Technological feature of hypan-acid treatment

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Abstract. The paper considers one of the effective methods of cleaning the well filter from various impurities and deposits – injection of hypanic acid. The technology of implementation of this promising type of treatments has been studied and the chemical compositions and their concentrations used in modern conditions of oil field development have been comprehensively studied. The results of laboratory studies to determine the optimal chemical composition for various tectonic and stratigraphic sites are presented. By screening and analyzing field experiments on injection of hypanoic acid, a number of recommendations have been formed concerning the issues of effective alignment of the pick-up profile: boundary parameters of geological and physical characteristics of productive formations have been determined, at which technological indicators of treatments will be the highest; a positive effect on the dynamics of changes in the indicator of water content of extracted products has been revealed, which significantly expands the scope of this technology. According to the results of the study, the use of this method of cleaning the bottom-hole formation zone is recommended for many deposits of the Russian Federation.

1 Introduction

The problem of enhanced oil recovery under the conditions of a natural decrease in recoverable oil reserves and long-term developed fields has become extremely relevant, since the oil recovery factor rarely reaches 0.4 – 0.55 for most deposits and fields.

The existing complex and specific features of the reservoirs structure and the properties of the fluids saturating them are augmented with their own complications like the imperfection of the reservoirs initial opening during drilling and development during the operation period. These complications are caused by changes in thermodynamic conditions near the bottom-hole area both during the well production removal and during well repair, when the PTA is contaminated as a result of the penetration of the corresponding operating fluids as well as physical, chemical and mechanical changes [1].

All this requires the wide use of various methods of bottom-hole area treatment and methods of enhanced oil recovery on the deposits.

One of such methods is the method of hypan-acid treatment of the bottom-hole area of a well. The essence of the method is as follows: a coagulant (CaCl), a polymer (hydrolyzed

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polyacrylonitrile (PAN) – hypan) and hydrochloric acid are pumped into the PTA in a certain sequence and in calculated quantities [2-3]. The coagulator saturates highly watered channels-fractures, and partially the pores of the watered reservoir, while it partially dissolves with fresh water of the buffer "pillows". The same thing happens with the polymer. Due to a partial decrease in the concentration of reagents, the "wedging effect" is eliminated.

As the polymer is forced through, a uniform increase in pressure, which rises by 3–7 MPa when the hydrochloric acid solution approaches the perforation interval, and a decrease in the absorption capacity of the reservoir are observed. Hydrochloric acid, partially following the polymer, enhances the strength of the flooded channels closure, and its main volume opens new channels in the oil layer of the reservoir. Calcium chloride solution is used as a coagulator, while hydrolyzed polyacrylonitrile (hypan) is used as a polymer [4,5].

The effectiveness of this type of treatment depends on how deep the acid penetrates into the formation, since it increases the likelihood of studying previously undiscovered bypassed oil, creating more ways for oil to flow into the PTA.

The reaction of HCl with limestone produces CO_2. Carbon dioxide contributes to an increase in the reaction rate, since when it is released in the form of bubbles, the solution and reaction products are mixed, and new portions of the unused acid solution are involved in the reaction process [6].

When the pressure increases, the reaction of the acid with the rock slows down, it becomes possible to push the solution further into the reservoir. The experience of acid treatments application shows that the injection pressure drops, and the reaction rate increases with an increase in the frequency of treatments. Thus, the impact of the acid is limited to the dissolution of carbonates in the immediate vicinity of the wellbore.

HYPAN α+ is a two-component technology based on polyacrylonitrile, which forms in-situ sediment well adsorbed on the rock walls. Depending on the second component (aluminum hydroxide chloride), the precipitate can acquire different properties from flaky-like to gel-like [7]. The technology is not sensitive to reservoir temperature and water salinity. The concentrations of the components are selected based on the injectivity of the well.

2 Methods and Materials

The article presents the obtained results being substantiated by the use of hydrodynamic simulators tested and recommended for use in the oil industry. When processing field data, analysis methods using a PC have been used. The recommendations developed in the article are field tested and are characterized by a positive technological effect.

3 Results and Discussion

The technology is applicable for injection wells with surrounding production wells (at least 2-3 wells) at a distance of no more than 1,000 m. The affected area at the date of treatment should have recoverable reserves depletion of no more than 90%, the water cut in the area can be from 50 to 90%.

The injectivity of the injection well can be equal to 150 to 600 m^3/day. If the injectivity is more than 600 m^3/day, injection of 50-150 m^3 of chalk (or other dispersed) suspension is allowed before injection of the main volume of the working solution.

The objects of influence are wells operating carbonate reservoirs with a water cut from 45 to 100% and meeting the following conditions: the presence of oil reserves in the

reservoir in the area of production wells [8]. Reservoir pressure must not be higher than hydrostatic pressure; vugginess, porosity, fracturing must be within the limits that provide a liquid injection pressure of 6–12 MPa at an injection rate of 100–600 l/min.

To conduct mud-acid treatment in the enterprise under consideration, the following components are used.

The following polymers are used: hypan-1 being hydrolyzed polyacrylonitrile (PAN and NaOH – 1:1) with 10–17% concentration and manufactured according to TU 2216-001-046998227-99; hyvpan being hydrolyzed polyacrylonitrile fiber with 10-15% concentration, manufactured according to TU49569-04-02-90.

As the temperature decreases, the polymer thickens and loses its fluidity at minus 5–10°C. When freezing, water settles from the polymer. For this reason, well treatment works are seasonal (from May to October). The pH of the solution is 12–14. It is transported by general purpose tank trucks (ACN-8, ACN-7.5, according to TU26-16-32-77) previously cleaned from other chemical products and reservoir water.

Upon contact with liquids containing ions of polyvalent metals (calcium, magnesium, iron, and others), the polymer coagulates with the release of dense clots and filaments of the polymer. Therefore, the contact of the hypan solution (hyvpan) with reservoir water leads to coagulation and sedimentation. At the contact of the polymer with a solution of hydrochloric acid, its precipitation occurs, that is, the isolation of polyacrylonitrile occurs in the form of a continuous bound mass [9].

The volume of polymer in mud-acid treatment is selected depending on the volume of water inflow channels. The volume of water inflow channels can be indirectly judged by the daily well flow rate and water cut, as well as by the porosity of the horizon planned for mud-acid treatment. The injectivity of the treated horizons is not always in direct proportion to the well flow rate [10]. For this reason, when determining the required volume of polymer, the following conditions are accepted:

- When deciding to process any horizon, its daily debit (total and water) is specified. At the same time, in the work plan, the volume of polymer is approximately taken within 0.3–0.5 of the daily water flow rate.
- In the process of preparatory work, the injectivity of the horizon is determined, the polymer volume (16%) is corrected, and a correction is made for its volume.

In accordance with the technological conditions, with an injectivity from 0.0033 to 0.0050 m^3/s, the polymer volume will be 2.0–3.0 m^3. Considering that 17% hypan is taken for treatment of these wells, the volume of the polymer will correspondingly decrease and will be approximately from 1.5 to 2.0 m^3.

The following substances are used as a coagulant:

- A solution of calcium chloride (calcium chloride dihydrate) being technical and fused ("flakes" corresponding to GOST 450-70 or powdered corresponding to TU 6-09-5077-83, grade 1 or 2).
- Reservoir saline water from Devonian deposits with the density equal to 1,190 kg/m^3. The concentration of the coagulator depends on the injectivity of the treated horizon and is tentatively presented in Table 1.

The volume of the coagulator is assumed to be 1.5–2.0 times higher than the volume of the polymer, since its viscosity is much lower than the viscosity of the polymer, and when it is introduced into the treated horizon, it will not only fill cracks and channels, but also enter the reservoir pores.

Based on the analysis of Table 1, it can be seen that with an injectivity of the treated horizon up to 400 l/min (500 m^3/day or 0.0058 m^3/s), the density of the coagulant should be up to 1,198 kg/m^3: for these purposes the reservoir water with a density of 1,190 kg/m^3 is applied. With an injectivity of 400–800 l/min, a calcium chloride solution of the appropriate density should be used.

Table 1. Coagulant concentration.

Injectability, m³/s	Coagulant concentration, %	Density, kg/m³
0.0058	20	1,178
0.0067	22	1,198
0.008	23	1,201
0.01	30	1,280
0.013	32	1,300

Most of the treated wells had daily flow rates from 2 to 10 tons per day with a water cut of 50–98%. Their injectivity did not exceed 0.0067 m³/s. Therefore, we can state that it is quite justified to use reservoir water with a density of 1,190 kg/m³ as a coagulator.

In this case, the volume of the coagulator is taken higher, specifically, 2–3 times exceeding the volume of the polymer.

The above materials are transported in general purpose tank trucks (ACN-8, ACN-7.5 according to TU 26-16-32-77).

Hydrochloric acid is used in different types:

- Hydrochloric acid inhibited according to TU 39-05765670-OP-212-95 grade A or grade B.
- Hydrochloric acid technical, synthetic (GOST 857-95).

For treatments, a 12–15% hydrochloric acid solution is used. Density is 1,060–1,073 kg/m³. The mass fraction of iron is less than 0.03%. The corrosion rate of steel (St-3) in 25% hydrochloric acid is less than 0.2 g/(m²/h). Mass fraction of turbidity after inhibition is less than 0.2%.

The volume of hydrochloric acid solution is taken at the rate of 0.5–0.7 m³ per 1 m of the exposed productive reservoir stratum. No positive effect has been observed from increasing the volume of hydrochloric acid solution to 1.5–2.0 m³ per 1 m of the perforation interval made for individual wells.

In practice, for rapid calculations aimed to determine the amount of hydrochloric acid when preparing 1 m³ of a solution of various concentrations, Table 2 should be used.

The calculation of the volumes of process materials is downloaded in the appropriate sequence (Table 2).

Table 2. Technological materials used for hypan-acid treatment of the bottomhole area.

Type of technological material	Aim	Estimated consumption, m³	Density, kg/m³
Calcium chloride solution	Coagulator	30	1032
Fresh water	Buffer pillow	0.15	1000
Hydrolyzed polyacrylonitrile:			
Hypan-1 (10–17%)	Polymer	2.0	1120
or Hyvpan (10–17%)		2.0	1120
Fresh water	Buffer fluid	0.2	1000
Inhibited hydrochloric acid, grade A, 15% or hydrochloric acid technical, synthetic or hydrochloric acid from exhaust gases	Working agent for strengthening the insulating mixture and creating new oil flow channels	3–6	1090
Reservoir water	Displacement liquid	1.5 tubing volume	1190

Special equipment used in hypan-acid treatment is as follows:

- Unit A-50 is designed for tripping operations with tubing (injection tubing) and drill pipes during current and major repairs of wells. It is mounted on the KrAZ-257 chassis.

Tower height is 22.4 m; the maximum length of the lifted pipe is 16 m; drum diameter is 1,100 mm; traction engine is YaMZ-38, power is 176.5 kW.

- ACN-7.5 tank truck is designed for transporting non-aggressive liquid media with temperatures up to plus 80°C and their supply to pumping and mixing plants during squeezing and flushing operations. It is mounted on the KamAZ-53212 chassis.

Tank capacity is 7.5 m^3; pump type is K45/55 with a flow rate of 10 l/s, a shaft speed of 48 s-1; overall dimensions of the tank truck 8330×2500×2820 mm; the mass of the tank truck 9039 kg.

The reservoir treatment process is uncontrollable, which results in spontaneous options:

- Option 1 implies that a hydrochloric acid solution injected into the reservoir under pressure creates new channels in the oil column of the reservoir. Anhydrous oil enters the well. At the same time, the polymer reliably closes the old channels of water inflow, since the dimensions of the channels correspond to the conditions for ensuring sufficient strength of the polymer so that it is not destroyed by reservoir pressure.

This option provides the possibility of long-term operation of the well with a significant addition of oil production and with a decrease in water cut.

- Option 2 denotes the effect identical to the one described in option 1, but due to unregulated subsequent waterflooding of the reservoir, to maintain reservoir pressure, the well being treated ends up in a zone of high reservoir pressure. The strength of the polymer is not enough; it collapses and leaves the blocked channels of water inflow, the well is sharply flooded.

- Option 3 represents the effect identical to the one described in options 1 and 2, the volumes of ingredients are correctly selected, the technology of work is sustained, but the well is treated with high reservoir pressure. When the well is put into operation, the polymer will be pushed out of the water supply channels and the well will be flooded. In this case, a decrease in oil production rate and an increase in water cut are possible. Therefore, wells with high reservoir pressure are not suitable for treatment [11].

- Option 4 suggests the effect identical to the one described in Option 1. However, the hydrochloric acid solution creates new channels in the flooded reservoir. The well after treatment will not give an increase in oil, the water cut will increase.

- Option 5 indicates the very high fracturing, the presence of caverns in the reservoir. The water inflow channels have dimensions at which the specific pressure on the polymer from the formation pressure exceeds its strength. It will be destroyed, and the well will be flooded again.

Everything described in option 5, due to caverns in the reservoir, it is impossible to correctly determine the volume of the polymer. With large volumes of caverns, it will not be possible to close the water inflow channels, and if the polymer volume is taken 3–5 times more, then there will be no payback of work due to its high cost.

The main reasons for unsuccessful mud-acid treatment include incorrect selection of wells due to lack of data on wells or inaccurate data that lead to erroneous decisions when accepting a well for treatment.

These decisions include the following: current flow rate of the well; water cut of products; reservoir pressure; excess of reservoir pressure over hydrostatic pressure during well operation; residual oil saturation (original reserves, withdrawal).

Errors in determining the injectivity of the well occur due to the following reasons: inaccuracies of the pressure gauge; inaccurate measurement of liquid volume; injection of a volume of liquid that is not sufficient to stabilize the injection; timing inaccuracies; etc.

Reasons concerning organization: the use of tankers for transporting ingredients not purified from other chemical products; dilution of the polymer when putting it into a tank truck; deviation from the technological scheme of injection of ingredients in the process of well treatment; injection of increased volumes of fresh water cushion; high performance of

the pumps when introducing the polymer into the reservoir, leading to an increase in injection pressure to the level of the hydraulic fracturing pressure.

Errors in the selection of polymer and coagulant volumes are due to incorrect determination of well injectivity.

4 Conclusion

Thus, the main goal of the technology is to equalize the injectivity profile and increase the sweep efficiency of the reservoir. This implies that before the operation, the injection well injects water mainly into one/two interlayers, which is confirmed by field geophysical tests (FT) of the injectivity profile.

The following requirements and criteria must be observed when selecting the object of influence:

- Reservoir permeability over 5 mD.
- More than two exposed interlayers.
- Information on the volume of the fracture is required in the case of hydraulic fracturing.

The emphasis of the activity of the enterprise under consideration is based on work with the carbonate fund of wells. Acid treatments and their various modifications are used with regards to the deterioration of operating conditions, the growth of water cut in products, and the deterioration of the stock structure.

At the field under consideration, the technology of carrying out hypan-acid treatments with increased water cut in well products is of high relevance.

At the moment, significant progress has been made in the implementation, development and improvement of methods for enhanced oil recovery. But despite this, there is still a lot to be done.

Not for all conditions there are clearly developed criteria for the applicability of various methods of processing the bottomhole area. Such criteria, in practice, are available only for carbonate reservoirs, but here there is no distinction in terms of geological and physical parameters and reservoir conditions. Further increase in the efficiency of work on intensification of inflows requires the justification of clearly defined criteria for the applicability of various treatments of the bottomhole area and a set of the most effective methods of influencing the reservoir for various types of deposits. And this, in turn, requires a complete analysis of all geological and technological parameters that affect the efficiency of work on methods of enhanced oil recovery.

References

1. R.T. Akhmetov, V. V. Mukhametshin, IOP Conference Series: Earth and Environmental Science, **194(6),** 062001 (2018)
2. E. M. Almukhametova, D. I. Fattakhov, A. I. Zakirov, IOP Conference Series: Earth and Environmental Science, **194(8),** 082002 (2018)
3. B. Bazin, SPE Production and Facilities, **16(1)** (2001)
4. G. Daccord, R. Lenormand, O. Litard, Chemical Engineering Science, **48(1)** (1993)
5. G. Daccord, T. Touboul, R. Lenormand, SPE Production and Engineering, **4(2)** (1989)
6. Sh. A. Gafarov, A. V. Lysenkov, A. Sh. Gafarov, A. V. Akimkin, Oil Industry. **2** (2018)
7. O. A. Grezina, IOP Conference Series: Earth and Environmental Science, **194(8),** 082016 (2018)

8. R. A. Kozikhin, A. M. Daminov, I. G. Fattakhov, L. S. Kuleshova, A. Kh. Gabbasov, IOP Conference Series: Earth and Environmental Science, **194(6),** 062013 (2018)

9. V.Sh. Mukhametshin, V. E. Andreev, S. A. Yaskin, IOP: Earth and Environmental Science, **579(1),** 012013 (2020)

10. V. V. Mukhametshin, SOCAR Proceedings, **4** (2020)

11. R. R. Shangareev, IOP Conference Series: Earth and Environmental Science, **194(2),** 022033 (2018)