On the use of geophysical research data aiming to increase the efficiency impact on the bottomhole zone of wells

V V Mukhametshin¹ and L S Kuleshova²

¹ Department of Oil and Gas & Oil Field, Development and Operation, Ufa State Petroleum Technological University, Ufa, Russia
² Department of Oil and Gas Field, Exploration and Development, Ufa State Petroleum Technological University, Branch of the University in the City of Oktyabrsky, Oktyabrsky, Russia

E-mail: vv@of.ugntu.ru, markl212@mail.ru

Abstract. Under the conditions of terrigenous Jurassic deposits in Western Siberia, we conducted a study on the influence of deposits’ geological structure features, reflected by the results of geophysical surveys of wells on the effectiveness of the impact on the bottomhole zone using the hydrochloric acid composition Aldinol-20. It was established that in predicting the effectiveness of the impact on the bottomhole well zone, it is necessary to use the data of geophysical studies. At the stage of putting the field into development, it is enough to limit this information in the absence of it. The article proposes a technique that allows us to solve the tasks at different stages of development. The technique is based on the use of geological and statistical models and it is built based on using various performance criteria for various amounts of information. It is to be conducted in the conditions of a limited amount of information about deposits due to insufficient volumes of field research of organizational and financial nature, as well as in case of changing the tactics and strategies of enterprises in market conditions.

1. Introduction

In field practice, when enough information is accumulated to generalize, the results of its generalization are often used to increase the efficiency of decisions. One of the areas of such activity is the generalization of the experience of impacts on the bottomhole formation zone (PZP) [1–3]. However, the weak point of such studies is the lack of the possibility of their use when changing conditions and scenarios for the development of situations in the future both on the analyzed object itself and on analogous objects. An important point in this case is the availability of the opportunity to use the experience gained under the conditions:

- various stages of development;
- lack of complete necessary information;
- the availability of heterogeneous information;
- the availability of a limited amount of information;
- changes in the market situation, etc.

As the experience of geological-field generalization of the results of the impact on the bottomhole zone of wells [4–6] shows, the effectiveness of the impact is determined by three large groups of factors:

1. – geological, physical and physic-chemical properties of the formations and the fluids saturating them;
2 – technological indicators of the operation of wells and deposits;
3 – technological parameters of the impact.

The degree and nature of their influence on performance indicators is different in the conditions of various objects and their groups [7–9], which indicates the need for a differentiated approach in the analysis and use of the results.

In order to eliminate the above-mentioned weaknesses, the article describes a generalization of the experience of conducting activities to intensify oil production in low-permeable terrigenous strata SE11 of Western Siberia using an acidic composition based on the Aldinol-20 composition. The main objective of this generalization was to establish the degree of influence of the initial geological and geophysical parameters, as well as the filtration-capacitive and thickness properties of the layers determined by them, on various impact indicators, taking into account the peculiarities of conducting hydrodynamic and flow metric studies of wells. The choice of this group of parameters is due to accessibility, representativeness and common standards that allow them to be used regardless of place and time.

2. Methods and materials
The acid composition of Aldinol-20 consists of a mixture of polyhydric alcohols, cations and nonionic surface-active substances, a corrosion inhibitor, hydrochloric acid and the modifying additive Aldinol-MK. The addition of the Aldinol-MK modifier to acid compositions increases the effectiveness of the latter due to their deeper penetration into the formation, destruction of the hydrocarbon film on the surface of mechanical impurities, and additionally inhibits the corrosiveness of acids, which allows transporting and storing the acid composition without compromising on quality.

Distinctive features of the composition Aldinol-20 are:
- low (less than 0.1 mN/m) interfacial tension at the oil-acid composition boundary, which ensures the destruction of persistent water-oil emulsions formed in the bottomhole zone of production wells and the effective displacement of residual oil in the bottomhole zone of the well;
- slower than an aqueous acid solution, the reaction rate with the carbonate components of the oil reservoir rock, which altogether leads to an increase in both the permeability of the reservoir and the penetration zone (processing radius);
- the ability to reduce the strength of the adsorption layers at the water-oil interface, formed by surface-active substances that make up oil (asphaltenes, resins, naphthenic acids) and mechanical impurities.

When such a composition is pumped into the bottomhole zone of the formation, processes of effective dispersion and removal of components of asphalt-resin-paraffin deposits (ARPD) from inorganic sediments that clog the formation (particles of clay, iron sulfide, hydroxides, calcium, magnesium, aluminum carbonates, etc.) occur simultaneously. The latter, having lost the acid-resistant "protective shell" of the above-mentioned organic components of ARPD, begin to actively react (dissolve) in a water-acid medium. Moreover, during the chemical reaction of some of them, gaseous components are released, which, in turn, loosen sediments and float the volume of surface-active substances-acidic dispersion medium, individual components of these sediments, which significantly speeds up the process of cleaning the bottom-hole formation zone.

An important distinguishing feature of Aldinol-20 from known surface-active substances-acid compositions is that the acid composition not only cleans the bottomhole zone of the formation well from pollution, but also retains, after its neutralization, high oil-displacing properties (due to the residual surface-active substances in the system) and hydrophobizing properties (due to adsorption of cationic surface-active substances) [10].

It is recommended to use this method in wells that produce a low oil flow during development, open low-permeability formations, and have a reduced production rate compared to surrounding wells, with reduced filtration characteristics in the near-hole zone of the formation. The formation had a decrease in production rate during operation with a constant or growing formation pressure with a high degree of
heterogeneity of reservoir properties of the reservoir and small working thicknesses; as well as with high water cut of the product.

3. Results
More than 120 wells studied the effect on impact indicators, reflected using the absolute \( Y_1 \) and relative \( Y_2 \) increase in oil production, absolute \( Y_3 \) and relative \( Y_4 \) decrease in water cut, the total increase in production during the effect \( Y_5 \) and the integrated efficiency parameter \( Y_6 \) [11], geological and physical properties of the formation (according to geophysical studies), technological parameters of the operation of wells and deposits, and technological parameters of the impact.

The geological and physical properties of the formation in the well were reflected using the following parameters: total \( (H_{total}, \text{ m}) \), effective \( (H_e, \text{ m}) \), effective oil-saturated \( (H_{oil}, \text{ m}) \) thickness of the formation, sandiness \( (K_s) \), stratification \( (K_p) \), open porosity \( (m) \), oil saturation \( (K_u) \); permeability coefficients \( (K_{perm}, 10^{-3} \text{ m}^2) \), self-polarization \( (a_e) \); readings in the reservoir according to BC \( (M_{BC}, \text{ Om-m}) \), PS logging \( (A_{PS}, \text{ Om-m}) \), on GZ1 \( (A_{0.40.1.0}, \text{ Om-m}) \), on GZ2 \( (A_{1.0.2.0}, \text{ Om-m}) \), on GZ3 \( (A_{2.0.5.0}, \text{ Om-m}) \), on GZ4 \( (A_{4.0.5.0}, \text{ Om-m}) \), on PZ \( (A_{0.56.0.5}, \text{ Om-m}) \), gamma ray logging \( (\gamma, \text{ mc/rh}) \), large tubing probe \( (\beta_{Tub}) \), small tubing probe \( (\beta_{Tub}') \), induction probe \( (\beta_{imp}, \text{ sim}) \); specific electrical resistance of the probe by IK \( (\rho_{IK}, \text{ Om-m}) \), on BC \( (\rho_{BC}, \text{ Om-m}) \), on a set of electric logging probes \( (A_{comp}, \text{ Om-m}) \), penetration zones for a complex of electric logging probes \( (A_{oil}, \text{ Om-m}) \), the ratio of the diameter of the zone of penetration of the filtrate of the washing fluid to the diameter of the well \( (d_{Z}/d_{C}) \).

The parameter values were used both as a whole along the section \( (X) \) and along the perforated part of it \( (X_I) \).

The technological parameters of the operation of wells and deposits characterized the parameters: time \( (t, \text{ month}) \), maximum oil production \( Q_{\text{max}}, \text{ t/month} \) from the beginning of the operation of the well until the impact; flow rate \( (Q_{\text{Hi}}, \text{ t/mon}) \), water cut \( (f_i, \%) \), cumulative oil production \( (Q_{\text{cum}}, \text{ t}) \) at the time of exposure; initial oil production \( (Q_{\text{Di}}, \text{ t/mon}) \), frequency of exposure \( (N) \).

Among the parameters reflecting the exposure technology, the following were used: consumption of Aldinol-20 \( (ALD, \text{ t}) \), 22 % hydrochloric acid \( (\text{HCl}, \text{ t}) \); the volume of the injected solution \( (V, \text{ m}^3) \), as well as various specific indicators.

Using systematic regression analysis, we built models for the dependence of all performance indicators on the considered geological and technological parameters in three versions:

1. using the whole complex of parameters;
2. using parameters reflecting the geological and physical properties of the formation and the technology of exposure;
3. using parameters reflecting the technological features of the work of wells and deposits, as well as the impact technology.

Models that reflect the influence of parameters on the absolute increase in oil production have the following form:

- **option 1:**
  \[
  Y_1 = -1333,083 - 90,481K_p + 22,523K_p - 2,255A_{PC} + 14,912H_{oil} + 42,403K_p + 1650,692m + \\
  + 157,254d_{aq} + 61,853a_{aq} + 5,145K_{0.4} - 68,513d_{eq}/d_{C} + 9,664B'_{Tub} - 0,001Q_{\text{cum}} + 0,464 + \\
  + 0,057Q_{\text{max}} + 1,735f_i - 0,466Q_{\text{Hi}} - 125,543ALD + 37,437V + 46,205N + 79,679/V_{\text{oil}} + \\
  + 1009,308ALD/V - 31,301ALD/H_{oil} (R = 0,793;)
  \]

- **option 2:**
  \[
  Y_2 = -745,687 - 159,44K_p + 16,781K_p - 1,668A_{PC} + 21,271H_{oil} - 56,541R_p + 1636,759m - \\
  - 418,022d_{aq} + 81,852d_{aq} - 16,85A_{0.4} - 7,752d_{eq}/d_{C} + 6,135B'_{Tub} - 195,85ALD + \\
  + 72,25V + 76,62N + 55,79/V_{\text{oil}} + 1362,594ALD/V - 29,818ALD/H_{oil} (R = 0,640;)
  \]

- **option 3:**
  \[
  Y_3 = -385,698 - 0,185t + 0,019Q_{\text{cum}} + 0,086 f_i - 0,425Q_{\text{Hi}} - 142,704ALD + 66,176V + \\
  + 52,021N - 29,26V/H_{oil} + 943,908ALD/V + 63,45ALD/H_{oil} (R = 0,518;)
  \]
A similar series of geological and statistical models was obtained for other performance indicators. The values of the multiple correlation coefficients (R) presented in the table allow us to use them in diagnosing and selecting wells for impact at a quantitative and qualitative level. This level is explained by the fact that the errors of the obtained models vary from 20 to 70% and make up on average 32%, although in the calculations for 7–10 wells the forecast is quite satisfactory.

Table 1. Values of multiple correlation coefficients of obtained models

| Option | Performance indicator |
|--------|-----------------------|
|        | $Y_1$ | $Y_2$ | $Y_3$ | $Y_4$ | $Y_5$ | $Y_6$ |
| 1      | 0.793 | 0.824 | 0.753 | 0.793 | 0.818 | 0.727 |
| 2      | 0.640 | 0.742 | 0.705 | 0.640 | 0.739 | 0.681 |
| 3      | 0.518 | 0.533 | 0.547 | 0.518 | 0.602 | 0.534 |

An analysis of the results shows that naturally the smallest error in the prediction has models built using the whole complex of geological and technological parameters considered. In the absence of parameters reflecting the technological parameters of the work of wells and deposits (option 2), which is typical for the stage of putting the fields into development, the error increases and the accuracy decreases. However, at this stage, the use of geological and geophysical data allows us to solve the problems of predicting the effectiveness and selection of wells for impact with a sufficient degree of accuracy.

In the absence of parameters characterizing the geological and physical properties of the formation in the well (option 3), a significant decrease in the predictive abilities of the models is observed, which indicates the need to use geophysical research data for solving such problems. Although in some situations, this group of models can also be used in practice for quantitative and qualitative assessment.

4. Conclusion
1. It was established that in predicting the effectiveness of the impact on the bottomhole zone of the wells, it is necessary to use the data of geophysical studies. At the stage of putting the field into development, it is enough to limit this information in the absence of it.
2. The article proposes a technique that is based on the use of geological and statistical models. It is built on the basis of using various performance criteria for various amounts of information, which allows us to solve the problems at different stages of development. Moreover, it is to be conducted in the conditions of a limited amount of information on deposits due to insufficient volumes of field research of organizational and financial nature reasons; as well as in case of changing the tactics and strategies of enterprises in market conditions.

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