Modeling and mathematical evaluation of sidetracked wells operation in Tuymazy oil field

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Abstract. In order to extract residual oil in the Tuymazy Oil Field, sidetracks were drilled from wells that fell out of use to reservoir zones where oil reserves are not yet developed. Enhanced oil field’s recovery is an urgent problem, the solution of which will affect the efficiency of geological exploration production, oil production and the region’s economic potential.

1. Introduction

One of the promising ways to enhance the efficiency and quality of work on the extraction of hard-to-recover residual oil reserves at the late and final stages of the hydrocarbon reserves’ development is the development and introduction of new technologies and technical means for their application.

The success of measures for the oil production’ intensification depends largely on the correct choice of measures’ targets. When choosing and planning a geological-technical measure, it is necessary to determine the micro-heterogeneity of the reservoir layer. Classifying of rocks by structural and textural properties and mineralogical composition, finding the relationships of the main rocks with productivity, allows us to take into account the variability of poroperm layer characteristics of the reservoir when selecting the target based on laboratory research of cores and analysis of geophysical and field material. Monitoring of the experiment to improve oil recovery in field conditions includes a set of methods, which usually consists of two parts. First, the analysis of the technological indicators of the well (flow rate of oil, water, fluid, the percentage of water in the product); secondly, the interpretation of the results of hydrodynamic studies in the well [1-3].

In recent years in order to extract residual oil in the Tuymazy oil field, sidetracks have been drilled from wells that fell out of use to reservoir zones where oil reserves have not yet been developed. Enhanced oil recovery of oil fields is an urgent problem, the solution of which will affect the efficiency of geological exploration production, oil production and the region’s economic potential.

The geological structure of the Tuymazy oil field includes the rocks of the crystalline basement of the Proterozoic group of the Riphean system and deposits of the Devonian, Carboniferous, and Permian systems and modern sediments of the sedimentary cover. The section is mainly represented by carbonate limestone sediments, dolomite, marl. Terrigenous sandstone rocks, sands, siltstones, mudstones, clays and hydrochemical gypsum, and anhydrites are of secondary importance. The
geological section of the field is typical for the platform part of Bashkiria. The section is opened by wells to the crystalline basement [4].

The total open thickness of the section is over 2,200 m. The Devonian system is represented by the middle (D2) and upper (D3) sections. The total thickness of sediments of the Devonian system varies from 310 to 450 m. The carbonate rocks predominate in the section. The thickness of the section’s terrigenous part ranges from 115 to 156 m.

Oil signs of industrial significance were found in the carbonate rocks of the Famensky stage. Productive sediments are limestone. The deposits are structural-lithological. The deposits’ mode of operation can be considered as a depletion mode. The average thickness of the reservoir is 18 m. The average porosity is 3%. [5] The average permeability is 0.25 μm2. Twenty-three deposits have been identified in the Upper-Famennian substage sediments, which are structural-lithological. The initial reservoir pressure is 13.76 MPa. The deposits are developed with the maintenance of reservoir pressure.

Tuymazy oil field is a multihorizon field. Currently, the DI, DII, DIII, DIV layers, the Bobrikovsky sandstones, the limestones of the Verkhneamensky substage and the Tournaisian stage are being exploited.

Characteristics of productive layers and objects are presented in table 1.

| Parameter                              | DIV   | DIII  | DII   | DI    | D1fm  | Ct   | C1bb |
|----------------------------------------|-------|-------|-------|-------|-------|------|------|
| Depth of burial, m                     | 1680  | 1640  | 1630  | 1600  | 1350  | 1120 | 1100 |
| Type of deposit                        | arch  | arch  | arch  | arch  | reef  | arch |      |
| Reservoir type                         | sand  | Sand  | sand  | sand  | carbonate | carbonate | sand |
| Oil saturated thickness of the layer, m| 2.7   | 2.0   | 9.9   | 5.8   | -     | 3.5  | 2.5  |
| Porosity, (fr.unit)                    | 0.19  | 0.19  | 0.22  | 0.22  | 0.03  | 0.10 | 0.225|
| Permeability, μm2                      | -     | -     | 0.411 | 0.522 | -     | 0.024| 0.676|
| Oil saturation, (fr.unit)              | 0.80  | 0.83  | 0.88  | 0.89  | 0.63  | 0.72 | 0.835|
| Net-to-gross sand ratio                | -     | -     | 0.94  | 0.82  | -     | -   |      |
| Average number of permeable intervals in the section | -     | -     | 1.5   | 1.9   | -     | -   | 1.5  |
| Initial reservoir pressure, MPa        | 18.1  | 17.7  | 17.2  | 17.2  | 14.0  | 12.5 | 12.5 |
| Initial reservoir temperature, °C      | 30    | -     | 30    | 30    | -     | 18-20| 18-20|

The Tuymazy oil field is at the late stage of development. The late stage of development of oil fields has its own features. The main one is the steady decline in oil production. The natural process of waterflooding leads to the flooding of reservoirs and a decrease in oil production in the most productive places and areas of fields. The fall in oil production is not only due to the depletion of reserves in the whole operational facility, but mainly due to changes in the structure of the remaining reserves [6].

The late stage of field development accomplishes two main tasks: ensuring the most complete
development of the waterflooded active oil reserves and beginning of the effective development of hard-to-recover oil reserves. The first of these is achieved mainly through systematic control and regulation of the drainage and water injection, the second is achieved through introducing the recommended methods of developing hard-to-recover reserves [7].

The main operating facilities are DI and DII. The main banks oil reserves of these reservoirs are mainly developed. Residual oil reserves are concentrated in the roof covering of the productive strata and, to a large extent, in the upper banks.

Geological and physical conditions for effective use of sidetracked wells:
- oil deposits with hard-to-recover reserves;
- deposits with reservoirs having natural vertical fracturing or faults;
- layers with high heterogeneity, especially vertically;
- layers with karst or cavernous formations;
- lenticular layers;
- layers with a small thickness;
- layers with uncemented sandstones.

Figure 1. The aim of building sidetrack wells

2. Materials and methods

Mathematicians managed to develop methods for solving problems of finding the largest and smallest value, or, as they are also called, optimization problem (from the Latin “optimum” – the best) [7]. Many problems of finding optimal solutions can only be solved with methods of differential calculus. A number of problems of this type are solved with the help of special linear programming methods, but there are also such extremum problems that are solved by means of elementary mathematics.

The substantive statement of the simulation problem can be made more precise and specific in the process of further model development. If the object of simulation is a technological process, a
machine, a structure or an item, then a substantive statement of the simulation problem is called a technical statement of the problem. Together with the additional requirements for the model implementation and the presentation of the results, a substantive statement of the modeling problem is drawn up in the form of a technical task for designing and developing a model [8].

To increase the reliability of algorithms, a combination of various methods, automatic parametric adjustment of methods, etc. are often used. Ultimately, values of reliability equal to or close to one are achieved. The use of methods, although undesirable, is allowed in certain particular cases, provided that the incorrect decision is recognized and there is no danger of mistaken this decision for the correct one [9].

Tuymazy area, as well as all Tuymazy field is at the 4th (final) stage of development. The stage is characterized by low production levels, due to the development of reserves. Water cut in the product is more than 90%. Stabilization of production is ensured by measures taken in wells to reduce watering and to involve residual reserves. One of these measures is the sidetrack drilling.

As for sidetracking, mainly, wells withdraw from development due to a high water cut in production wells and inefficient injection into injection wells. A significant part of the wells is not suitable for further use due to corrosion and destruction of casing [10, 11].

On the main objects of the Tuymazinsky field, the oil-and-water factor from the beginning of the development: DI = 2.3 t/t, DII = 2.2 t/t, DIII = 2.3 t/t, C1bb = 3.6 t/t, C1kz = 1.3 t/t. Along with the oil, from the start of development, about 1.2 million m3 of water was produced in the Tuymazy oil field.

| Figures                                       | I Year | II Year | III Year |
|-----------------------------------------------|--------|---------|----------|
| Oil production, ths. tons                     | 695.9  | 691     | 691.1    |
| Water cut, %                                  | 89.3   | 89.1    | 89       |
| Oil production rate, t/day                    | 1.6    | 1.5     | 1.5      |
| Gas collection, mm m³                         | 21.35  | 21.39   | 20.42    |
| Oil well operation stock                      | 1277   | 1316    | 1350     |
| Oil well operation stock exploitation rate    | 0.962  | 0.953   | 0.954    |
| Oil well operation stock utilization rate     | 0.894  | 0.892   | 0.898    |

At the Tuymazy oil field, the task of maintaining the current values of profitable oil production in conditions when the current oil recovery factors approach the design ones and the production water-cut exceeds 90% becomes urgent.

This problem is partially solved through the use of enhanced oil recovery methods. For example, at the Tuymazy oil field, at various times, such methods as hydraulic fracturing, injection of zeolite, complex sediment-gel-forming compositions, acid treatments, hydrodynamic methods of enhanced oil recovery and others were used. Lately a method of sidetrack drilling is being used.

Let us consider, using the example of the Tuymazy oil field, the effectiveness of the SW drilling. During the study period, 38 SW were drilled. Over the past year, 19 % of oil production fell on wells with sidetracks. [7] Wherein the share of wells with SW in the operating well stock of the field is 11.2 % [12].

Sidetracking is carried out from old wells by cutting a “window” in the production string, as well as by milling a portion of the string, or by lifting the uncemented top of the string. In the Tuymazy oil field, when sidetracking is cut, part of the column is milled (from 8 to 20 m), followed by the installation of a cement bridge.

Oil well production rates varied from 0.7 to 2.7 tons / day, averaging 1.60 tons/day with a water cut of 26.4 %. In total, 48,724 thousand tons of oil was produced on the sidetracks of the Kizel horizon. From each ton of oil 0.5 tons of water is produced.
Currently, within the limits of the Tuymazinsky field, nine major productive objects have been identified, where the sidetracks were drilled: DII and DIV layers in the sediments of the Old Oskol horizon, DII layer in the Mullinian deposits, DI layer in the Pashi deposits, productive layer in the Tournaisian stage, productive stratum in terrigenous sediments of the Lower Carboniferous, in carbonates of the Zavolzhsky and Aleksinian horizons. The choice of implementation objects was based on the reduction of well production rates. In order to develop innovative technologies in the field of exploration and production, as well as in determining the depth of the SW, as well as the direction of drilling, reservoir modeling programs are used, such as “ROXAR RMS”, “PetroInfoComplex”.

3. Results and Discussion
From Table 1 it can be seen that with an intensive increase in the number of operating SW, the annual production of oil and liquids also increases. There is also an increase in wells water production with the development of residual oil reserves in the zones of sidetracks drainage. The water cut in recent years is within 28.9–35 % [5]. The production rate on the liquid is 9.4–14.3 m³ / day. From table 1 it can be seen that all the objects in development have rather high exploitation rates for the SW of terrigenous Devonian deposits: 26 wells produced 326.9 thousand tons of oil, the average daily well flow rate for oil was 6 tons / day. Oil production in the lateral trunk formation “Svv” [6].

Sidetracks are drilled in the Tuymazy oil field to transfer wells to the operation of the overlying horizon, the underlying horizon (recess), the current object with a shift within 25-100 m and a sidetrack length of 80-220 m. Depending on the angle of SW entry into the reservoir several types are distinguished: lateral tracks with a horizontal bottom (lateral horizontal tracks), with a vertical primary opening of the reservoir and with the entry of the SW into the reservoir at a certain zenith angle. Sidetracks are used for the operation of one productive object, and for simultaneous operation when opening several layers.

The use of sidetrack drilling technologies is most appropriate at the late stage of field development due to the fact that by this time a significant part of the main and reserve stocks had already been drilled into operational facilities, and the reserves had not yet been fully developed. At the same time, the value of residual reserves is often so small that drilling new vertical wells is simply unprofitable [13-15].

Side tracks can be used for oil production in most deposits, with the exception of loose, strongly fractured and collapsing rocks, in which even vertical wells are difficult to drill.

4. Conclusion
The aim of building sidetrack wells is:
- enhancing developing object’s oil recovery as a result of drilling the BS and condensing the net of wells;
- increasing the current oil production by restoring the existing amount of wells by drilling SW from inactive unprofitable wells, conserved or eliminated for technical reasons (accidents with downhole equipment, sticking of tubing during cementing);
- involving the higher - and lower-lying productive sediments in the oil deposits’ development; [2]
- increasing in the development rate of lenticular deposits, opened by an insufficient number of wells;
- involving oil deposits in the development, coinciding only partially with the main, almost fully developed ones.

Sidetracking is carried out from old wells by cutting a “window” in the production string, as well as by milling a portion of the string, or by lifting the uncemented top of the string. In the Mikhaylovskoye oil field, when sidetracking is cut, part of the column is milled (from 8 to 20 m), followed by the installation of a cement bridge.

Oil well production rates varied from 0.7 to 2.7 tons / day, averaging 1.60 tons/day with a water cut of 26.4 %. In total, 48,724 thousand tons of oil was produced on the sidetracks of the Kizel horizon. From each ton of oil 0.5 tons of water is produced.
Sidetracking was performed mainly out of wells awaiting liquidation or transferred to the observational stock due to watering. In some of the wells the drilling was performed out of an inactive stock and in seven cases - out of operating producing low-yield wells.

Thus, the growth of the average daily oil production rate in the first years of the method’s implementation is due to the commissioning of sidetracks drilled on the Devonian layers, that have better poroperm characteristics compared to the coal deposits [8]. Subsequently, after the initial, sharp drop, the average oil well production rate varies between 5–4.8 tons / day. As of December 31, 2017, oil production out of 38 sidetracks amounted to 432.9 thousand tons, with an average daily production rate of 5.7 tons / day.

The total oil production by productive layers of coal deposits of 12 drilled lateral shafts for the annual period from the beginning of operation is 94 thousand tons.

References
[1] Safaria A, Dowlatabad M M, Hassani A and Rashidi F 2016 Numerical simulation and X-ray imaging validation of wormhole propagation during acid core-flood experiments in a carbonate gas reservoir J. Nat. Gas Sci. Eng 30(3) 539–47
[2] Nianyin L, Jinxin D, Pingli L, Zhifeng L and Liqiang Zh 2016 Experimental study on influencing factors of acid-fracturing effect for carbonate reservoirs Petroleum 126 146–53
[3] Alvarado V and Manrique E 2010 Enhanced oil recovery: field planning and development strategies (Gulf Professional Publishing)
[4] Akhmetov R T and Mukhametshin V V 2018 Estimation of displacement coefficient with due account for hydrophobization of reservoir using geophysical data of wells IOP Conf. ser. Earth Env. 194(6) 062001
[5] Márton L S, Casper S H, Wei Y, Jens H W and Stefan L G 2018 Near-wellbore modeling of a horizontal well with Computational Fluid Dynamics J. Petrol. Sci. Eng. 160 119–28
[6] Akhmetov R T, Mukhametshin V V, Andreev A V and Sultanov Sh Kh 2017 Some Testing Results of Productive Strata Wettability Index Forecasting Technique SOCAR Proc. 4 83–7
[7] Yamamoto H 1987 Fiber optical sensors and its application Otomesen: Automation 32(5) 31–5
[8] Shen M, Liu S, Zhao W, Qi H and Peng G 2018 Sampled fiber gratings for picosecond time delay signal processing Optics and Laser Technology 105(9) 52–7
[9] Almukhametova E M 2018 Modelling and assessing the effectiveness of developing the Shumovskoye field IOP Conf. ser. Earth and Env. Sci. 194(6) 1–4
[10] Almukhametova E M and Gizetdinov I A 2018 Optimization of FPM system in Barsukovskoye deposit with hydrodynamic modeling and analysis of inter-well interaction J. of Physics: Conf. Ser. 1015 1–4
[11] Andreev A V, Mukhametshin V Sh and Kotenev Yu A 2016 Deposit Productivity Forecast in Carbonate Reservoirs with Hard to Recover Reserves SOCAR Proceedings 3 40–5 DOI: 10.5510/OGP20160300287
[12] Goryunova M V, Kuleshova L S and Khakimova A I 2017 Application of signal analysis for diagnostics IEEE (Int. Conf. on Industr. Engineer., Applicat. and Manufactur. (ICIEAM)) pp 1–5 DOI: 10.1109/ICIEAM.2017.8076487
[13] Grezina O A 2018 Assessment of the results of acid implosion stimulation of the near-wellbore area based on statistical data IOP Conf. ser. Earth and Environmental Sci. 194(8) 1–6
[14] Almukhametova E M, Shamsutdinova G F, Sadvakasov A A, Tyntcherov K T, Petrova L V and Stepanova R R 2018 Modeling development of Fyodorovsky deposit IOP Conf. ser. Mat. Sci. and Engineer. 327(4) DOI: 10.1088/1757-899X/327/4/042100
[15] Tyntcherov K T, Mukhametshin V Sh, Paderin M G, Selivanova M V, Shokurov I V and Almukhametova E M 2018 Thermoacoustic inductor for heavy oil extraction IOP Conf. ser. Mat. Sci. and Engineer. 327(4) 042111 DOI:10.1088/1757-899X/327/4/042111