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MODEL-BASED APPROACH TO THE DIAGNOSIS OF TRANSIENT PROCESSES IN OIL PRODUCTION

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ABSTRACT

When comparing the condition of a production facility at various stages of development, it is important to pay attention to differences related to their organization and regulation levels. Such an approach allows for reliably identifying critical time intervals of production indicators, which forms the basis for conducting dynamic analyses during these intervals and implementing procedures that enable the refinement of recoverable reserves. Efficient development of oil and gas fields requires timely and well-founded decisions for regulating technological processes aimed at intensifying oil and gas production during the transition period.

Decisions regarding the selection of enhanced oil recovery strategies mainly depend on determining the characteristic phase of the field's development. Most existing analysis methods do not consider the evolutionary mechanism of the reservoir system during field development, and various factors affecting oil production complicate the analysis process and make well-founded decision-making more difficult.

Keywords: reservoir system, development stage, oil and gas production, recoverable reserves, transient processes, systematic analysis

Introduction

During the exploitation of oil fields, reliable forecasting of well productivity and maintaining the profitability of oil production are important tasks. Traditional methods for predicting the liquid and oil flow rates of wells in various fields, including geological-hydrodynamic modeling and displacement characteristics, do not always yield high-quality results. Due to the complex geological structure of the fields and the uniqueness of each productive reservoir, the direct application of evaluation methods used in one production facility to other facilities is challenging. Therefore, the development of a methodology that enables reliable forecasts regardless of the geological and technical conditions of oil and gas fields is a pressing task.

Objective

Currently, a large number of oil and gas fields are in the final stage of development and are characterized by a significant stock of idle wells, despite having relatively high residual recoverable hydrocarbon reserves. For instance, in Azerbaijan's onshore fields, the share of idle wells exceeds 33% of the total number of production wells.

In such fields, intensification of the oil and gas production process requires additional capital investment related to drilling new wells and applying secondary and tertiary recovery methods. However, under conditions of limited financial and technical resources, this is not always feasible. Field development experience shows that due to a number of technical and geological factors, prolonged suspension of oil and gas production in certain reservoirs can lead to the restoration of reservoir productivity characteristics when they are later brought back into production. This may be associated with the redistribution of hydrodynamic flows, reservoir pressure, and other factors.

In this regard, the rational use of the existing stock of idle wells is of great importance. This can be achieved through restoration activities that enable the intensification of oil and gas production processes with minimal material and technical costs.

Methods

The management of oil and gas field development processes requires timely and well-grounded decisions for regulating a complex of technological measures. For this, it is necessary to conduct both individual analysis of specific facilities and a joint consideration of these facilities within a functionally unified system.

To this end, under the guidance of Academician A.Kh.Mirzajanzade, a fundamentally new approach was developed for the management and control of field development. Methods, methodological approaches, and principles based on a cybernetic approach to the analysis and interpretation of geological and production data were created.

The dynamic analysis of the oil production process is based on the following principle: the system's heterogeneity, nonlinearity, and nonequilibrium lead to self-organization.

The heterogeneity and nonlinearity of the reservoir system are determined by geological factors, the properties of the reservoirs and formation fluids, and particularly by the uneven dynamics of the active well stock and the interaction between wells, which all affect the characteristics of the oil production process.

In nonequilibrium systems, the rate of equilibrium recovery in response to changes in external parameters is slower than the rate of change of those external parameters. Nonequilibrium behavior may result from the system's inherent characteristics (gas-liquid flows, water-oil emulsions, interactions between formation fluids and porous media, etc.) and depends not only on the current values of the parameters but also on their dynamics - that is, on the historical development of the production process.

The process of self-organization (coordinated interaction of the system's components) occurs in heterogeneous, nonlinear, and nonequilibrium systems and is influenced by external factors — through inflows and outflows of matter and energy (fluid production, reservoir exposure to various impacts, etc.).

The degree of self-organization of the system (level of orderliness) can be assessed through changes in entropy, fractal characteristics, and other indicators. This approach enables the identification of development trends and supports timely decision-making for the management of the oil production process. A distinctive feature of the proposed approach is that it allows for the improvement of the system based on the identification of characteristic development features during reservoir exploitation.

Entropy Analysis of the Oil Production Process

To diagnose the current state of the oil production process and evaluate the influence of various factors on this process, entropy change analysis can be used; entropy is considered a measure of uncertainty.

It should be noted that the course and development of natural processes in closed systems occur in the direction of increasing entropy.

In information theory, entropy is regarded as a measure of uncertainty of a random variable. If the set of possible values of a random variable is $\{x_1, x_2, ..., x_n\}$ and the probability distribution is given by $(p_1, p_2, ..., p_n)$, then the entropy of this probability distribution is defined as:

$$\mathbf{S} = - \Sigma p_i \log p_i \qquad (1)$$

As seen from equation (1), it follows that the increase in entropy is functionally related to the increase in the probability of the system's state. This means that in an irreversible process, the increase in entropy is accompanied by an increase in the probability of the state — that is, a disordered (more chaotic) state is more probable than an ordered one.

Before the development of the reservoir and the impact on the formation, oil and water exist in a state of equilibrium - that is, an ordered state. The process of fluid production and water injection into the formation disrupts this equilibrium and leads to an increase in entropy.

During oil field development, technological processes must be designed in such a way that the system maintains a condition in which entropy does not increase and remains within a certain limit. This can only be achieved through the regulation of development processes.

A distinctive feature of the presented analysis method is as follows: In traditional approaches, the transition of the system from one state to another is determined based on the moment the change has already occurred. However, the entropy-based approach allows for the earlier detection of the onset of the transition from one state to another and enables proactive diagnostics.

The increase in entropy during the field development process may be associated with the nonequilibrium state of the reservoir system. This, in turn, can be explained by heterogeneous water breakthrough in the oil zone, instability of the displacement front, the formation of stagnant zones of oil isolated from the drainage system by water, and similar phenomena.

This type of analysis of the dynamic changes in technological parameters allows for the real-time diagnosis of the “reservoir-well” system and the identification of optimal time points for implementing various impact techniques on the formation.

Prior to the development of the reservoir and exposure to external influence, oil and water are in equilibrium — in other words, in an ordered state. The production and interaction of oil and water disturb this equilibrium and cause an increase in entropy.

During oil field development, technological processes related to oil production should ensure that system entropy does not increase and remains at a stable level. This can be achieved through proper regulation of production processes.

The analysis of the oil production process at the Kürsəngi field is based on a data set of monthly oil and water production values over a 360-month period for wells No. 2, 4, 6, and 8.

As can be seen from the relevant figure, this dependency exhibits a fluctuating nature, which makes interpretation using traditional methods quite difficult.

In this case, the entropy-based approach allows for a sufficiently accurate interpretation of the system's condition and enables the diagnosis of transitions between different states of the system.

From the fragments of the entropy change graphs (Figures 1.1–1.4) for various time intervals, it can be observed that the minimum entropy value in terms of oil and water production corresponds to the development period during which inter-well interactions are intensified.

In the subsequent stage of reservoir exploitation, the behavior of the oil and gas field system becomes unstable. This is due to an uneven state between the reservoir and the well system (entropy for oil production increases, while it decreases for water).

The results of the analysis make it possible to determine the optimal timing for implementing various Geological and Technical Measures aimed at regulating production.

A distinctive feature of the presented analysis method is that, unlike traditional methods—which identify the transition of a system from one state to another only after the system reaches a steady state—the entropy approach enables early diagnosis of the initial moment of the transition.

When applied to the dynamic analysis of technological indicators of oil production, the aforementioned approach facilitates real-time diagnostics of the reservoir condition and supports decision-making regarding changes in development tactics.

This approach, when applied to the dynamic analysis of oil production technological parameters, enables the operational diagnosis of the reservoir's state and supports decisions on modifying development strategies.

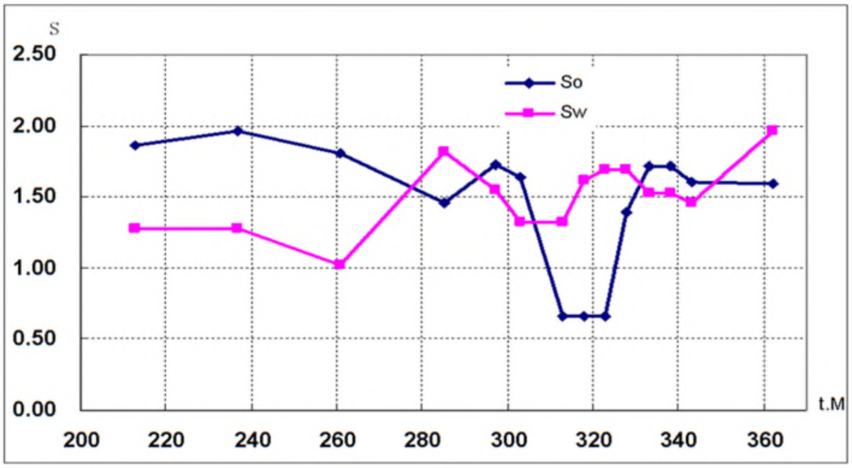

Figure 1. Change in the entropy of the production process of well No. 2

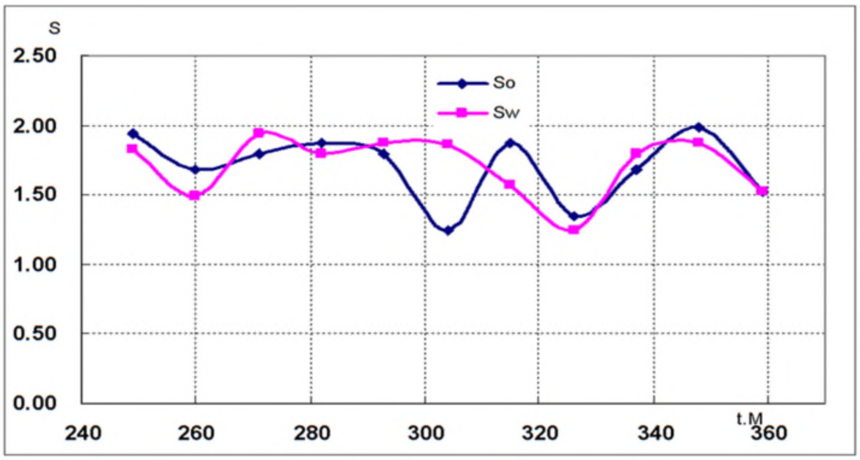

Figure 2. Change in the entropy of the production process of well No. 4

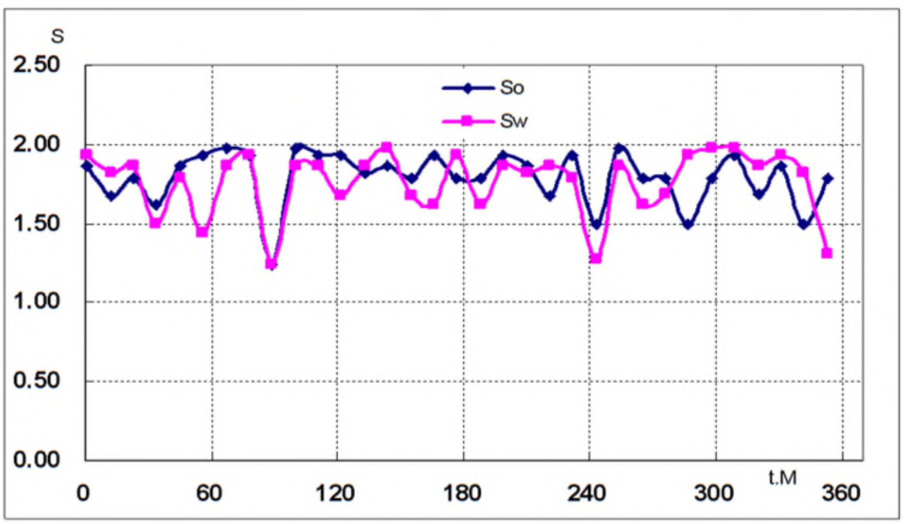

Figure 3. Change in the entropy of the production process of well No. 6

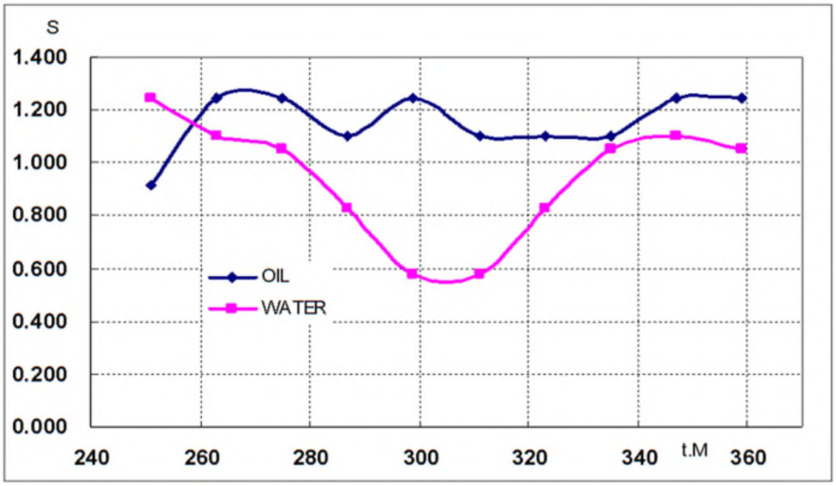

Figure 4. Change in the entropy of the production process of well No. 8

Conclusion

1**.** It has been demonstrated that during the selection of well operation modes, the dynamic interaction between oil and water production should be considered not only for individual wells but also across wells.

2. Based on the obtained results, the use of the conflict model-specifically the "predator-prey" system—as a tool to analyze the current state of oil production has been proposed. By considering the dynamics of this system, recommendations are made for selecting rational operation modes

3. Within the framework of a dynamic approach to oil production, the degree of disequilibrium in the reservoir system is assessed through changes in entropy, fractal characteristics, and other indicators. This approach helps to identify development trends in the production process and enables timely decisions regarding the adjustment of well operation regimes, taking into account their mutual interactions.

A key advantage of this analysis method is that, unlike traditional approaches where the transition time between system states is determined after the fact, the entropy-based method allows for earlier detection of the onset of such transitions.

As a result of analyzing the dynamic changes in technological parameters, it becomes possible to rapidly assess reservoir conditions and determine the optimal timing for applying different types of impact to the bottom-hole zone.

4. The analysis of variability in technological indicators of oil production allows for the identification of tendencies in the transition of the reservoir system from stable to unstable states, considering transitional processes. This ensures the timely and efficient selection of rational operational modes for wells.

5. A comprehensive approach based on the dynamic analysis of information and timely diagnosis of reservoir system conditions-taking into account transitional processes and the interaction between production objects-enables effective evaluation of oil production processes. This, in turn, supports the development of more well-founded decisions regarding production strategy and tactics.

REFERENCES

1. Quang Minh Nguyen; Mustafa Onur: A Deep-Learning-Based Reservoir Surrogate for Performance Forecast and Nonlinearly Constrained Life-Cycle Production Optimization Under Geological Uncertainty, May 09 2025, Paper Number: SPE-220002-PA https://doi.org/10.2118/220002-PA
2. Hedong Sun - “Advanced Production Decline Analysis and Application”, 2015, Pages 263-289, https://doi.org/10.1016/C2014-0-01693-0

3. Denis José Schiozer, Antonio Alberto de Souza dos Santos - “Model-based decision analysis applied to petroleum field development and management” , May 2019 DOI:10.2516/ogst/2019019
4. V. D. Slabnov Metody Matematicheskogo Modelirovaniya I CHislennogo Resheniya Zadachprognozirovaniya I Optimal'nogo Regulirovaniya Processa Izvlecheniya Nefti , 2015
5. Vidyakin, V.V. O modelirovanii processa razrabotki neftyanogo mestorozhdeniya / V. V. Vidyakin [i dr.] Matematicheskoe modelirovanie. - 2011. - T. 23, № 1. - S.19-28
6. Anson Abraham, Technology Focus: Reservoir Simulation (July 2023), pages 61-62Paper Number: SPE-0723-0061-JPT https://doi.org/10.2118/0723-0061-JPT
7. O. E. Abdelaziem; S. F. Farrag; A. E. Abdelgawad; M. Mehrem: Enhancing Well Intervention Strategies: A Data-Driven Framework for Water-Shutoff Candidate Selection and Post-Treatment Assessment (March 2025) Paper Number: SPE-224041-MS https://doi.org/10.2118/224041-MS
8. Avansi G., Rios V., Schiozer D.J. (2019) Numerical tuning in reservoir simulation: It is worth the effort in practical petroleum applications, Braz. Soc. Mech. Sci. Eng. 41, 59. https://doi.org/10.1007/s40430-018-1559-9

NEFT HASİLATININ KEÇİD PROSESLƏRİNİN DİAQNOZLAŞDIRILMASINDA MODEL YANAŞMASI

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XÜLASƏ

İstismar obyektinin müxtəlif işlənmə mərhələlərində vəziyyəti müqayisə edərkən, onların təşkil olunma dərəcəsinə aid fərqlərə diqqət yetirmək vacibdir. Belə yanaşma, işlənmə göstəricilərinin kritik zaman intervallarını kifayət qədər etibarlı şəkildə müəyyən etməyə imkan verir, bu intervallarda dinamik analiz aparmaq, çıxarıla bilən ehtiyatları dəqiqləşdirməyə imkan verən prosedurları həyata keçirmək üçün əsas yaradır. Neft və qaz yataqlarının səmərəli işlənməsi, keçid dövründə neft və qaz hasilatının intensivləşdirilməsinə yönəlmiş texnoloji proseslərin tənzimlənməsi üçün vaxtında və əsaslandırılmış qərarların qəbul edilməsini tələb edir. Neft yataqlarının əlavə işlənməsi strategiyasının seçilməsi qərarları əsasən yatağın inkişaf mərhələsinin xarakterik dövrünün müəyyən edilməsi ilə bağlıdır. Əksər mövcud analiz metodları yatağın işlənməsi zamanı lay sisteminin təkamül mexanizmini nəzərə almır və neft hasilatına təsir edən müxtəlif amillər analiz prosesini çətinləşdirir və əsaslandırılmış qərarın qəbulunu mürəkkəbləşdirir.
Açar sözlər: lay sistemi, işlənmə mərhələsi, neft-qaz hasilatı, çıxarıla bilən ehtiyatlar, keçid prosesləri, sistemli analiz

МОДЕЛЬНЫЙ ПОДХОД В ДИАГНОСТИКЕ ПЕРЕХОДНЫХ ПРОЦЕССОВ ДОБЫЧИ НЕФТИ

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РЕЗЮМЕ

При сравнении состояния объекта эксплуатации на различных стадиях разработки важно обратить внимание на различия в степени их организации. Такой подход позволяет достаточно надёжно определить критические временные интервалы эксплуатационных показателей, что создаёт основу для проведения динамического анализа и реализации процедур, направленных на уточнение извлекаемых запасов. Эффективная разработка нефтяных и газовых месторождений требует своевременного и обоснованного принятия решений для регулирования технологических процессов, направленных на интенсификацию добычи нефти и газа в переходный период. Выбор стратегии дополнительной разработки нефтяных месторождений в значительной степени зависит от определения характерного периода стадии развития месторождения. Большинство существующих методов анализа не учитывают механизм эволюции пластовой системы в процессе разработки и усложняются различными факторами, влияющими на добычу нефти, что затрудняет проведение анализа и принятие обоснованных решений.

Ключевые слова: пластовая система, стадия разработки, добыча нефти и газа, извлекаемые запасы, переходные процессы, системный анализ

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