Atlantis Highlights in Material Sciences and Technology (AHMST), volume 1
International Symposium "Engineering and Earth Sciences: Applied and Fundamental Research" (ISEES 2019)

Estimation of The Wells Hydrodynamic Drag Level Based on Wells Geophysical Survey Data

Kuleshova L.S.
Department of Oil and Gas Field Exploration and Development
Ufa State Petroleum Technological University,
Branch of the University in the City of Oktyabrsky
Oktyabrsky, Republic of Bashkortostan, Russia
markl212@mail.ru

Mukhametshin V.V.
Department of Oil and Gas &Oil Field Development and Operation
Ufa State Petroleum Technological University
Ufa, Republic of Bashkortostan, Russia
vv@of.ugntu.ru

Abstract — **Based on the generalization of different groups of fields of the terrigenous strata of the lower Cretaceous age of Western Siberia flooding experience, models are obtained that allow to assess the degree of hydrodynamic interaction of producing and injection wells, reflected by the maximum value of the cross-correlation function determined by analyzing the time series of production and injection wells. An algorithm for predicting the values of the cross-correlation function using the geophysical studies of wells and distances between wells data is proposed. It also allows making justifiable management decisions when choosing measures to identify and improve flooding systems in different geological conditions of objects.**

Keywords — production and injection wells; cross-correlation function; flooding; geological-statistical modeling; correlation.

I. INTRODUCTION

The analysis of the studies results presented in the works [1-9] showed that the efficiency of the process of oil displacement by water is largely determined by the degree and nature of the interaction of producing and injection wells.

After the deposits are put into operation, the degree of hydrodynamic interaction is determined by hydrodynamic, flowmetric and tracer studies. However, to determine the objects development strategies it is important to know how the wells will interact already at the stage of field withdrawal from exploration. It will allow to reasonably choose the density of the well grid and the system of their location and to determine the parameters of injection that largely determines the efficiency of flooding and, as a consequence, – the efficiency of development as a whole. I. e. at the stage of fields input in development there has to be a complex of algorithms that allow carrying out diagnostics of the size characterizing hydrodynamic interaction on indirect data at various values of distances between production and injection wells, pressures and volumes of injection in water layer on sites with various geological structure.

II. METHODS AND MATERIALS

In the process of developing oil production facilities, there is often a lack of representative material based on hydrodynamic and other direct methods of well and reservoir studies, due to financial and organizational reasons. This does not allow justifying decisions aimed at improving the process of deposits flooding and requires the creation of methods that allow carrying out this justification, the purpose of which is to increase the efficiency of development. Moreover, the methods should be based on the use of current field-geological information available. Some issues of solving this important problem of decisions substantiation based on current information from specific fields were considered in works [10-13]. However, the use of these results in other fields requires justification and adaptation.

III. RESULTS

When selecting water injection sources, it is important to know not only whether the producing wells will react to water injection, but also the degree of this response, since the well flow rates and the possibility of regulating the process of oil reserves production depend on this. The knowledge of the response degree is of particular importance for idle and transit well stocks.

In both cases, the absence of time series of discharge and injection makes estimation of the interaction degree based on the use of the cross-correlation function (CCF) impossible and requires the creation of a method for forecasting the maximum values of cross-correlation functions. One of such ways is to study the influence of these geophysical studies of wells on the CCF value and to create a predictive algorithm with the use of these indirect data.

The influence of thickness and reservoir properties of the reservoir in the producing and injection wells, as well as the distances between them (F) on the change in the maximum values of the cross-correlation functions for R $\geq$ 0.5 was studied, i.e. the producing wells that are affected by the injection of water into the reservoir were investigated.

The pair correlation conducted on the basis of different function types exhaustive search yielded the following best regression equations for wells of group 2 objects identified in [14] on the basis of the West Siberian oil and gas province Lower Cretaceous deposits grouping:

$$R = 0{,}588 + 3{,}09 \cdot 10^{-3} \cdot H^{P}_{gross} \quad (r = 0{,}061); \qquad (1)$$

Copyright © 2019, the Authors. Published by Atlantis Press.
This is an open access article under the CC BY-NC license (http://creativecommons.org/licenses/by-nc/4.0/).

$$R = 0,549 + 1,38 \cdot 10^{-2} H^{P}_{perf} \quad (r = 0,149); \quad (2)$$

$$R = e^{-0,702+4,28 \cdot 10^{-2} H^{P}_{net}} \quad (r = 0,281); \quad (3)$$

$$R = 0,731 - 0,232 / H^{P}_{s} \quad (r = 0,312); \quad (4)$$

$$R = 0,625 - 5,02 \cdot 10^{-3} n^{P} \quad (r = 0,05); \quad (5)$$

$$R = 0,390 + 0,01 m^{P} \quad (r = 0,031); \quad (6)$$

$$R = e^{-0,696+4,36 \cdot 10^{-4} K^{P}_{pr}} \quad (r = 0,647); \quad (7)$$

$$R = e^{-1,123+0,876 \alpha^{Д}_{ПС}}, \quad (r = 0,594); \quad (8)$$

$$R = 0,483 + 1,63 \cdot 10^{-2} \rho^{P}_{IL} \quad (r = 0,486); \quad (9)$$

$$R = 0,540 + 1,09 / M^{P}_{LL} \quad (r = 0,289); \quad (10)$$

$$R = 0,455 + 3,04 \cdot 10^{-3} K^{P}_{I} \quad (r = 0,162); \quad (11)$$

$$R = 0,519 + 9,2 \cdot 10^{-3} H^{I}_{gross} \quad (r = 0,231); \quad (12)$$

$$R = 0,539 + 1,07 \cdot 10^{-2} H^{I}_{perf} \quad (r = 0,351); \quad (13)$$

$$R = 0,683 - 0,324 / H^{I}_{net} \quad (r = 0,202); \quad (14)$$

$$R = 0,704 - 0,159 / H^{I}_{s} \quad (r = 0,247); \quad (15)$$

$$R = 0,628 - 3,24 \cdot 10^{-2} / n^{I} \quad (r = 0,259); \quad (16)$$

$$R = 0,181 + 9,69 / m^{I} \quad (r = 0,121); \quad (17)$$

$$R = e^{-0,67+3,41 \cdot 10^{-4} K^{I}_{pr}} \quad (r = 0,492); \quad (18)$$

$$R = e^{-0,841+0,484 \alpha^{Н}_{ПС}}, \quad (r = 0,918); \quad (19)$$

$$R = 0,716 - 0,648 / \rho^{I}_{IL} \quad (r = 0,306); \quad (20)$$

$$R = 0,494 + 1,77 / M^{I}_{LL} \quad (r = 0,192); \quad (21)$$

$$R = 0,588 + 5,34 \cdot 10^{-4} K^{I}_{s} \quad (r = 0,239); \quad (22)$$

$$R = 0,476 + 2 \cdot 10^{-4} F. \quad (r = 0,047); \quad (23)$$

where as the independent variables influencing successfulness were considered respectively in producing and injection wells:

- gross ($H^{P}_{gross}, H^{I}_{gross}$ (m)), perforate (H^{P}_{perf}, H^{I}_{perf} (m)), net oil (H^{P}_{net}, H^{I}_{net} (m)) pays of zone;
- average (H^{P}_{l}, H^{I}_{l} (m)) of oil-saturated interlayers pay;
- number of oil-saturated interlayers (n^{P}, n^{I});
- gross sand (K^{P}_{s}, K^{I}_{s}), conductivity (K^{P}_{gross}, K^{I}_{cond} (10^{-3} μm^{2})), void structure (m^{P}, m^{I} (%)), oil saturation (K^{P}_{O}, K^{I}_{O} (%)) coefficients;
- spontaneous potential reduction factor (α^{P}_{SP}, α^{I}_{SP});
- induction ($\rho^{P}_{IL}, \rho^{I}_{IL}$ (Ωm)), 2 meter sonde ($\rho^{P}_{2,25}, \rho^{I}_{2,25}$ (Ωm)), lateral logging layer (M^{P}_{LL}, M^{I}_{LL} (Ωm)) resistance;
- distance between production and injection wells (F, m).

Other parameters were not considered due to either the absence of their multiple determination or small intervals of their change.

The correspondences obtained show that the better reservoir properties of the reservoir in both injection and production wells are, the greater the value of cross-correlation functions are. Significant are the relations of cross-correlation functions values and permeability coefficient, spontaneous potential reduction factor, induction logging layer resistance in the production wells, as well as their relations with permeability coefficient and spontaneous potential reduction factor in the injection wells. However, insufficiently high values of correlation coefficients and significant inaccuracies do not allow using the obtained dependences as reference ones for predicting cross-correlation functions from indirect geophysical data. In this regard, geological and statistical modeling with the use of multivariate regression analysis was carried out.

As a result, the following model is obtained:

$$R = 1,070 + 0,0003K^{P}_{cond} - 0,009M^{P}_{LL} + 0,010H^{I}_{gross} + 0,010H^{I}_{net} + 0,044H^{I}_{s} - 0,024m^{I} - 0,036\rho^{I}_{IL} + 0,004K^{I}_{s} - 0,0002F. \quad (r = 0,929) \quad (24)$$

The pair correlation conducted on the basis of function exhaustive search in conditions of group 7 objects [14] yielded the following best regression equation:

$$R = 0,73 - 0,25 / H^{P}_{gross} \quad (r = 0,07); \quad (25)$$

$$R = 0,59 + 0,015 H^{P}_{perf} \quad (r = 0,27); \quad (26)$$

$$R = 0,56 + 0,002 H^{P}_{perf} \quad (r = 0,29); \quad (27)$$

$$R = 0,69 - 0,02 \ln n^{P} \quad (r = 0,42); \quad (28)$$

$$R = 0,77 - 0,25 / H^{P}_{s} \quad (r = 0,44); \quad (29)$$

$$R = e^{-1,57+0,057 m^{Д}}, \quad (r = 0,08); \quad (30)$$

$$R = 0,34 + 0,067 \ln K^{P}_{pr} \quad (r = 0,48); \quad (31)$$

$$R = 0,26 + 0,47 \alpha^{P}_{SP} \quad (r = 0,40); \quad (32)$$

$$R = 0,30 + 0,14 \ln \rho^{P}_{IL} \quad (r = 0,33); \quad (33)$$

$$R = 0,16 + 0,17 \ln M^{P}_{LL} \quad (r = 0,42); \quad (34)$$

$$R = 0,90 - 13,1 / K^{P}_{s} \quad (r = 0,36); \quad (35)$$

$$R = 0,45 + 0,12 \ln H^{I}_{gross} \quad (r = 0,34); \quad (36)$$

$$R = 0,48 + 0,11 \ln H^{I}_{net} \quad (r = 0,43); \quad (37)$$

$$R = 0,58 + 0,02 H^{I}_{s} \quad (r = 0,47); \quad (38)$$

$$R = 0,68 + 0,003\,n^I \quad (r = 0,40); \quad (39)$$

$$R = 1,23 - 11,45\,/\,m^I \quad (r = 0,02); \quad (40)$$

$$R = 0,75 - 12,1\,/\,K^I_{pf} \quad (r = 0,29); \quad (41)$$

$$R = 0,91 - 0,21\,/\,\alpha^I_{SP} \quad (r = 0,28); \quad (42)$$

$$R = 0,44 + 0,095\ln \rho^I_{IL} \quad (r = 0,12); \quad (43)$$

$$R = 0,81 - 2,37\,/\,M^I_{LL} \quad (r = 0,37); \quad (44)$$

$$R = 0,46 + 0,004\,K^I_I \quad (r = 0,31); \quad (45)$$

$$R = 0,05 + 6,3 \cdot 10^{-5} F, \quad (r = 0,05). \quad (46)$$

The equations obtained show that, like in the conditions of group 2 objects, the better reservoir properties of the reservoir in both injection and production wells are, the greater the value of cross-correlation functions are. However, the degree of this influence is different, so as the set of geophysical parameters. Significant are the relations of cross-correlation functions values and average thickness of oil-saturated interlayers, their number, permeability coefficient, spontaneous potential reduction factor, induction and lateral logging layer resistance, production wells hydrocarbon saturation coefficient, as well as their relations with total and effective oil-filled thicknesses, the average thickness of oil-saturated interlayers, their number and the lateral logging layer resistance in the injection wells.

Similar to the previous group of objects, insufficiently high values of correlation coefficients do not allow using the obtained dependences as reference ones for predicting cross-correlation functions from indirect data. Therefore, the following multivariate model is proposed for practical use:

$$R = -0.138 - 0.0084H^I_{gross} - 0.020H^P_{perf} + \\ +0.030H^P_{net} + 0.038m^P + 0.0115H^I_{net} + 0.0087\rho^I_{IL} - \\ -0.0003F. \quad (r = 0,821) \quad (47)$$

IV. Conclusion

The cross-correlation functions maximum values prediction algorithm for the conditions of different groups of objects in terrigenous reservoirs of Western Siberia on the basis of the constructed models are proposed. Their purpose is to make the decisions of determining the modes of production and injection informed and to apply the methods of influence on the bottom-hole zone and layer using the data of geological and geophysical studies of wells. The physical interpretation of the obtained models is given. The parameters that have a predominant influence on the values of cross-correlation functions are revealed. It is established that the degree of wells interaction in the conditions of different objects and their groups is influenced by different sets of geological parameters that must be taken into account when solving problems of improving the development efficiency.

References

[1] V. Alvarado, G. Thyne, G.R. Murrell, "Screening Strategy for Chemical Enhanced Oil Recovery in Wyoming Basin", pp. 1–14, 2008 [SPE Annual Technical Conference and Exhibition]. DOI: 10.2118/115940-MS

[2] R.F. Yakupov, V.Sh. Mukhametshin, K.T. Tyncherov, "Filtration model of oil coning in a bottom water-drive reservoir", Periodico Tche Quimica, vol. 15, no. 30, pp. 725–733, 2018.

[3] Norwegian Petroleum Directorate, Ch. 4: Recovery of oil, The petroleum resources on the Norwegian continental shelf. Stavanger, Norwegian: Norway Petroleum Directorate, 2005, pp. 30–37.

[4] V.V. Mukhametshin, "Efficiency estimation of nanotechnologies applied in constructed wells to accelerate field development", Nanotechnologies in Construction, vol. 10, no. 1, pp. 113–131, 2018. DOI: 10.15828/2075-8545-2018-10-1-113-131.

[5] J.O. Kay, Why our goals are best achieved indirectly. New York: Penguin Books, 2010, 228 p.

[6] R.R. Kadyrov, L.S. Kuleshova, I.G. Fattakhov, "Technologies and technical devices for annual regulated flooding of a productive strata, Advances in Engineering Research (AER)", vol. 157, pp. 232–235, 2018 [International conference "Actual issues of mechanical engineering" (AIME 2018)]. DOI: 10.2991/aime-18.2018.45

[7] D. Beliveau, "Waterflooding Viscous Oil Reservoirs", pp. 1–13, 2008 [SPE Indian Oil and Gas Technical Conference and Exhibition]. DOI: 10.2118/113132-MS

[8] N.Sh. Khayredinov, A.M. Popov, V.Sh. Mukhametshin, "Increasing the flooding efficiency of poor-producing oil deposits in carbonate collectors", Oil industry, no. 9, pp. 18–20, 1992.

[9] R.W. Watson, F.H. Boukadi, "Effect of surface area and pore-size distribution on oil recovery at breakthrough, oil recovery at floodout, residual oil saturation, and wettability (Paper SCA 9007)", 1990, Proceedings of the Society of Core Analysts [Fourth Annual Technical Conference].

[10] Yu.V. Zeigman, V.Sh. Mukhametshin, V.V. Sergeev, F.S. Kinzyabaev, "Experimental study of viscosity properties of emulsion system with SiO_2 nanoparticles", Nanotehnologies in Construction, vol. 9, no. 2, pp. 16–38, 2017. DOI: 10.15828/2075-8545-2017-9-2-16-38.

[11] V.V. Mukhametshin, V.E. Andreev, "Increasing the efficiency of assessing the performance of techniques aimed at expanding the use of resource potential of oilfields with hard-to-recover reserves", Bulletin of the Tomsk Polytechnic University, Geo Assets Engineering, vol. 329, no. 8, pp. 30–36, 2018.

[12] M.M. Kulkarni, Chen Hung-Lung, A.C. Brummert, "CO_2 IOR Evaluation for the U.S. Rocky Mountain Assets", pp. 13, 2008. [SPE Symposium on Improved Oil Recovery]. DOI: 10.2118/113297-MS

[13] V.Sh. Mukhametshin, "Dependence of crude-oil recovery on the well spacing density during development of low-producing carbonate deposits", Oil Industry, no. 12, pp. 26–29, 1989.

[14] V.V. Mukhametshin, "Rationale for trends in increasing oil reserves depletion in Western Siberia cretaceous deposits based on targets identification", Bulletin of the Tomsk Polytechnic University, Geo Assets Engineering, vol. 329, no. 5, pp. 117–124, 2018.