

Forecasting Methods Applied to Oil Production Deposits at Bazhenov Formation

A A Sevastianov¹, K V Korovin¹, O P Zotova¹, D B Solovev^{2,3}

¹Faculty of Development and Operation of Oil and Gas Fields of the Institute of Geology and Oil and Gas Production Industrial University of Tyumen, 38, Volodarskogo street, Tyumen, 625000, Russia

² Far Eastern Federal University (FEFU), 8, Sukhanov St., Vladivostok, 690950, Russia

³ Vladivostok Branch of Russian Customs Academy, 16, Strelkovaya St., Vladivostok, 690034, Russia

E-mail: contact@ogtcentre.ru, solovev.db@dvfu.ru

Abstract. Analysis of the experience of operating wells in the territory of the Khanty-Mansiysk Autonomous Okrug - Ugra (KhMAO-Yugra) using the displacement characteristic "ALGOMES-2", presented in the work, allows to identify trends in the development of these sediments taking into account the presence of a dual environment of the productive reservoir, to estimate the nearest and medium term prospect of development taking into account application of modern technologies and influence on a layer. According to the results of the assessment, it is established that the profitability of the development of the Bazhenov formation does not provide more than 80 percent of the wells that drain less than 30,000 tons of oil, the development of these deposits in modern conditions is possible with the use of hydraulic fracturing, HS and Multistage hydraulic fracturing of the reservoir (MGRP). The forecast of oil production levels using the ALGOMES-2 methodology and the Monte Carlo probability-statistical simulation method used in Petroleum Resources Management System (PRMS) showed that the oil production level is expected to be around 700000-800000 tons per year in the period up to 2030. These figures indicate the advisability of involving in the development of bituminous shales taking into account the technology of impact on these layers. The work noted that the development of deposits Bazhenov formation should be conducted selectively, it is necessary to rely on the data obtained as a result of the amplitude-frequency characteristics of the seismic exploration of the Bazhenov formation, and the wells should be located in fractured rocks.

1. Introduction

The main experience in the exploitation of the deposits of the Bazhenov formation belongs to the territory of the Khanty-Mansiysk Autonomous Okrug-Yugra. As of 01/01/2016, there was an experience of development of 368 wells in 39 fields. The accumulated oil production from the Bazhenov formation amounted to 8.54 million tons, of which oil production in 2015 was 0.6 million tons. In 2015, 188 wells with an average oil production rate of 13.4 tons per day worked on the beds of the Bazhenov formation, for liquid – 16.9 tons per day. The bulk of oil production (66.0%) and operating wells (59.0%) falls on the fields of JSC Surgutneftegaz [1].

During the analysis of production data for wells operating the Bazhenov formation, it was found that the dynamics of the performance of most wells is characterized by alternating increases and decreases in oil production, which indicates the activity of cracks as a result of the change in effective pressure. In addition, the geological features of the Bazhenov formation predetermine the practically anhydrous character of the production of well production.



The above factors make it difficult to apply known methods to assess the nature of the development of reserves by wells, and to determine the drainable reserves. In this connection, in the present work, a mathematical formula was proposed to predict the indices of production of reserves for the conditions for the development of the deposits of the Bazhenov formation.

In the mathematical description we use the following notation: Q_1 and Q_2 – current reserves in the conductive and reserved layer per unit volume of the formation. Obviously, the pressures under which they are located are proportional to their volumes and therefore the intensity of the fluxes from the layers to the channels can be taken as:

$$-\frac{dQ_2}{dt} = \beta(Q_2 - Q_1) \quad (1)$$

and the intensity of the selection of reserves from the channels:

$$-\frac{dQ_1}{dt} = \alpha Q_1 + \beta(Q_2 - Q_1) \quad (2)$$

Here α and β – constant coefficients with dimension, inverse time.

If we throw back the second term in (2), then a law will be obtained, which establishes that the rate of selection of reserves is proportional to their availability. This law is confirmed by numerous observations of changes in the rate of selection, depending on the residual reserves.

To solve the system of equations (1) and (2) it is useful to replace residual reserves Q_1 and Q_2 on the extracted quantities: $\bar{Q}_1 = Q_0 - Q_2$; $\bar{Q}_2 = Q_0 - Q_1$,

where Q_0 – initial drained reserves without its separation into layers and channels, pores and cracks. In the conditions of the Bazhenov formation, the development, which is carried out under natural conditions, Q_0 will be determined by the volume of geological reserves of oil involved in the development.

In the new notation, we obtain the following system of equations:

$$\frac{d\bar{Q}_2}{dt} = \beta(\bar{Q}_1 - \bar{Q}_2) \quad (3)$$

$$\frac{d\bar{Q}_1}{dt} = \alpha(Q_0 - \bar{Q}_1) + \beta(\bar{Q}_2 - \bar{Q}_1) \quad (4)$$

The need for such a replacement is dictated by the fact that \bar{Q}_1 and \bar{Q}_2 , or rather their sum, is determined by field measurements. To simplify further tildes over variables Q_1 and Q_2 will be omitted. A system of two differential equations (3) and (4) is reduced to one differential equation of the second order:

$$D^2 Q_1 + (\alpha + \beta) D Q_1 + \alpha \beta Q_1 = \alpha \beta Q_0 \quad (5)$$

This equation can be solved if the initial conditions are given, which at the instant $t=0$ the function Q_1 and its first derivative DQ_1 . Since Q_1 corresponds to the volume of reserves extracted from the deposit, then $Q_1(0) = 0$, the magnitude of the derivative DQ_1 corresponds to the rate at which they are extracted, which is usually set in proportion to the initial recoverable reserves, so that you can take $DQ_1 = \gamma Q_1$, where γ – some quantity, inversely proportional to time, like the previously entered parameters α and β . We will replace $Q_1(t)$ with $Q_n(t)$.

For given initial conditions, the solution of (5) is represented in the form

$$Q_n(t) = Q_0 \left(1 - \frac{\gamma - \beta}{\alpha - \beta} e^{-\alpha t} - \frac{\alpha - \gamma}{\alpha - \beta} e^{-\beta t} \right) \quad (6)$$

Taking in to account physical processes, we assume $\alpha > \beta$ and therefore the first term (6) decreases faster, characterizing the production of reserves from the fissure channels, so that after a certain period of time, the largest contribution to the extraction of oil from the deposit will be made by the second

term determining the flow of oil from the pore matrix. In order to disclose the physical meaning of the coefficients, let us consider a well operated by a mechanized method with a constant bottom hole pressure (p_b) p_3 , while under conditions of an elastically closed regime, the formation pressure and the performance indicators can be described by the following system of equations:

$$q = K (p_n - p_3), \quad (7)$$

$$q = \frac{dV}{dt} = -\beta_n V \frac{dp_n}{dt}, \quad (8)$$

where K – coefficient of well productivity; V – geological reserves of oil in deposits; β_n – elastic capacity of oil. Since the elastic capacity of oil is much greater than the compressibility of the skeleton, it can be neglected to simplify the calculations of the skeleton. Equating (7) and (8), we obtain an ordinary differential equation for p_n , then resolving p_n will be:

$$p_n(t) = p_3 + (p_0 - p_3)e^{-at}, \quad (9)$$

$$\text{Where } a = \frac{K}{\beta_n V}.$$

As can be seen, for a sufficiently long time t , the reservoir pressure will equal the pressure at the bottom of the wells and the flow of oil to them will cease.

From (9), taking into account (7), we obtain the following expression for the daily selection

$$q(t) = q_0 e^{-\frac{a_0 t}{Q_0}}, \quad (10)$$

or for accumulated oil recovery:

$$Q_n(t) = Q_0 \left(1 - \exp\left(-\frac{Q(t)}{Q_0}\right) \right) \quad (11)$$

W_{hereq0} – daily production rate at the moment of start-up; $Q(t)$ – accumulated fluid production.

It is important to note that the dynamics of the decline in reservoir pressure during the depletion of the elastic reserve determines the dynamics of the accumulated liquid and, accordingly, the limiting volume of accumulated oil for the conditions of a double medium, the dependence (11) with allowance for (6) can be rewritten in the following form:

$$Q_n(t) = Q_0 \left(1 - Q_1 \exp\left(-\alpha \frac{Q(t)}{Q_0 Q_1}\right) - (1 - Q_1) \exp\left(-\beta \frac{Q(t)}{Q_0 (1 - Q_1)}\right) \right) \quad (12)$$

Thus, it follows from (12) that the coefficients α, β – characterize the intensity of the decay of the selection of oil reserves Q_1 and $1 - Q_1$ respectively from the conducting and nourishing environment. At the same time, the features of the manifestation of the natural regime are reflected. Ratio of coefficients $\frac{\alpha}{\beta}$ it corresponds to the ratio of hydro conductivity of the conductive and energizing medium.

In order to determine the parameter entering into the dependence (12), we denote by $Q_n^\phi(t)$ actual accumulated oil production and form the difference $\Delta_n = Q_n(t_n) - Q_n^\phi(t_n)$, where t_n – the time values within the specified observation period. The parameters α, β, Q_1, Q_0 are in such a way that the sum of the quadratic deviations $S = \sum_n \Delta_n^2$ had a minimum value.

To find the minimum, the method of steepest descent using standard programs is applied. The above algorithm was called "ALGOMES-2" by the name of the authors RI. Medvedsky and A.A. Sevastianov.

Figure 1 shows the adaptation of the ALGOMES-2 model to the above algorithm. Parameters determined during the processing of field data from one of the wells draining the Bazhenov formation at the field confined to the Surgut arch are the following: $Q_0 = 256.7$ kt.; $Q_1 = 0.794$; $a = 0.741$; $b = 0.143$; predictable oil recovery 23.5 kt., that makes 9,5 % from the involved reserves and is comparable to a flexible reserves.

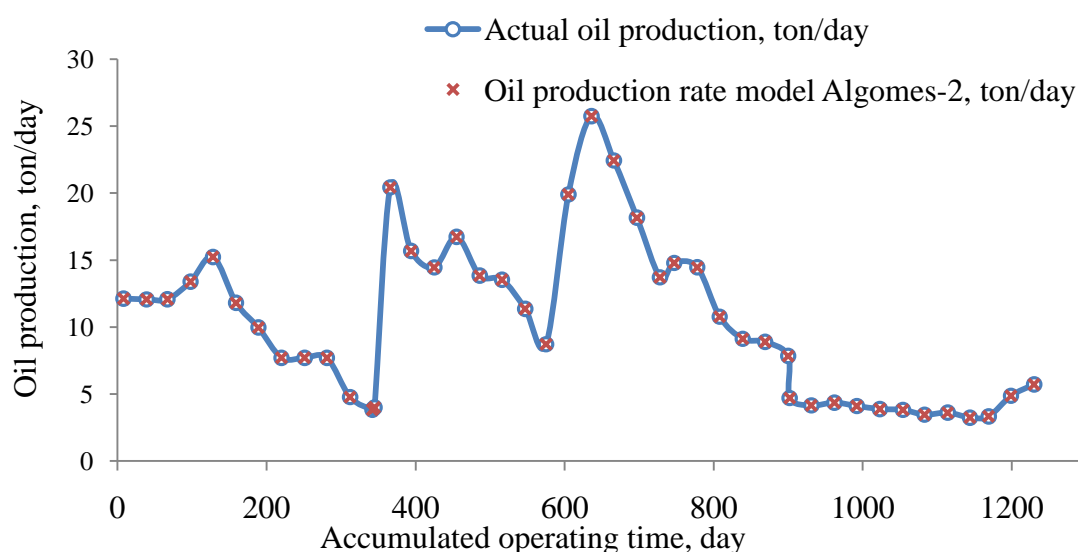


Fig.1. Example of adaptation model ALGOMES-2.

Based on the results of the well operation analysis, 80% of the fund has drained oil reserves of less than 30 thousand tons, which do not ensure the profitability of the development of the Bazhenov formation. Accumulated production of oil over 30 thousand tons / well is recorded for 20% of wells, the drainage area for them exceeds 150 ha / well, which indicates the location of the faces in the vast zones of fracturing of rocks.

If we bear in mind the prospects of applying modern technologies to impact the reservoir, the amount of accumulated production using HW (horizontal well) technologies with MSHF (multi-stage hydraulic fracturing of the reservoir) at the analogues of "shale oil" abroad reaches a level of 13-15 thousand tons. to the well, which also does not fundamentally change the efficiency of producing oil reserves. The rate of decline in production at the North American fields of Bakken and Eagle Ford is 25.0-40.0% per year, their development can pay off in 7-10 years, provided that the input oil rates and oil prices remain at \$ 73 per barrel, which is currently is not a realistic scenario.

Based on the analysis carried out, as well as data on the application of hydraulic fracturing and the GS with the MGRPS, the authors carried out a forecast of oil production levels for objects on the state balance sheet, taking into account the use of modern technologies for impact on the formation (Figure 2). The forecast was carried out using the ALGOMES-2 technique and the algorithms described in [1-4].

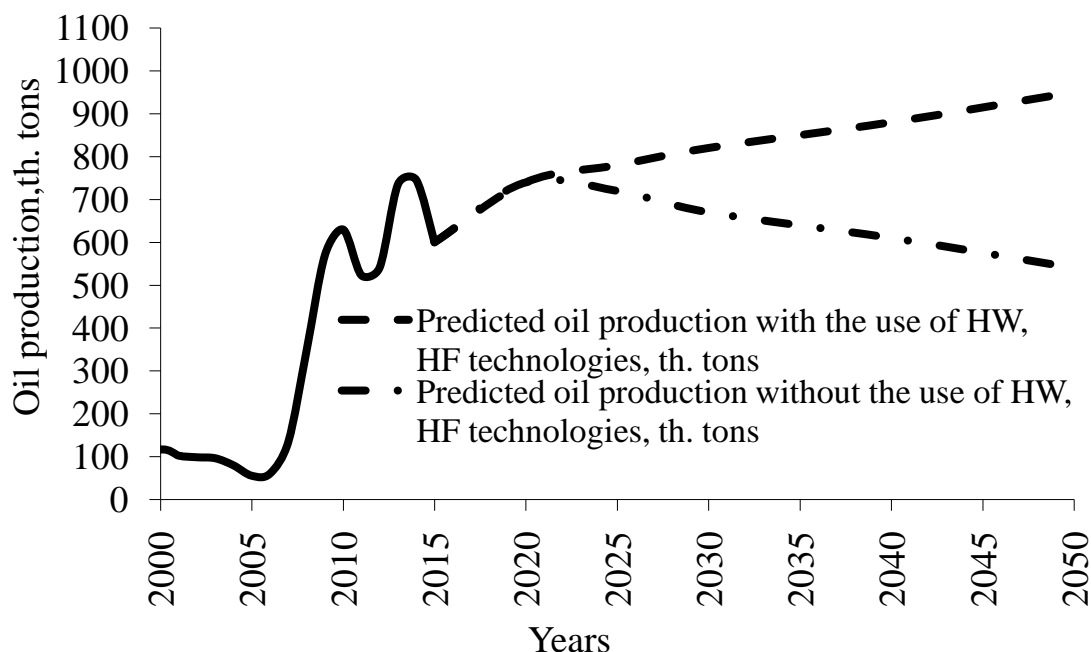


Fig. 2. Forecast of oil production from the Bazhenov Formation of Khanty-Mansi Autonomous Okrug

Conclusion

According to the fulfilled forecast, the oil production levels both with the use of well construction technologies with horizontal termination and hydrofracturing of the formation, and without them, are estimated in the range of 700-800 thousand tons per year until 2030. Obviously, without the active introduction of technologies to impact bituminous shales, the Bazhenov formation cannot be of significant significance for the Russian oil industry.

In the current conditions, the approach to the development of the deposits of the Bazhenov formation in the territory of the Khanty-Mansiysk Autonomous Okrug-Ugra should be selective, with the location of the wells in the fractured zones of rocks, which involves the search for and application of methods for localizing zones of increased productivity on the basis of an analysis of the amplitude-frequency characteristics of the Bazhenov seismic surveyformation.

References

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