangopai formation productive layers, whenever surfactants are added into the working acid solution, a considerable increase in the formation sweep by acid effect is occurred, which increases the efficiency of CAT [17, 18].

When surfactants are added to the working acid solution, the injectivity of the wells is higher comparing to analogic acidizing without surfactants [19, 20].

![The flow rate before CAT + surfactant](image)

Figure 7. The correlation dependence between well flow rates before and after acidizing with the addition of surfactants

In the situation where there were no surfactants in the acidic solution linear correlation coefficient between the studied quantities was 0.975, and at 5% surfactants concentration was 0.92, which implies increasing the efficiency of CAT + surfactants on the low production rate wells fund, comparing to the acidizing without surfactant addition [22-25].

### 4. Conclusion

By summing up the research, we can draw the following main conclusions:

- The recommendation for acidizing with high rate production and high flow injection wells.
- Adding surfactants to the acid solution significantly increases the acidizing efficiency.
- The greatest effect of acid exposure on the formation with adding surfactants was obtained in the marginal wells stock that exploits the Sangopai formation productive strata.

### References

[1] Karapetov R V, Mokhov S N, Akopov A S, S B Beketov 2017 Optimization of the composition for acidizing of the bottom-hole zone of the terrigenous formation Stavropol: LLC Publishing House "TESERA" pp 211-213.

[2] Dimitriadi Yu K, Kaverzin S A, Akopov A S, Lukin R R 2018 Analysis of the oilfield services market, Actual problems of the oil and gas industry of the North Caucasus Federal District: materials of the VI annual scientific and practical conference of the North
Caucasian Federal University "University science - to the region" Stavropol pp 152-156.
[3] Belousov S L, Grishkevich V F, Eliseev V G et al 2001 Suggestions for the regional stratigraphic scheme of the Mesozoic deposits of the West Siberian Plain Khanty-Mansiysk: Oil and Gas pp 57–62.
[4] Verderevsky Yu L, Arefiev Yu N, Chaganov M S 2000 Increasing the wells' productivity in carbonate reservoirs with compositions based on hydrochloric acid Oil industry 1 pp 39-40.
[5] Gutorov Yu A, Shakurova A F 2007 Analysis of the hydrochloric acidizing effectiveness of production wells based on a scientific review and technical sources Collection of scientific papers "Technologies of oil and gas business" Ufa pp 111-121.
[6] Zakirov S N, Kontarev A A, Knysenko A G 2006 Intensification of the oil reserves development in lenticular reservoirs Oil industry 12 pp 24-26.
[7] Ikonnikova L N 2008 Application of research Daccord and Lenormand during hydrochloric acidizing, IX international youth scientific conference "Severgeoetech2008": materials of the conference Ukhta: USTU pp 252–256.
[8] Ikonnikova L N 2013 Forecasting well flow rate after hydrochloric acidizing at bottom-hole pressure below bubble point The equipment and technologies for the oil and gas complex. - Moscow: VNIIOENG 2 pp 35–37.
[9] Karpov A A, Gilmutdinov B R 2003 The research in sediment formation during the polymer solutions coagulation Ufim. state oil. tech. un-t. – Ufa pp 16 - 17.
[10] Telin A G, T A Ismagilov, Akhmetov N Z, Smakov V V, Khismatdinov A I 2001 An integrated approach to increasing the acidizing efficiency of wells Oil industry 8 pp 69-74.
[11] A Asan, M Kabasakaloglu, M Isiklan, Z Kilic 2005 Corrosion inhibition of brass in presence of tetradentate ligands in chloride solution Corrosion Science 47 pp 1534-1544.
[12] E Barmatov, J Geddes, T Hughes, M Nagl 2012 Research on corrosion inhibitors for acid stimulation NACE.
[13] E Cano, J L Polo, A La Iglesia, J M Bastidas 2004 A study on the adsorption of benzotriazole on copper in hydrochloric acid using the inflection point of the isotherm Adsorption 10, pp 219-225
[14] E A Noor, A H Al-Moubaraki 2008 Thermodynamic study of metal corrosion and inhibitor adsorption processes in mild steel/1-methyl-4[4′(-X)-styril pyridinium iodides/hydrochloric acid systems Materials Chemistry and Physics 110 pp 145-154
[15] M Yadav, D Behera, U Sharma 2012 Nontoxic corrosion inhibitors for N80 steel in hydrochloric acid Arab. J. Chem. http://dx.doi.org/10.1016/j.arabjc.03.011.
[16] M Benabdellah, R Souane, N Cheriaa, R Abidi, B Hammouti et al 2009 Significant Factors for Successful Matrix Acidizing SPE Centennial Symposium at New Mexico Tech. Society of Petroleum Engineers.
[17] A Popova, M Christov, A Zvetanova 2007 Effects of the molecular structure on the inhibitor properties of azoles on mild steel corrosion in 1M hydrochloric acid Corrosion Science 49 pp 2131-2143
[18] S Ali, J S Reyes, M M Samuel, F M Auzerais 2010 Self-Diverting Acid Treatment with Formic-Acid-Free Corrosion Inhibitor US Patent 2010/0056405 A1 Schlumberger Technology Corporation.
[19] Shafiq M U, Mahmud H Ben 2017 Sandstone matrix acidizing knowledge and future development. J. Pet. Explor. Prod. Technol. Springer Berlin Heidelberg 7 4 pp 1205–1216.
[20] M Benabdellah, R Souane, N Cheriaa, R Abidi, B Hammouti, J Vicens 2007 Synthesis of calixarene derivatives and their anticorrosive effect on steel in 1 M HCl Pigment and Resin Technology 36 pp 373-381
[21] X Wanga, H Yang, F Wang 2011 An investigation of benzimidazole derivative as corrosion inhibitor for mild steel in different concentration HCl solutions Corrosion
[22] Y Yan, W Li, L Cai, B Hou 2012 Electrochemical and quantum chemical study of purines as corrosion inhibitors for mild steel in 1 M HCl solution *Research on Chemical Intermediates* 38 2

[23] Zh Tao, Sh Zhang, W Li, B Hou 2009 Corrosion inhibition of mild steel in acidic solution by some oxo-triazole derivatives *Corrosion Science* 51 pp 2588–2595

[24] Kunze K R, Shaugnessy C.M. Acidizing sandstone formations with fluoboric acid 1983 *SPEJ* 23 1 pp 65-72.

[25] Hong L V, Mahmud H B 2019 A preliminary screening and characterization of suitable acids for sandstone matrix acidizing technique: a comprehensive review *Journal of Petroleum Exploration and Production Technology* 9 pp 753–778