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ANALYSIS AND EVALUATION OF TECHNOLOGICAL INDICATORS IN THE OIL PRODUCTION PROCESS

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ABSTRACT

Considering the geological structure features of oil fields, the specific characteristics of reservoir oil, the thermobaric conditions of its formation, as well as the limited experience in designing the development of such fields, the retrospective analysis of the main technologies used for the development of this unique field, along with the evaluation of their efficiency and outcomes, is of practical interest. Not all of the various technologies applied for the development of reserves have yielded significant positive results, and assessing the most successful among them is of great importance. During the development of the reservoir, the significant changes that sometimes occur in the properties of reservoir oil necessitate conducting special studies to evaluate these changes, as they can negatively impact the efficiency of oil recovery. The analysis of the reservoir development status includes the study and assessment of the impact of the main applied recovery systems on the efficiency of hydrocarbon production, as well as the investigation of changes in oil properties during the development process.
Keywords: technological indicators, oil production, recoverable reserves, hydrocarbon reserves, correlation coefficient.

Introduction

Currently, increasing the efficiency of reservoir stimulation processes in existing oil fields is a primary objective. Hard-to-recover reserves have begun to play an increasing role in oil production, and achieving efficiency in their extraction is only possible through the use of new, highly effective hydrocarbon recovery technologies. Despite the widespread application of modern methods, on average, at least half of the initial reserves still remain unrecovered. The current stage of development in the oil industry is characterized by a large number of highly productive oil fields reaching the final stage of development, a sharp decline in oil production volumes, and a significant increase in water content in well production. In this context, the efficient operation of fields and the effective exploitation of specific reserves require the widespread application of new and improved known reservoir stimulation methods. Moreover, particular attention is given to enhancing the efficiency of developing complex, multilayer oil fields through the prediction and analysis of technological indicators.

Objective

Currently, a large number of oil and gas fields are in the final stage of development and, despite possessing relatively high remaining recoverable hydrocarbon reserves, are characterized by a significant number of idle wells. For instance, in Azerbaijan’s onshore fields, idle wells account for more than 33% of the total number of production wells.
Intensification of oil and gas production in such fields requires additional capital investments related to drilling new wells and the implementation of secondary and tertiary recovery methods, which is not always feasible given the limited financial and technical resources.

Experience in field development shows that due to various technical and geological reasons, when oil and gas production in individual reservoirs is suspended for a long period, the productivity characteristics of these reservoirs may be restored upon their reactivation. This phenomenon can be associated with the redistribution of hydrodynamic flows, reservoir pressure, and other factors.

In this regard, the rational use of the existing idle well stock is of great importance. This can be achieved through rehabilitation operations that enable the intensification of oil and gas production processes with minimal financial and technical expenditures.

The identification of the most effective methods for reservoir stimulation involves the analysis of geological, physical, and field data, as well as hydrodynamic and physicochemical calculations, aimed at determining the main factors influencing irreversible changes in oil properties.

To address these problems, a comprehensive approach including analytical and experimental studies was used. Factors affecting the efficiency of oil reservoir development were evaluated, employing mathematical statistics methods during the processing of reservoir data results.

Methods

Correlation analysis of features and algorithm for forecasting key development indicators.

In the actual forecasting processes for key development indicators, involving more development indicators in the forecast does not necessarily mean higher accuracy. The inclusion of low-correlated or uncorrelated development indicators will reduce the accuracy values of the forecast for key development indicators. Therefore, before performing the forecasting of key development indicators, it is necessary to conduct a feature correlation analysis between the selected set of indicators and the key development indicators. Currently, commonly used correlation analysis methods include standard computational techniques such as the correlation coefficient method and gray correlation analysis. Additionally, feature correlation analysis algorithms based on deep learning are also available.

The correlation coefficient method typically evaluates the correlation between two features by establishing a linear functional relationship. However, in practical applications, it becomes evident that the correlation between features is not always a simple linear relationship but also includes various other types such as exponential and polynomial correlations. Therefore, there are multiple methods for calculating correlation coefficients. Commonly used correlation coefficients include the Pearson correlation coefficient, Spearman rank correlation coefficient, Kendall rank correlation coefficient, and others.

The Pearson correlation coefficient is calculated by first determining the mean values of the features X and Y, then calculating the covariance Coϑ(X, Y) between X and Y, as well as the standard deviations of X and Y, and finally computing the correlation coefficient as follows:

$$E(X) = \frac{\sum_{i=1}^{n} x_i}{n}, E(Y) = \frac{\sum_{i=1}^{n} y_i}{n} \quad (1)$$

$$Co\vartheta(X,Y) = \frac{\sum_{i=1}^{n}(X_i - E(X))(Y_i - E(Y))}{n} \quad (2)$$

$$\sigma_x = \sqrt{\frac{\sum_{i=1}^{n}(X_i - E(X))^2}{n}},\ \sigma_y = \sqrt{\frac{\sum_{i=1}^{n}(Y_i - E(Y))^2}{n}} \quad (3)$$

$$Pearson = \frac{Co\vartheta(X,Y)}{\sigma_x \sigma_y} \quad (4)$$

The calculation of Spearman's correlation coefficient involves first ranking the data separately, that is, ordering each data element from smallest to largest. Then, the correlation coefficient is evaluated by calculating the degree of difference between the ranks of the two data sets.

$$d_i = X_i - Y_i \quad (5)$$

$$Spearman = 1 - \frac{6 * \sum_{i=1}^{n} d_i^2}{n(n^2 - 1)} \quad (6)$$

Kendall's rank correlation coefficient, similar to Spearman's rank correlation coefficient, evaluates correlation by measuring the ordering or sequence of variables. However, the main difference lies in how they assess the relationship between data pairs. Spearman's rank correlation coefficient takes into account the relative distance error between the ranks of corresponding data pairs, focusing on the differences in their respective positions. In contrast, Kendall's rank correlation coefficient evaluates the concordance of changes in the rankings of two variable sets by specifically counting the number of concordant and discordant pairs. A concordant pair refers to a situation where the ranks of corresponding elements in two variable sets agree in their ordering (i.e., both increase or both decrease), whereas a discordant pair refers to a situation where their rankings do not agree. The Kendall tau coefficient is calculated by dividing the difference between the number of concordant and discordant pairs by the total number of possible pairs. This approach makes the Kendall coefficient less sensitive to outliers compared to Spearman's coefficient and more robust in certain scenarios. The formula for Kendall's correlation coefficient is as follows:

$$Kendall = \frac{n_c - n_d}{n(n-1)/2} \tag{7}$$

Here, n_c is the number of concordant data pairs, n_d is the number of discordant data pairs, and n is the total number of data pairs.

The crude oil recovery factor serves as a crucial indicator for evaluating the efficiency of oil field development. Forecasting this value can provide insights into both the current development stage of the oil field and its future production potential.

Based on the results of the correlation analysis, it is found that there is a quadratic relationship between the total annual oil production and the crude oil recovery factor. It should be noted that this relationship is asymmetric with respect to the Y-axis, indicating that its functional dependence can be approximately modeled as follows.

$$y = a(x - b)^2 + c \tag{8}$$

The relationship between water cut and crude oil recovery factor is exponential and deviates from the standard exponential function. Therefore, a direct relationship between water cut and crude oil recovery factor can be approximately fitted.

$$y = e^{ax+b} + b \tag{9}$$

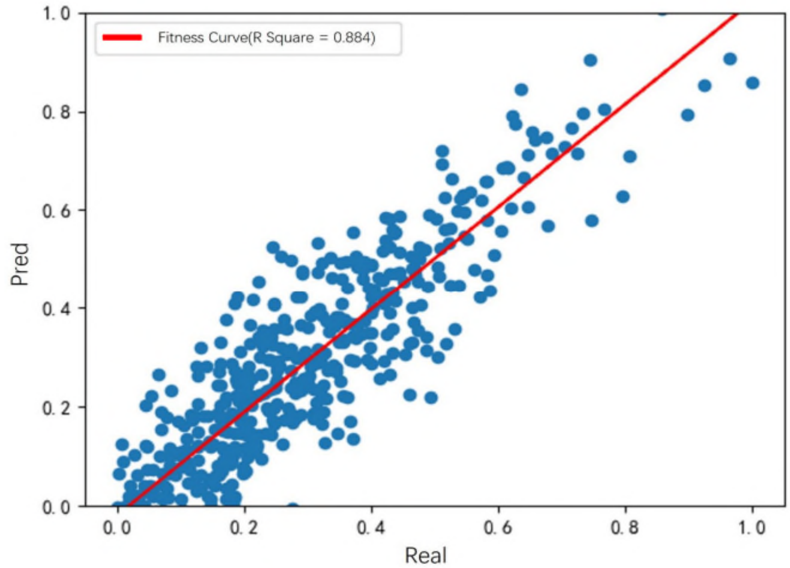
The remaining indicators have a linear relationship with the crude oil recovery factor:

$$y=kx+b \tag{10}$$

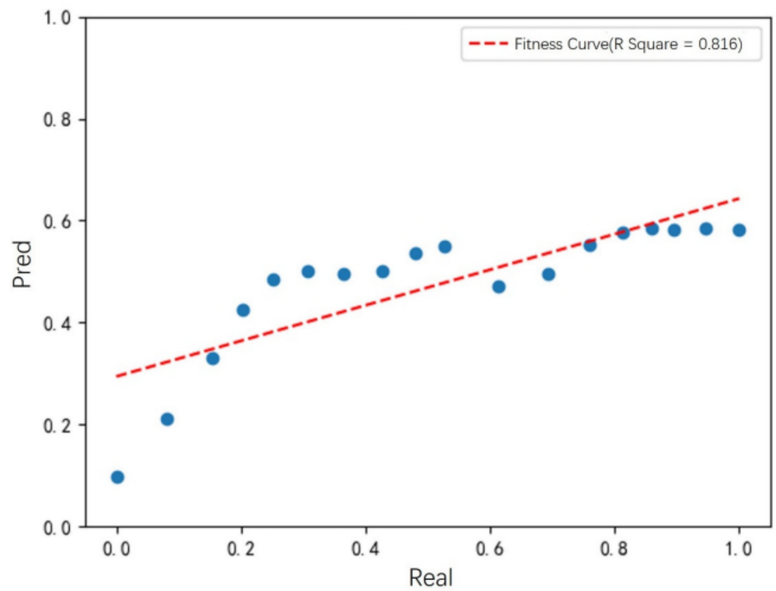
These relationships are established using real oil field data. Since all data are normalized during the model development process, a direct return to the original scales may weaken the functional relationship between the indicators.

Therefore, this paper derives a specific empirical formula by fitting normalized indicators. When using this formula, all data must be normalized before calculation, and the calculation results should then be converted back to the original scales.

Since the feature selection during the aggregation process is random and nonlinear (e.g., max pooling, min pooling, median pooling), this subsampling method can significantly affect the reconstruction of the original indicator features. The correlation coefficient between the results fitted by the empirical formula and the actual values can reach up to 0.884, and when using single well data for validation, the correlation coefficient can also reach 0.816



Picture 1. Scatter plot of crude oil recovery factor calculated by the empirical formula and actual values



Picture 2. Validation effect of the empirical formula for crude oil recovery factor

Conclusion and recommendations

The forecasting of oil field development indicators plays a crucial role in the overall exploitation process of an oil field. Accurate prediction of these indicators not only enhances the overall economic efficiency achievable from the oil field but also enables proactive adjustments to the methods and tools of field development based on the forecast results. This, in turn, can help prevent delays in overall production progress and deterioration in production quality at oil fields in advance. In the process of forecasting key development indicators, this study initially utilized grey correlation theory and the GRN-VSN algorithm to optimize the selection of input data and reduce the dimensionality of input features.

This study employs various artificial intelligence algorithms to forecast the extraction rate of oil fields, and compares the predicted results from different algorithms to select the optimal forecasting

model for key development indicators.
A method for fitting the corresponding empirical formula of the oil field using SHAP has been developed. SHAP was employed to analyze the relationship between the input index and the output index. Considering the model's high prediction accuracy, the precision of this fitted relationship can also be ensured, significantly reducing the difficulty of manual analysis. Moreover, this method can be applied to other oil fields as well.

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NEFT HASİLATI PROSESİNDƏ TEXNOLOJİ GÖSTƏRİCİLƏRİN TƏHLİLİ VƏ QİYMƏTLƏNDİRİLMƏSİ

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XÜLASƏ

Neft yataqlarının geoloji quruluşunun xüsusiyyətlərini və lay neftinin spesifik xüsusiyyətlərini, onun meydana gəlməsinin termobarik şərtlərini, habelə belə qurğuların işlənməsinin layihələndirilməsində təcrübənin azlığını nəzərə alaraq, bu unikal yatağın ehtiyatlarının işlənməsinin əsas texnologiyalarının retrospektiv təhlili, onların səmərəliliyi və nəticələrinin qiymətləndirilməsi praktiki maraq doğurur. Ehtiyatların işlənməsi üçün müxtəlif texnologiyaların hamısı əhəmiyyətli müsbət nəticələr verməmişdir və onlardan ən uğurlularının qiymətləndirilməsi böyük əhəmiyyət kəsb edir. Yatağın işlənməsi zamanı lay neftinin xassələrinin bəzən əhəmiyyətli dərəcədə dəyişməsi bu dəyişikliklərin qiymətləndirilməsi üçün xüsusi tədqiqatların aparılması zərurətini diktə edir ki, bu da ehtiyat hasilatının səmərəliliyinə mənfi təsir göstərir. Yatağının işlənməsi vəziyyətinin təhlili, yataqda həyata keçirilən əsas təsir sistemlərinin neft ehtiyatlarının hasilatının səmərəliliyinə təsirinin öyrənilməsi və təhlili, habelə ehtiyatların işlənilməsi prosesində neftin xassələrində baş verən dəyişikliklərin öyrənilməsidir.

Açar sözlər: texnoloji göstəricilər, neft hasilatı, çıxarıla bilən ehtiyatlar, karbohidrogen ehtiyatları, korrelyasiya əmsalı.

АНАЛИЗ И ОЦЕНКА ТЕХНОЛОГИЧЕСКИХ ПОКАЗАТЕЛЕЙ В ПРОЦЕССЕ ДОБЫЧИ НЕФТИ

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РЕЗЮМЕ

Учитывая особенности геологического строения нефтяных месторождений и специфические характеристики пластовой нефти, термобарические условия её образования, а также недостаток опыта в проектировании разработки таких объектов, представляет практический интерес ретроспективный анализ основных технологий разработки запасов этого уникального месторождения, оценка их эффективности и результатов. Не все технологии разработки запасов дали значительные положительные результаты, поэтому оценка наиболее успешных из них имеет большое значение. При разработке месторождения иногда наблюдаются значительные изменения свойств пластовой нефти, что диктует необходимость проведения специальных исследований для оценки этих изменений, что негативно влияет на эффективность добычи запасов. Анализ состояния разработки месторождения включает изучение и оценку влияния основных воздействующих систем на эффективность добычи нефтяных запасов, а также исследование изменений свойств нефти в процессе разработки запасов.
Ключевые слова: технологические показатели, добыча нефти, извлекаемые запасы, углеводородные запасы, коэффициент корреляции

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