Justification of impact and planning of technology efficiency on the basis of limy-emulsion formulation in low-permeability highly-rugged reservoirs of Tyumen deposits

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Abstract. Justification of the effective chemical methods and technologies for oil production increase of highly rugged low-productive reservoirs is a relevant area of focus. The primary objective in this area is to justify the selection and planning of technologies of injection of chemical agents for field-geological factors of Tyumen deposits. Tyumen deposits are characterized by a high degree of heterogeneity of the structure and are represented by irregularly discontinuous interlensing of sandstones, aleurolites, clays and coals. High internal heterogeneity of the reservoir determines abnormally low permeability (on the average less than 6 mD) and weak pressure communication in the bed. Due to the complex geological structure there has been an intensive production decline, decreasing of injectivity and initially high water cut of production during well operation. In order to increase the production stimulation and injectivity at the operating wells, more than 50 exposure technologies have been tested. The main scope of work on wells with injectivity less than 120 m³/day is performed by injection of surfactant-containing and emulsion formulations. Factors determining the efficiency of applied technologies in Tyumen deposits were studied. It is necessary not only to consider and compare the achieved efficiency of certain technologies, but also to continue searching for new chemical formulations to increase oil production of highly-rugged low-productive reservoirs. The paper presented an algorithm for analyzing the results of operations conducted at the injection wells.

1. Introduction
Discovering effective chemical methods and technologies for oil production increase of highly rugged low-productive reservoirs is a relevant area of focus. The primary objective in this area is to justify the
selection and planning of technologies for injection of chemical agents for field-geological factors of Tyumen deposits.

2. Materials and methods
The bed US2/1, which is the main object of exploration and development of Tyumen deposits, is characterized by a high degree of heterogeneity of the structure and represented by irregularly discontinuous interlensing of sandstones, aleurolites, clays and coals. High internal heterogeneity of the reservoir determines abnormally low permeability (on the average less than 6 mD) and weak pressure communication in the bed.

Tyumen deposits are being developed at 32 fields within producing well stock of operating wells with about 4 thousand units and injection wells with about 2 thousand units. More than 90 million tons of oil was withdrawn at the productive rate of 10 tons per day and 60% water cut. Due to the complex geological structure of the wells there has been an intensive production decline, decreasing of injectivity and initially high water cut of production during well operation. In order to increase the production stimulation and injectivity at the operating wells, more than 50 exposure technologies have been tested. The main methods among them are refrac, side-tracking method, and pumping equipment optimization. However, it is impossible to maintain the level of production without the organization of an effective system of maintenance of reservoir pressure (MRP), including the use of methods of intensification of well injectivity and increasing oil recovery [1-5].

The main methods of influence on the injection stock are chemical (technologies of injection of chemical agents), aimed at redistribution of filtration flows, increasing the coverage of the reservoir by waterflooding and additional washing of residual oil. Increasing the efficiency of their application requires a detailed, systematic approach to the planning of work with a mandatory assessment of the results already achieved [6-14].

Currently, the main basic technology is the injection of limy-emulsion formulations (LEF). In total, 639 treatments were carried out on wells in different zones of formation structure, development conditions, and in areas with different pressure characteristics of the MRP system. In this way, a sufficient amount of information has been accumulated on LEF injection, which allows to analyze the efficiency of their application in order to develop a reasonable approach to the selection and planning of technologies for injection the emulsion formulations for the field-geological factors of Tyumen deposits. For this purpose, the factors determining the efficiency of the applied technologies on the deposits of Tyumen deposits have been studied [3-9]. The analytical processing included the following steps:

- Consideration of the peculiarities of the impact of injection on the reservoir slugs on the basis of limy emulsion formulations;
- Assessment of LEF injection efficiency;
- Determination of parameters that have the highest impact on the use of LEF on the basis of multifactorial analysis;
- Assessment of the impact of LEF on the injection capacity of well;
- Development of the recommendations to improve the efficiency of the LEF injection technologies;
- Development of areas of work to improve the efficiency of technologies for injection of chemical agents.

3. Results and Discussions
3.1. The peculiarities of the impact of injection on the reservoir slugs on the basis of limy emulsion formulations (LEF).
LEF are used to equalize the conformance control of injection wells regulate waterfloods at the mine sites. The important property of emulsions is the absence of chemical and thermal destruction of the emulsifier in the bed, which causes the preservation of the working properties of the formulation at its deep penetration into the bed. LEF is neutral in relation to corrosion rate, salt deposition rate, development of sulphate reducing bacteria in oilfield equipment. The listed properties determine the
universal application of emulsion formulations to increase the efficiency of development of Tyumen deposits. Geological and physical criteria of the technology application do not exclude the efficiency of its application on low-permeability reservoirs (Table 1).

Table 1. Geological and physical criteria of the technology application (LEF).

| Indicators                                      | Value   |
|------------------------------------------------|---------|
| Initial oil reservoir saturation coefficient, unit fraction | >0.4    |
| Average reservoir permeability at depth of burial > 2500m, μm² | >0.003  |
| Heterogeneity in permeability, 10⁻³              | 3-60    |
| Reservoir temperature, °C                       | 60-100  |
| Permeable oil saturated thickness of reservoir, m | >3      |
| Reservoir injectivity, m³/day                   | >50     |

3.2. Current assessment of LEF injection efficiency

Typically, the technological efficiency of reservoir stimulation techniques is characterized by the volume of additional oil production. However, when performing analytical work to correctly assess the results of the impact on the reservoir through the system of injection wells, it is necessary to consider additional specific parameters of efficiency, allowing to take into account the state and performance of the surrounding production well stock [9-11]. In this paper, additional indicators were introduced and considered. These indicators allow to take into account the impact on the efficiency of the treatment of the condition of the surrounding production well stock (the number and performance of the observation wells):
- the average incremental oil rate of observation wells by treatment;
- the percentage of incremental oil rate of observation wells, determined by comparing the initial average oil rate with the average incremental oil rate by treatment.

Table 2. Key performance indicators in assessing the efficiency of LEF slugs injections

| Indicators                                      | Units of measure | Variation interval | Average value |
|------------------------------------------------|------------------|--------------------|---------------|
| Net oil thickness                              | m                | 2-17               | 8.3           |
| Permeability                                   | mD               | 1-30               | 8.2           |
| Oil saturation                                 | %                | 45-88              | 70            |
| The volume of the slug per one treatment        | m³/well.-treat   | 50 – 307.4         | 130.4         |
| Injectivity of treated injection wells         | m³/day           | 26 – 410           | 107           |
| Specific additional production (SAP)           | th. t / well.-treat | 0.01– 5.0         | 1.4           |
| Duration of effect                             | day              | 28 – 861           | 320           |
| Increase in daily oil production by treatment (ΔQo.day) | t/day           | 0.3 – 17.0         | 4.3           |
| Specific incremental oil rate of the observation well (Δq.o.day) | t/day          | 0.1– 6.9          | 1.1           |
| The percentage of the average incremental oil rate of the observation well (ΔI) | %             | 0.3 –35          | 9.1           |

Table 2 presents the current performance indicators of emulsion treatment of injection wells included in the information database.

As it can be seen from the table, the operations were carried out at wells with injectivity from 26 to 400 m³/day, the volume of the slug varied in a wide range of m³/well.-treat.
3.3. Determination of parameters that have the highest impact on the use of LEF

To determine the most important parameters affecting the efficiency of LEF, a multifactor regression analysis was conducted.

The information was collected by parameter groups: geological, technological and complex. In total, more than 30 parameters were considered.

Based on the results of the multifactor regression analysis, the main parameters affecting the average daily increase in oil production by the area of impact are as follows:
- surface pressure of MRP system;
- operating parameters of the surrounding production wells (daily oil production by area);
- linear reserves of the affected well area characterizing the oil-bearing potential of the affected area;
- specific volume of the slug.

The increasing of slugs efficiency of emulsion formulations is possible by increasing the volume of slug of the injected formulation and increasing the pressure of its penetration with water in accordance with the bed structure. However, the realization of the required pressure for the uniform movement of the limy-emulsion slug is often limited by the pressure characteristics of the sewerage pump station (SPS) equipment and technical characteristics of wellhead equipment with an operating pressure of only 21 mPa.

3.4. Assessment of the impact of LEF injection operations on the injection capacity

Today, when solving the problems of the current state of development of the Tyumen deposits, it is noted that when working on the conformance control according to the existing technologies, the injectivity of wells is reduced. To consider this tendency, the indicator "the Shortness of Change of the Injection Capacity" was introduced in this paper. This indicator is assessed on the basis of direct measurements during the direct performance of operations.

To determine the parameters affecting the injection capacity changes after LEF treatments, a multifactor regression analysis (MRA) was also conducted. According to the results of MRA, the relationship between the injected volume parameters, injection pressure and net oil thickness affect the injectivity reduction.

3.5. Development of the recommendations to improve the efficiency of the LEF injection technologies

The identified dependencies of the factors affecting the injection of LEF slugs made it possible to develop practical recommendations to improve the efficiency of their application:

1. When planning operations, it is necessary to consider the areas of the linear reserves in order to determine the optimal volume of the slug (at least 20 m³/net oil thickness);
2. To inject the recommended volume of the slug on the wells it is necessary to conduct preliminary measures to influence the bottomhole formation zone (restoration of the injection capacity of well);
3. The injection of the recommended slug volume should be carried out at the maximum possible injection pressure (if necessary, the recommended slug volume should be injected cyclically);
4. If the MRP system allows to produce water injection not higher than 17-18 mPa, then after injecting the recommended volume of the slug it is necessary to squeeze the LEF slug (by a pumping plant) with water volume not less than 50-100 m³ and with pressure not less than 20-21 mPa.

3.6. The main areas of work to improve the efficiency of technologies for injection of chemical agents

Henceforth, it is necessary not only to analyze and compare the achieved efficiency of individual injection technologies, but also to continue searching for new chemical formulations in order to increase oil production in highly-rugged low-productive reservoirs. The paper presented an algorithm for analyzing the results of operations conducted at the injection wells.

4. Conclusion

To increase the efficiency of injection technologies, it is necessary to carry out works on the main areas within the complex:
1. Laboratory testing (control) of new formulations presented for the field testing;
2. Planning of works with regard to:
   - the zones of different reservoir structure and development state,
   - the optimal injection of slug volumes of the chemical agents,
   - the MRP system maximum possible injection pressure in the area of exposure;
3. Monitoring the efficacy of treatments with different formulations
4. To consider the specific efficiency parameter, which is "an average incremental oil rate in observation wells" ($\Delta q/o_t\text{/day}$), when evaluating (comparing) the results of treatments;
5. To conduct systematically analytical works on the development and clarification of geological and physical criteria that determine the efficiency of the formulations applied.

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