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Oil Well Stimulation at Oil Fields of Groznensky Oil-Bearing District

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Abstract **– Among the objectives of the oil industry of the Chechen Republic is stable covering of requirements of the republic for hydrocarbons; attaining this objective significantly depends on acceleration of scientific and technical progress within the industry. It assumes increase in oil and associated gas production not only by means of accelerated development of new deposits, but also by wide application of progressive formation stimulation that ensures increasing output of wells in already developed deposits. One of the principal methods used to increase oil production efficiency is physical and chemical interaction with the bottom-hole zone with the aim of increasing its permeability and providing connectivity between the bottomhole and the formation; among the solutions applied, the most common are mud acid and hydrophobic acidic emulsions on its base. This work gives comparative analysis of various chemical methods used to stimulate oil inflow to bottomhole. It has been established that when acid is injected, it is mostly accumulated in highly permeable intervals, while those of low permeability comprising the bulk of the formation are barely exposed to the chemical action. Due to that, treatment with this technology leads to increased permeability of individual sublayers that had high permeability to begin with. Another cause of low efficiency of acid treatment is that increase in formation temperature leads to an abrupt shortening of the hydrochloric acid neutralization period and increased corrosive activity of the acid. Shortened neutralization period significantly contributes to worsening reservoir properties for deeper productive formation, in particular, fracture opening reduction. As a result, only the areas of the formation in the immediate vicinity of the well bore are subjected to the treatment. The authors emphasize that additional research is needed to find more efficient processes for developing Mesozoic deposits.**

Keywords – mesozoic deposits; acid emulsions; bottomhole zone; acid neutralization period; hydrophobic compositions.

I. Introduction

In the oil production industry of the Chechen Republic, the most common method to increase the output of wells drilled to deep Mesozoic formations is treatment of bottomhole with hydrochloric acid or hydrophobic emulsions on its base.

Success rate in treatment of production well is relatively low. The highest rate of failures is associated with hydrochloric acid solutions treatments. Increase in oil production per one treatment falls with time. Low effectiveness of formation treatment with HCl solutions is determined by a number of causes, one of them being a non-uniform distribution of acid flow along the thickness of the treated interval.

Another cause of low efficiency of acid treatment is that increase in formation temperature leads to an abrupt shortening of the hydrochloric acid neutralization period and increased corrosive activity of the acid.

II. Oil production stimulation at oil fields of Groznensky oil-bearing district

Shortened neutralization period is significantly affected by worsening reservoir properties of deeper productive formation, in particular, fracture opening reduction. As a result, only the areas of the formation in the immediate vicinity of the well bore are subjected to the treatment [1]. High success rate and effectiveness of acid treatment during the first stage of the period in question are explained by a high ratio of first applications of the treatment. In this case, even small depth of formation coverage allows achieving positive effect by means of cleaning the bottomhole zone of the formation that was mudded during completion. Application of hydrophobic acidic emulsions allowed increasing the effectiveness of treatment, especially during the initial stage of development of Mesozoic oil deposits. It is explained by their deeper (in comparison with the acid treatment) chemical action at relatively small most highly-permeable intervals of the penetrated part of the formation section. However, being structured systems, emulsions hardly seep in the low-permeability intervals of the section. This fact is not only limiting possibilities for increasing well output, but also leads to unfavorable consequences due to premature flooding [2]. Analysis of factual data from OAO Grozneftegaz has shown that if the drained intervals are located near the oil-water interface, then performance of deep chemical treatment at highly-permeable intervals in a number of cases is accompanied with appearance of water and progressive flooding of wells. On the other hand, mismatch between emulsion globule size and fracture size in low-permeability formation leads to mechanical deemulsification directly on the borehole wall, which totally negates all advantages of treatment with hydrophobic acidic emulsions in comparison to regular acid treatment. Besides, injection of hydrophobic emulsified acid into formation in a number of cases is complicated by extremely high pressures even at slow injection rates. This is especially typical of low-permeability formation treatment. Ensuring treatment is not always possible under such conditions, first, due to extremely long duration of injection comparable to the emulsion stability period, and second, due to insufficient strength of wellhead and production string.

Analysis of oilfield materials shows that similar conclusions are correct with respect of treatment of injection wells as well. As it may be seen from materials of OOO Grozneaftegaz (PO Grozneft), additional injection of water into formation per a single HCl treatment was in the range from 10 to 25 thousand m^3. Certain increase in effectiveness of treatment may be seen in the following years, which is caused by application of concentrated (24 – 27%) HCl that increased solubility and has longer neutralization period in comparison to the 15% solution. Average success rate of treatments is 85%. Relatively high success rate is primarily due to a longer neutralization period that the acid undergoes in a formation pre-cooled by prolonged injection of water, thus providing significant depth of action through the formation along its course. Effectiveness of injection well treatment with hydrophobic acid emulsions (HAE) is significantly higher that that of acid treatment. This is due to increased radius of formation treatment in comparison with a regular acid treatment. However, trends in effectiveness indicators for HAE and AT are qualitatively similar. For example, increase in water injection per a single HAE treatment reduced by a factor of more than 2.5 over the analyzed period. As the treatments were conducted following the same procedure, these changes in results are due to action on the same zones of the formation. While depth of action is significantly increased during the first treatment, the subsequent treatments increase the depth of action insignificantly. That is why degradation in permeability of treated formation zone by means of pressure of suspended particulate matter coming with injected water happens faster, thus reducing the effectiveness of treatment [3]. Under such conditions, significant increase in treatment activity would require not only expanding the coverage along the radius, but also inclusion of new intervals within the perforation interval into filtration. As it has been shown in [4, 5, 6], increase in well output with increased relative perforation of formation in fractured reservoir rocks is related to reduced filtration resistance due to spatial curvature of the flow. To increase the formation coverage, a number of experimental treatments were performed involving small-molecule organic acids mixed with polar solvents. These treatments showed no significant effect in comparison to traditional methods. The principal cause of insufficient treatment effectiveness is non-uniformity of reagent absorption by the formation, which leads to a situation when the treatment largely involves high-permeability intervals of the formation section [7]. Besides, organic acids have low dissolving ability with respect to rock, which does not allow significantly increasing formation permeability with small volumes (under 10 m^3).

Several foam-acid formation treatments were also performed by way of experiment. Most of them turned out being ineffective in production wells. This is due to low degree of aeration of the foam (less than 0.2) under the formation conditions, which cannot be improved because of high formation pressure. Low degree of aeration did not provide diverting the acid to low-permeability oil-saturated zones, thus the treatment again was applied to high-permeability zones which are the main filtration channels for formation water. Success of foam-acid treatment of injection wells is somewhat higher than that of regular acid treatments, however, they are not better than HCl treatments by increase in water injection per single treatment. Taking into account that aeration of the acid increases its corrosive activity, use of foam-acid treatments in deep wells has been deemed impractical. A positive effect has been obtained in selective treatment of production wells using polyolefins as insulating materials. In case of selective treatment of oil-saturated formations, there is equalization of oil inflow profile due to increased permeability of oil-saturated zones. In partially flooded reservoirs, in parallel to stimulated oil production there is also a significant reduction or complete cessation of water inflow to the well.

Success of selective treatment is at a level of 64%, while specific increase in oil production amounts to 550 t. Despite the positive results, this type of treatment is uncommon due to low effectiveness in cases when there is a good hydrodynamic connection between individual sublayers. This is due to modest penetration of the isolating material into the formation, which results in diversion of acid to low-permeability sublayers at the borehole wall or at some distance from it [8]. Beyond the isolating partition the acid is filtered through high-permeability intervals. Besides, the isolating partition has rather high permeability, thus only partially limiting the acid’s flow. Limited solubility of polymers in oil when they find their way to oil-saturated intervals may reduce oil inflow from the formation for a period of time. In this regard, recently developed polymer-bituminous compositions are more promising. It should be noted that polymers from the coarse suspension group are somewhat inert; due to this, their filtration is possible only through sufficiently open cracks. With increase in well depth, reservoir properties of formations consistently deteriorate, thus application of such suspensions as a temporarily isolating material for selective treatment of formations with low degree of crack opening is problematic or impossible [9].

Analysis shows that the methods used to stimulate fluid inflow (imbibition) in deep non-uniformly permeable fractured reservoirs with high formation temperature are insufficiently effective. This is due to high speed of neutralization of acidic agents and their predominant filtration through high-permeability intervals of the section, that leads to a situation where only high-permeable zones of the formation in the immediate vicinity of the borehole wall are subjected to the treatment. At that, low permeability intervals remain practically untreated. Apart from high speed of acid neutralization in the formation, high temperatures also cause significant corrosive wear of underground well equipment. Under the conditions at depth it leads to a necessity of replacing the tubing string after 3-4 treatments, implying well workover and subsequent development.

Currently, there is a large number of ways to stimulate oil and gas production where other acids are used in place of HCl, e.g., sulfamidic [10, 11], sulfuric [12, 13], phosphoric acid or its salts. The results of treatment application at a number of oilfields in Russia and abroad discussed in literature show their high success rate and effectiveness [14, 15, 16], however, due to some causes or others, these methods do not find wide acceptance.

Most Mesozoic deposits are at a late development stage that creates a number of problem, the main one being large production flooding and sharp decrease in oil inflow.

The main method used in OAO Grozneftegaz to stimulate wells operating on Lower Cretaceous sand-aleurolite producing layers is treatment of bottomhole zone with mud acid or hydrophobic oil-acidic emulsion on its base. The treatment procedure involves preparation of the working fluid (mud acid solution or emulsion), its injection into the well and squeezing it into the formation with water or oil. The type of working fluid was selected depending on formation temperature and purpose of the treatment. Treatments with mud acid solutions were conducted primarily in wells that operate on formations with a temperature up to 110°C. Besides high speed of acid neutralization in the formation, such temperatures involve significant corrosive wear of tubing string. Due to that, well stimulation involving formations with higher temperatures were mainly performed using hydrophobic acidic emulsions.

The procedure involved mud acid, containing 12-15 % HCl and up to 3 % of HF. The volume of the working fluid ranged from 0.2 to 1.5 m3 per 1 linear meter of casing string perforation interval, the volume of displacement fluid was 1.0-1.5 times the lift volume, the exposure time of the working fluid on the formation varied from 0.5 to 24 hours.

Analysis of available data shows that the success rate depends on the type of the working fluid. Oil-acid emulsions showed the highest success rate; at the same time, effectiveness of treatment depends on necessary depth of treatments. For example, the average success rate with emulsions applied during well completion (inflow) was 55%, while average success rate of emulsions application for well stimulation was 66.6%. For mud acid solutions, the dependency is reversed: the success rate in completion was 62%, while that well stimulation was only 50%. This fact may be explained with the speed of acid neutralization and difference in formation coverage with the chemical action.

Well treatment success rate in completion following drilling as a function of the degree of cleaning the bottomhole that was mudded during the completion.

Treatment of production wells usually requires influencing more remote zones of the formation, which are hard or impossible to treat with the mud acid solutions due to their fast neutralization. Under such conditions, application of emulsified acid is significantly more effective. These conclusions are supported with data on effectiveness of producer well treatment depending on formation temperature. In producer wells, use of the mud acid solutions is practical at temperatures below 115 - 110° C, while use of oil-acid emulsions is practical for temperatures up to 140-170 °C [17].

Application of hydrophobic acid emulsions, along with reduction of corrosion wear of well underground equipment allowed increasing effectiveness of chemical treatment on the most permeable intervals of the exposed part of formation.

Analysis of results from treatment of deep wells with mud acid solutions shows that effectiveness of these treatment methods on sand-aleurolite formations is determined by geophysical and process factors and has a range of use limited by formation temperature of about 170°C. Under these conditions, existing methods cannot ensure protection of well underground equipment against excessive acid corrosion. Besides acids, other substances capable of dissolving formation minerals were considered. It is well known [18, 19, 20] that under low temperature and concentration, NaOH solutions are significantly less corrosive in comparison with mud acid. It allows avoiding excessive corrosive destruction of underground equipment of wells.

Sodium hydroxide solutions have a number of positive properties that may be used in development of technologies aimed at increasing efficiency of chemical formation treatment. Among them are

high dissolving power, low corrosion power, interaction of reaction products with ions of divalent metal salts that are dissolved in formation water with formation of a gel that has structural mechanical properties.

For application of treatment with NaOH solution, the wells of OAO Grozneftegaz were selected that operate on deposits at a depth between 2242 and 5250 m at a temperature of 103-170° C. Analysis of the results shows that 78.5% of treatments were successful. Among the wells that showed positive reaction to the treatment, the duration of the effect was from 8 to 285 days, averaging at 118 days. After treatment with NaOH solution the well output in oil increased from 28 to 50 t/day and operated with such parameters for a month. Subsequently, water appeared in the production and in two months water cut in the production stream reached 53.

Thus, the treatments conducted at OAO Grozneftegaz showed that it is possible to apply concentrated alkaline solutions, which are an effective reagent for physical and chemical treatment of bottomhole area of deep sand-alevrolite formations. Use of 20-40% solutions of sodium hydroxide is recommended for treatment of bottomhole areas of formations at a temperature of 125-180°C.

Operation of deep Mesozoic wells on a number of oilfields of OAO Grozneftegaz is complicated with deposition of high-melting asphalten-tarry substances (ATS) in the tubing and borehole zone. It leads to reduced productivity of the well (up to complete stoppage of inflow from the formation), impedes and sometimes makes completely impossible conducting thermohydrodynamic surveys and bottom-hole fluid sampling. In this regard, there is a technology for removal of organic deposits from tubing and bottomehole that is being developed and implemented with considerations for deep high-temperature wells and uses aromatics and saturated hydrocarbons, as well as hydrophilizing agents.

Butylbenzene or benzene-toluene fractions were used as aromatic solvents, while water solutions of NaOH or 30-40% solutions of liquid glass were used as hydrophilizing agents [20]. The volume of the butylbenzene or benzene-toluene fraction per single treatment was 6-8 18 m^3 and in most cases matched the volume of tubing; the volume of hydrophilizing agents was 0.5-3 m^3. The treatments were conducted to prevent complications in operation of deep wells at the following oilfields: Pravoberezhnaia, Goriachistochnenskaia, Mineralnaia, Starogroznenskaia, Andreevskaia, Eldarovo and Zamankul. There is still high relevancy of scientific and oilfield research into increasing well output of oil producer wells at various stages of deposit development, stabilization of operation of various process equipment of wells by means of preventing deposition of asphaltene-tarry substances (ATS) at the borehole walls and fluid lift walls.

III. RESULTS AND RECOMMENDATIONS

Success of selective treatment is at a level of 64%, while specific increase in oil production amounts to 550 t. Despite the positive results, this type of treatment is uncommon due to low effectiveness in cases when there is a good hydrodynamic connection between individual sublayers. This is due to modest penetration of the isolating material into the formation, which results in diversion of acid to low-permeability sublayers at the borehole wall or at some distance from it [7]. Beyond the isolating partition the acid is filtered through high-permeability intervals. Besides, the isolating partition has rather high permeability, thus only partially limiting the acid's flow. Limited solubility of polymers in oil when they find their way to oil-saturated intervals may reduce oil inflow from the formation for a period of time. In this regard, recently developed polymer-bituminous compositions are more promising. It should be noted that polymers from the coarse suspension group are somewhat inert; due to this, their filtration is possible only through sufficiently open cracks. With increase in well depth, reservoir properties of formations consistently deteriorate, thus application of such suspensions as a temporarily isolating material for selective treatment of formations with low degree of crack opening is problematic or impossible [8].

IV. CONCLUSION

Analysis shows that the methods used to stimulate fluid inflow (imbibition) in deep non-uniformly permeable fractured reservoirs with high formation temperature are insufficiently effective. This is due to high speed of neutralization of acidic agents and their predominant filtration through high-permeability intervals of the section, that leads to a situation where only high-permeable zones of the formation in the immediate vicinity of the borehole wall are subjected to the treatment. At that, low permeability intervals remain practically untreated. Besides, acid agents are corrosive and their use in deep wells is related to intensive corrosion of tubing.

All this determines a necessity to develop new acid compositions and procedures for their application that provide reduced corrosion of underground equipment of wells, increased effectiveness of chemical action onto deep non-uniform reservoirs by means of increasing treatment's formation coverage along both the bearing and the thickness of the formation.

References

[1] A.Sh. Khaladov, Increasing the efficiency in removal of asphaltene and paraffin deposits during production of oil with large pressure differential in fountain lift. Dissertation. Ufa: Ufa State Petroleum Technological University, 2002, pp. 156.

[2] N.D. Bulchaev, Iu.N. Bezborodov, N.F. Orlovskaia, "Determining corrosivity of waters in Vankor oil field", Questions in Fundamental and Applied Science, pp. 51–57, 2015 [Materials of the International Scientific conference. Moscow].

[3] I.V, Krivonosov, G.A. Makeev, G.S. Arnopolskii, "On effectiveness of first and subsequent acid treatments", Oilfield Engineering, iss. 1, pp. 29–31, 1973.

[4] V.V. Belov, On fluid influx to an imperfect well from a non-uniform fractured reservoir. Annals of SevKavNIPIneft, iss. 288. Grozny, 1976.

[5] E.V. Sokolovskii, V.V. Belov, Influence of penetration degree of thick fractured reservoirs onto oil well output, iss. 2. Moscow: Neftyanoye Khozyaystvo, pp. 47–49, 1976.

[6] A.A. Elmurzayev, A.Sh Khaladov, I.I. Aliyev, P.S. Tsamayeva, M.M. Dudaev, "Features of oil production and complications of Mesozoic deposits operation (on the example of the Grozny oil region Advances in Engineering Research", vol, 177, pp. 458–462, 2018 [International Symposium on Engineering and Earth Sciences (ISEES 2018)]. Retrieved from: http://creativecommons.org/licenses/by-nc/4.0/.

[7] A.Sh. Khaladov, Peculiarities of complicated operation of wells when developing Mesozoic deposits in the Chechen Republic, iss. 1584-B98, May. Moscow: All-Russia Institute of Scientific and Technical Information of the Russian Academy of Sciences, 1998, pp. 12.

[8] N.D. Bulchaev, A.Sh. Khaladov, R.Kh. Mollaev, "Peculiarities of oil production from Mesozoic deposits in the Chechen Republic", Development prospects of the fuel and energy complex and the current state of oil-and-gas engineering education in Russia, pp. 160–170, June 2018 [Scientific and Technical conference dedicated to 105 years since the birth of M.D. Millionshchikov].

[9] A.Sh. Khaladov, L.Kh. Kadyrov, M.M. Bakraev, A.A. Umaev, M.M. Dudaev, "Methods to increase oil recovery of high temperature Mesozoic deposits (as exemplified by Groznensky oil-bearing district)", Development prospects of the fuel and energy complex and the current state of oil-and-gas engineering education in Russia, pp. 95–107, June 2018 [Scientific and Technical conference dedicated to 105 years since the birth of M.D. Millionshchikov].

[10] A.A. Glazkov, F.N. Marichev, “On possibility of using sulfoamidic acid for treatment of terrigenic collectors”, Oilfield Engineering, no. 7, pp. 35–38, 1980.

[11] V.S. Ugolev, V.P. Shalipov, P.M. Iuzhapikov, “Special acids to increase well productivity”, Oilfield Engineering, no. 10. pp. 26–28.

[12] R.I. Zlotsevskaia, V.I. Divisilova, G.A. Kuprina. Studying the interactions of clays with acidic and alkaline solutions during clay swelling. Bound water in dispersed systems, iss. 3. Moscow: Moscow State University, 1974, pp. 4–19.

[13] V.P. Shalipov, V.S. Ugolev, S.B. Shafran, P.M. Iuzhapinov, “Experience from treating injection wells with refinery wastes that contain sulphuric acid”, Oilfield Engineering, 1973, no. 5, pp. 22–24.

[14] A.I. Komisarov, R.M. Khachaturov, R.Kh. Mollaev, A.G.Khurshudov, V.A. Iarovoi, Guidelines for physical and chemical treatment of low-permeability formations in deep wells of Grozneft, Grozny, 1980.

[15] A.M. Iziumova, Hydraulic fracturing at oilfields of Grozny. Grozny, 1959, pp. 24–26.

[16] E.M. Tosunov, A.I. Komisarov, R.Kh. Mollaev, “Formation treatment using polymers: Express Information”, RNTS Oilfield Engineering, no. 1. Moscow: VNIIOENG, 1977, pp. 5–7.

[17] A.I. Komisarov, V.A. Iarovoi, N.N. Lemeshko, “Stimulating fluid inflow from deep terrigenic deposits of Chechen-Ingush ASSR”, Oilfield Engineering, no. 9, pp. 18–19, 1983.

[18] A.I. Komisarov et al., Stimulating oil production from deep fractured reservoirs, iss. VIII. Moscow, 1985, 146 p.

[19] V.M. Glazova, G.I. Trakhtman, “Improving well stimulation methods by means of acid treatment:, Summary, ser. Oilfield Engineering. Moscow: NIIIOENG, 1985, 60 p.

[20] R.Kh. Mollaev, Yu.I. Makeev, G.Ia. Tolmacheva, E.P. Smirnova, N.V. Grishchenko, G.A. Shepeleva. Evaluating efficiency of anti-corrosion protection of wellhead and pressure maintenance systems, including recommendations to improve the efficiency. Grozny: SevKavNIPIneft, 1991. pp. 7–12, 34–36, 40–43.