Table

Digitalization of upstream industry

	Effective Equipment	Smart equipment	Robotic Equipment
Wells	- Drilling rate increase without drilling risks - Equipment cost reduction - Overall NPT reduction +15-30 %well construction rate increase	- Real-time geological well model updates, prediction and prevention of drilling risks - Drilling risks prediction and prevention -15-20 % decrease in overall NPT	- Applied during the robotic drilling machine and automatization of the field development in general
Fields	- Applied at the well level	- Optimizing the field development in general, decreasing CAPEX, decreasing construction risks. +5-7 %Well construction cost reduction +10-15 %increase in wells construction speed	- Automated maintenance of each well within the field +7-9 %increase of efficiency of field development
Drilling	- Rig data collection Preventive maintenance cost reduction +10-15 % increase of production efficiency	- Drilling parameter control, accident decrease, optimal use of resources -10-15 %decrease in cost of development	- Robotized drilling machine +15-18 %increase in development efficiency

Thus, in our technologically advanced world innovations and new trends in O&G increases oilfield and well productivity, decreases human labor. So, IoT plays a crucial role in advancing the O&G industry.

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ANALYSIS OF THE CALCULATION OF THE OIL DISPLACEMENT CURVE FOR PREDICTING DEVELOPMENT PERFORMANCE

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The system of field development implies a controlled set of sequential technological and geological-technical measures (GTM) to extract hydrocarbons (HC) from the subsurface. And the task facing production companies is not only to control oil recovery factor (ORF), oil depletion ratio, oil flow rate and other key development parameters, but also to forecast performance in the short term with a minimum error. The results of forecasting are also used to identify the most complicated areas for development, which are the primary targets for well interventions, thus allowing to form the optimal development programme for the whole field [1, 2, 7].

An effective method to diagnose the current state of development, analyse and a business case making for the technological optimision and economic performance of oil and gas production is a set of tools based on a proactive block-factor analysis (BFA) model based on the material balance equation. One of the main components of the BFA block is determination of the reference (model) characteristic displacement (CD) curve and further its behaviour [3].

The purpose of this work is upgrading CD block by complex methods application for ORF calculation, oil and fluid flow rates, watercut and also reduction of model curve deviation limit value from actual curve to 5 %.

To perform the computational task the actual, technological values indicators of development has been used and taken from the database (DB) according to the field or its analogues, for which the difference of filtration-volumetric properties (FVP) and pressure-volume-temperature properties (PVT properties) is not more than 10 % of values of the same parameters of the considered field.

Based on literature research, the formula described by El-Khatib was chosen to determine the reference oil recovery factor. This algorithm can be applied in the absence of hydrodynamic models and the need to perform calculations in the shortest time [1, 3]:

$$K_{orf}^{m} = K_V \cdot \left[0.5 - 0.5 \cdot erf\left(\frac{\sigma}{\sqrt{2}} + erf^{-1}\left(\frac{\left(1 - \frac{F_{wo}}{m}\right)}{\left(1 + \frac{F_{wo}}{m}\right)}\right) + \frac{\tau}{(1 + F_{wo})}\right)\right] \quad (1)$$

Where: Kmorf – model oil recovery factor, e.g., σ – standard deviation of permeability distribution in the block, e.g., Fwo – water-oil factor, e.g., τ – dimensionless time, e.g., m – mobility factor, e.g., Kv – displacement factor, e.g.

Residuality function value is minimized in the process of model adaptation [2]. Depending on a field maturity, either regression analysis for 1-2 stages of development with the use of the least squares method and gradient descent algorithm or retrospective forecasting, for the 3-4 stage of development [5]. The peculiarity of regression equation calculation is connected with the number of data basis.

In this article, a replacement for gradient descent has been offered at quantity of records from 1000 to 5000, through the modification of a method of the least squares.

To transform a linear dependence into a curve as close as possible to the actual graph of the characteristic displacement, a Bezier curve is approximated, the results of which are presented as curve reference points. These points are used for reconstruction of the curve by means of defining a number of arbitrary power values [5]. The final CD and prognosis calculated by El Hatib method are compared with actual curve and evaluated for correctness of their calculation as well as oil and fluid flow rates, ORF and water cut. Examples of graphs are shown in Figures 1 and 2.

In case of parameters' deviation and curves by more than 5% - the other methods are used. In this paper, we have created an algorithm for selecting alternative CD methods taking into account the stage of development of the field. For mature fields we calculate ORF using differential watercut curves, differential decline curves and logarithm of oil-water factor [1, 5, 8].

In case of initial development stages the laboratory tests are used by all means (water saturation of reservoir, relative phase permeability of water and oil, their viscosities). The CD curve is plotted using the Buckley-Leverett method. In the absence or unreliability of laboratory data, the scheme uses the clustering existing studies by the "K-Means" method, followed by the use of Euclidean distance as a metric.

As a result of the described operations, a cluster mean Buckley-Leverett curve is created by the least-squares method with the introduction of a genetic algorithm, which maintains high calculation accuracy while reducing the expended computational resources.

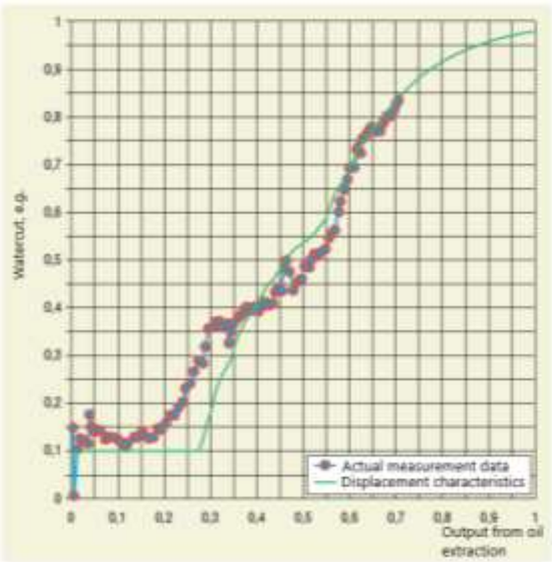

Fig. 1. Example of comparison between obtained displacement characteristic and actual operating data [6]

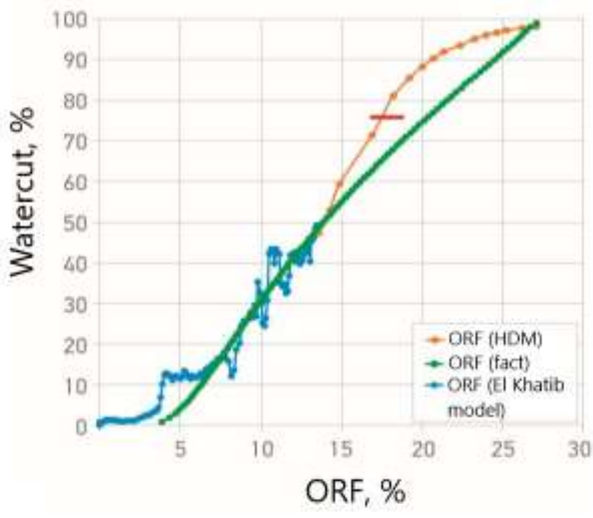

Fig. 2. Example comparison of the displacement characteristics obtained from the El-Khatib model and the hydrodynamic model (HDM) for a single block [3]

Next, all above alternative methods are tested for convergence by a multi-criteria optimization method using a genetic algorithm where the quality criteria is the adequacy criteria, which is analogous to regression analysis and accuracy criteria, that is analogous to retrospective prediction [5].

Moreover it is necessary to define one method for approximation, which in case of good convergence will be the result of BFA block as the selection of optimal DC by ranking method is made (Figure 3). In the course of the work more than twenty alternative CD(s) were considered by the authors, after that the best results were shown by the six presented in Fig. 3.

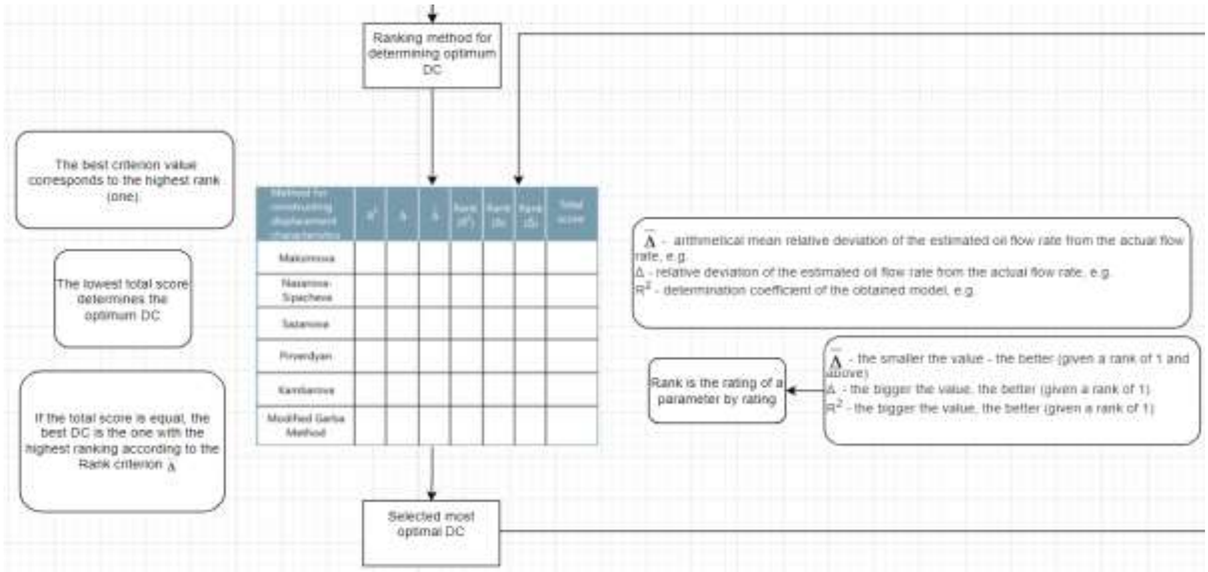

Fig. 3. Fragment of the "displacement characterization and prediction" block - ranking method

If the resulting CD curve shows incorrect values based on verification results, the next method is taken from the list until a "reference" curve with better convergence to the development history fact is found. The reference CD curve and the forecast are stored for further BFA work, however, there is also a situation where the CD curve may not be selected due to incorrect calculation results for the methods being used. In this case, the actual data for the CD curve taken from the database are retained. This result may also indicate poor quality of history data development and/or a change abrupt in the field development strategy.

The above algorithm allows to comprehensively cover different cases of data availability and validation for mathematical calculation of CD curve parameters and material balance prediction. As a result, it verifies the validity of the actual data to determine the mode perfect operation mode and the selection of well interventions to optimise oil and fluid flow rates and water cut.

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