Express method of injection well treatment

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***Abstract*−During water injection in the bottomhole zone, except corrosion products, which are the main plugging agent, mechanical particles containing in the injected water are collected. They form a sediment that pollutes the filtration channels of the formation, gradually reducing the absorption capacity of the injection well. In order to inject as much water into the formation as it's possible during the planning period, it is necessary to carry out repairs in a well with the help of one-time mud-pulse treatments. The introduction of this express method of treatment allowed reducing the material costs significantly and maintaining a stable level of injection and a stable coefficient of selection.**

Keywords−overhaul period; injection capacity; water injection well; treatment; repair

I. INTRODUCTION

When flooding production zone, built up by tight sandstones, the bottom-hole zone of injection wells is grouted with mechanical impurities brought into the formation by injected water within definite time. As a consequence, the injection wells gradually reduce the injection capacity, which adversely affects the injection balance. To restore the injection capacity of a well, the following methods are used: drained acid formation treatment, hydraulic fracturing, hydraulic acid treatment without sand cracks fixing, thermal treatment of formation, mud-pulse one-time treatment, draw-down pressure, shot-firing operations, etc [1-13].

However, it should be noted that these technical measures are very hard and expensive for implementing. Performing of these works for a long time causes a continuous cease of water injection and withdrawal of a significant amount of previously injected water from the reservoir.

II. MATERIALS AND METHODS

At the Stakhanovskoye field of the NGDU «Oktyabrskneft», NK «Bashneft», to restore the injection capacity of wells, which were for a long time under injection, one-time mud-pulse bottomhole treatments were performed (Table 1) [1]. After acidizing job, without reducing the pressure at the wellhead, water injection through the water pipe is immediately resumed, which allows processed products to be taken to a remote zone of the formation. A similar technology for water-injection well repairing was also used in the oil fields of OAO «Tatnefteprom». However, the analysis of the data obtained showed that these treatments cannot be carried out indefinitely, since the efficiency of subsequent treatments is usually reduced (Table 1).

During water injection in the bottomhole zone, in addition to corrosion products, which are the main sealing agent, mechanical particles in the injected water accumulate. They form residue that pollutes the filtration channels of the formation, gradually reducing the absorbing capacity of the injection well.

To determine the maximum water injection into the formation during mud-pulse treatments in the period between two well repairs and the number of repairs, let's assume that the first repair of the injection well was carried out at the beginning of the considered period *T*. After repair, it was put into operation with an initial injection capacity q_0, cub. m/day. Subsequently, its injection capacity fell according to the law: [2]

$$q = q_0 \cdot e^{\frac{t}{t_0} \ln \beta}, \qquad (1)$$

where t− well operation time during the time between overhauls, a day;

t_0−time, during which well injection capacity becomes equal to $\beta \cdot q_0$ (according to the field data), a day;

β – the relation of well injection capacity in the moment t_0 to the injection capacity q_0.

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TABLE I. THE APPLICATION OUTCOMES OF ONE-TIME MUD-PULSE TREATMENTS IN THE INJECTION WELLS OF THE FIELDS OF OAO "TATNEFTEPROM"

Well number	Injection capacity before treatment, cub. m/day	Injection pressure, MPa	Injection capacity before treatment in (cub. m/day)		
			10 natural days	20 natural days	30 natural days
6513	120	8	260	240	210
6646	80	8	190	180	160
6780	110	8	220	200	185
7223	50	8	110	100	65
7704	60	8	140	135	110
7821	90	8	230	235	210
8432	65	8	180	170	150
8640	85	8	145	140	130
8784	105	8	280	220	200
9629	75	8	170	160	130

In order to inject the most possible quantity of water during the target period *T*, it is necessary to conduct the repair in a well with the help of one-time mud-pulse treatments. It is known that it is possible to conduct not more N treatment in a well during the target period *T*. Suppose that after each j treatment in the bottomhole zone the well injection capacity is defined by: [2]

$$q_{oj} = a + bt_j , \tag{2}$$

where multiplying factors a and b should be defined providing that:

$$q_{oj} = q_0 \text{ at } t_j = \tau ; \; q_{oj} = \alpha q_0 \text{ at } t_j = t_k , \tag{3}$$

where τ–time of repair, a day;

t_k – time at which the proportionality factor a is defined, a day.

III. RESULTS AND DISCUSSIONS

It is necessary to determine how many repairs it is necessary to carry out in the well in order to pump the maximum possible amount of water into the reservoir during the target period *T*.

In this case, the mathematical problem comes down to determining of the total injection: [3]

$$V = n \left\{ \begin{array}{l} -\dfrac{q_0 \cdot t_0}{\ln \beta}\left[1 + m\left(\dfrac{t_k - \alpha \cdot \tau}{t_k - \tau} - \dfrac{1-\alpha}{t_k - \tau}\left(\dfrac{\tau + t_p}{2}\right)\right)\right] \times \\ \times \left(1 - e^{\frac{t_p \cdot \ln \beta}{(m+1)t_0}}\right) - q_0 \cdot \tau \end{array} \right\} \tag{4}$$

under conditions:

$$n(t_p + \tau) = T , \tag{5}$$

$$n(\upsilon + m) \le N , \tag{6}$$

where *n*- is the number of repairs;

t_p - overhaul period of the well performance, a day;

m- is the number of one-time mud-pulse treatments that can be carried out during a single overhaul period t_p;

υ- is the total number of one-time mud-pulse treatments.

If we assume that the total expenditures for all repairs and mud-pulse treatments should not exceed *S* dollars, then the solution of the problem can be limited to one more condition [3]:

$$n(C_p + mC_n) \le S , \tag{7}$$

where C_p, C_n– one repair and one-time mud-pulse treatment cost, dollar.

In this case the problem reduces to determining the maximum of the function (4), but under the conditions (5), (6) and (7).

Suppose that it is necessary to determine how many repairs and mud-pulse treatments should be carried out in each of M injection wells of the oil field, in order to make the total water injection maximum. Presuming that the problem formulated above is valid for the well *i* of the group under consideration, so the mathematical problem for this group reduces to determining the maximum of the total problem [3]

$$\sigma = \sum_{i=1}^{M} V_i = \sum_{i=1}^{M} \left\{ \begin{array}{l} \dfrac{q_{oi} t_{oi}}{\ln \beta}\left[1 + m_i\left(\dfrac{t_{ki} - \alpha \cdot \tau_i}{t_{ki} - \tau_i} - \dfrac{1-\alpha_i}{t_{ki} - \tau_i}\dfrac{t_{pi}}{2}\right)\right] \times \\ \times \left(1 - e^{\frac{t_{pi} \cdot \ln \beta_i}{(m_i+1)t_{oi}}}\right) - q_{oi}\tau_i \end{array} \right\} n_i , \tag{8}$$

under conditions:

$$n_i\left(t_{pi} + \tau_i\right) = T \ , \quad i=1,2,3,\ldots,M; \qquad (9)$$

$$\sum_{i=1}^{M} n_i(\upsilon_i + m_i) \le N \ ; \qquad (10)$$

$$\sum_{i=1}^{M} n_i(C_{pi} + m_i C_{ki}) \le S \qquad (11)$$

Calculation data for determining the total water injection into the well 9629 (Table 2) allowed graphically (Figure1) to study the limits and boundaries of the optimal conditions selection (area) of one-time mud-pulse treatments.

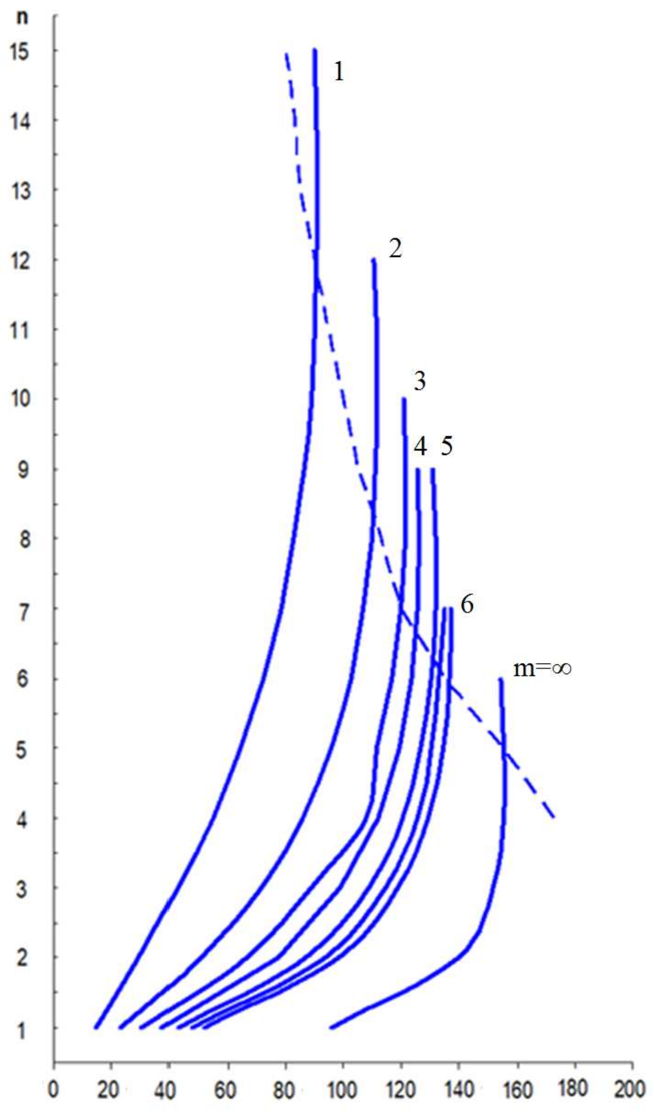

Fig. 1. Graphic charts of the total fluid injection V = f (n, m) for the injection well 9629.

IV. CONCLUSION

1. The parabolical arrangement of the curves $V = f\ (n,\ m)$ makes it possible to distinguish the area of optimal conditions for the use of one-time mud-pulse treatments.

2. The area of optimal conditions (Figure 1, dotted graph) expresses the increase in the number of repairs n with the decrease in the total volume of injected water, while the increase in mud-pulse treatments m leads to a rather noticeable increase in the total water absorption.

3. The maximum total water injection can be achieved by the infinite carrying out of mud-pulse treatments. However, this option (variation) is irrational in conditions of a considerable length of water lines, because corrosion products along the entire length of the pipelines will be injected to the bottomhole zone.

4. The best conditions for maintaining the stable operation processes of the studied injection wells are shown at m=5 and n=7, resulting in the total water injection of 134985 m^3. The same cannot be said for those optimum points, which are located above and below the selected point of the injection well operating mode. This is explained by the following:

- the low points of optima on parabolic curves tend to decrease the total injection;

- the upper point obtained when $m = \infty$ is certainly the most advantageous theoretically, but it is very difficult to achieve it practically.

Therefore, the most advantageous regime should be considered as one that can be achieved in the zone of approximation of the value m to the conditions of infinity. Such a regime, as can be seen from Figure 1, to the greatest extent meets the point at which $m = 5$, since the difference between the values V at points $m = \infty$ and $m = 5$ is calculated with a tenuous limit of 20756 m^3.

5. A similar problem was considered for groups of simultaneously operating injection wells.

6. The use of one-time mud-pulse treatments by express method made it possible to reduce material expenses significantly and maintain a stable level of injection and a percent of oil recovery, which enabled only with 16 treatments to save about $ 45.000.

TABLE II. TOTAL INJECTION (M^3) ACCORDING TO CALCULATIONS FOR THE WELL 9629 (OAO "TATNEFTEPROM")

Number of repairs, *n*	Number of mud-pulse treatments, *m*							Acid water injecting, m^3
	0	1	2	3	4	5	6	
1	14646	22790	30442	37090	42930	47540	51919	95 998
2	29199	50691	66629	77609	86700	93572	98375	140 037
3	42866	71565	89200	98766	108686	114799	119019	151 783
4	54772	86030	108078	112226	120405	125682	129228	155 475
5	64539	95947	111644	119452	126936	130548	134388	155 741
6	72313	102560	116858	123421	130303	133106	136635	154 509
7	78320	107041	119952	125409	131679	134985	137221	-
8	82904	109764	121363	125981	131747	134685	136587	-
9	86207	111192	121618	125568	131008	133454	134256	-
10	88750	111639	121164	124386	129508	131738	133245	-
11	90234	111461	119560	122875	127498	129940	130719	-
12	90812	110661	118286	120741	125123	126931	128202	-
13	91294	109306	116276	119051	122464	124139	125246	-
14	90663	107620	114241	115717	119621	121110	122082	-
15	89889	105530	111657	112719	116531	117877	118745	-

References

[1] M. Ya. Habibullin and D. I. Sidorkin, "Determination of Tubing String Vibration Parameters under Pulsed Injection of Fluids into the Well," SOCAR Proceedings, vol. 3, pp.27-32, 2016. https://doi.org/10.5510/ogp20160300285

[2] M. Ya. Khabibullin, R. I. Suleimanov, D. I. Sidorkin and I G. Arslanov, "Parameters of Damping of Vibrations of Tubing String in the Operation of Bottomhole Pulse Devices," Chem Petrol Eng, vol. 53, pp. 378-384, 2017. https://doi.org/10.1007/s10556-017-0350-6

[3] Korn G A, Korn T M. Mathematical Handbook for Scientists and Engineers: Definitions, Theorems, and Formulas for Reference and Review. Moscow: Nauka, 1984.

[4] R.M. Shaidullina, A.F. Amirov, V.S. Muhametshin and K.T. Tyncherov, "Designing economic socialization system in the educational process of technological university," European Journal of Contemporary Education, Vol. 6 (1), pp. 149-158, 2017. DOI: 10.13187/ejced.2017.1.1494

[5] N.Y. Golovina, L.G. Akhmetov, A.N. Vikharev and I.G. Arslanov, "Analysis on compressor blading conditions of helicopter's gas-Turbine engine working in polluted environment," International Journal of Applied Engineering Research, vol. 12, pp. 293-296, 2017

[6] G.R. Igtisamova and N.O. Kovalev "Reliability evaluation for improved screw dies of coiled tubing unit injector," Tribology in Industry, vol. 39, pp. 45-49, 2017.

[7] M.V. Goryunova, L.S. Kuleshova and A.I. Khakimova, "Application of signal analysis for diagnostics," International Conference on Industrial Engineering, Applications and Manufacturing (ICIEAM) (Saint Petersburg, 16-19 May 2017), SPb.: IEEE, 2017. DOI: 10.1109/ICIEAM.2017.8076487

[8] 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

[9] K.T. Tyncherov, V.Sh. Mukhametshin and L.B. Khuzina, "Method to Control and Correct Telemetry Well Information in the Basis of Residue Number System," Journal of Fundamental and Applied Sciences, vol. 9, no. (2S), pp. 1370-1374, 2017. DOI: 10.4314/jfas.v9i2s.848

[10] G.A. Teptereva, G.V. Konesev, R.A. Ismakov, E.A. Kantor and T.D. Dikhtyar, "Obtaining drill reagents by modification of neutral-sulphite alkali phosphonic compounds," Bulletin of the Tomsk Polytechnic University, Geo Assets Engineering, vol. 328, pp. 94-101, 2017.

[11] L.A. Kovaleva, R.Z. Minnigalimov, R.R. Zinnatullin, V.N. Blagochinnov and A.I. Mullayanov, "Study of integrated effects microwave electromagnetic radiation in the field of centrifugal forces on the water-oil emulsion," Neftyanoe Khozyaystvo - Oil Industry, vol.2, pp. 100-102, 2017.

[12] A. Davletbaev, V. Kireev, L. Kovaleva, A. Zainullin, R. Minnigalimov, "Cold heavy oil production and production by radio-frequency electromagnetic radiation: Comparative numerical study," AIP Conference Proceedings International Conference of Computational Methods in Sciences and Engineering, ICCMSE 2016, vol. 1790, pp. 150021, 2016.

V.N. Polyakov, Yu.V. Zeigman, Yu.A. Kotenev, V.V. Mukhametshin, Sh.Kh. Sultanov and A.P. Chizhov, "System solution for technological problems of well construction completion," Nanotechnologies in Construction, vol. 10, no. 1, pp. 72–87, 2018. DOI: 10.15828/2075-8545-2018-10-1-72-87