Statistical analysis of dynamics of decrease in oil production after well interventions

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Abstract. The paper is based on the theoretical aspects of studying the success of oil production projects. To conduct clustering based on the empirical data from the producing well stock, a classifier has been compiled describing the types of interventions in 2013-2018. The selection of indicators was carried out on the basis of theoretical qualitative analysis. The following statistical indicators were included in the study information base: well profile, well diameter, field, horizon, and oil flow rate. The dynamics of the oil flow rate is translated into a comparable form using time synchronization. Since the initial attribute space is represented in various units of measurement, in order to ensure comparability, at the stage of formation of information array, standardization of indicators was carried out to the maximum. The interventions revealed the following combinations of factors which showed the greatest effect in terms of growth and total oil production: well profile, well diameter, field, as well as critical factors that can be interpreted as factors of ineffective interventions. The obtained factors were verified by various methods of multivariate statistical data analysis. The author suggests conclusions and recommendations for the most efficient interventions in oil wells.

1. Introduction

At oil fields, work is carried out on wells during their operation to regulate its development and maintain target levels of oil production. This set of works is called well interventions (WI) [1].

When selecting the type of WI, the issue of their effectiveness is brought to the fore and it is one of the grounds for the feasibility of the entire oil production project. For this purpose, the list of WI is planned and refined during the implementation process and is subject to systematic correction and refinement as current information on production volumes from the field becomes available. It is this process that largely influences the success of the implementation of projects of oil production.

2. Theory

For the purpose of evaluating the effectiveness of WI, wells are divided by the degree of reaction to the work performed. The well that received a positive effect or additional oil production is considered to have reacted, and the well that received a negative effect is considered not to have reacted to the WI.

The following principle is used to evaluate the effectiveness of WI: if separate production well of the exposure area has a positive effect, the duration is calculated up until the actual production of oil will not decrease below the baseline level; if the well has a negative effect, either immediately after the WI, or after a short-term positive effect, the calculation of the effect stops, that is calculated only positive component effect [2].
For statistical analysis, the initial data is the current production obtained as a result of the WI for the period under review for all activities.

The analysis is based on the assumption of a typical effect of WI. We assume that all wells work with some accuracy with the same dimensionless decrease rate of the flow rate \( f(t) \), and \( f(0) = 0 \), but each \( i \)-th well has its own initial flow rate \( q_{0i} \). Therefore, the additional oil rate received as a result of the WI depends on the accumulated operating time \( t \) according to the law \( q_i(t) = q_{0i} f(t) \), or in logarithmic form:

\[
\ln q_i(t) = \ln q_{0i} + \ln f(t) + \epsilon_i(t).
\] (1)

where \( \epsilon_i(t) \) is the remainder that is not explained within the specified model.

The quality criterion of the constructed model is to minimize the sum of squares of errors. Unknown values are the initial well flow rates \( q_{0i} \) and the values of the empirical function of the monthly flow rate drop \( f(t_j) \). The resulting family of empirical decrease functions \( f(t_j) \) is suitable for the determination of significant events and application of the results in the future WI planning process.

3. Results

In order to determine significant WIs, a cluster method of data analysis was used, the purpose of this method is to divide the initial set of WIs for wells with different characteristics into two clusters. The first cluster includes the best WIs for the total oil production and its growth, and the second cluster includes the worst of the interventions. Table 1 and Table 2 present the results of clustering of WI by total oil production rate and its increment for salt-acid treatment of wells and gas-dynamic fracturing (Figure 1). The following symbols are used in the table: ID – well number, PROF-well profile (HW-horizontal well, DS-Directional well, VW-vertical well), D-well diameter, A-area, HOR-horizon, \( \Delta NT \)-increase in oil production, S_NT-total oil production.

![Figure 1](image_url). Result of the clustering of gas-dynamic fracturing
Table 1. Summary table of clustering of WI for oil production rate (the best ones).

| Type of WI              | ID   | PROF | D   | A   | HOR | ΔNT | S_  |
|-------------------------|------|------|-----|-----|-----|-----|-----|
| Gas-dynamic fracturing  | 27649| DW   | 146 | 903 | 529 | 0.5 | 594 |
|                         | 28015| DW   | 168 | 903 | 529 | 1   | 417 |
|                         | 32546| DW   | 168 | 911 | 529 | 1   | 308 |
|                         | 32071| DW   | 168 | 911 | 529 | 261 | 5213|
|                         | 32071| DW   | 168 | 911 | 529 | 171 | 1809|
|                         | 28015| DW   | 168 | 903 | 529 | 158 | 1422|
|                         | 27046| DW   | 146 | 1   | 476 | 17.9| 1262.9|
| Salt-acid treatment     | 27194| DW   | 146 | 303 | 461 | 217 | 733 |
|                         | 27736| DW   | 146 | 201 | 481 | 139 | 329 |
|                         | 61693| HW   | 168 | 302 | 450 | 128 | 887.3|
|                         | 27248| DW   | 146 | 201 | 481 | 1   | 64 |
|                         | 27151| VW   | 168 | 302 | 450 | 4   | 80 |
|                         | 27046| DW   | 146 | 1   | 476 | 20  | 1309|
|                         | 27046| DW   | 146 | 1   | 476 | 17.9| 1262.9|
|                         | 32425| DW   | 168 | 246 | 481 | 30  | 1215|
| Traditional hydraulic fracturing | 27261| DW   | 168 | 903 | 529 | 2   | 34 |
|                         | 32582| VW   | 168 | 911 | 529 | 22.5| 42.5|
|                         | 27404| DW   | 146 | 1   | 476 | 28.3| 127 |
|                         | 32071| DW   | 168 | 911 | 529 | 261 | 5213|
|                         | 33854| DW   | 146 | 903 | 529 | 15.5| 3813.1|
|                         | 59990| DW   | 146 | 902 | 529 | 91  | 2085|

Table 2. Summary table of clustering of WI for the production of oil (the worst ones).

| Type of WI              | ID   | PROF | D   | A   | HOR | ΔNT | S_  |
|-------------------------|------|------|-----|-----|-----|-----|-----|
| Gas-dynamic fracturing  | 27649| DW   | 146 | 903 | 529 | 0.5 | 594 |
|                         | 28015| DW   | 168 | 903 | 529 | 1   | 417 |
|                         | 32546| DW   | 168 | 911 | 529 | 1   | 308 |
| Salt-acid treatment     | 63084| HW   | 168 | 302 | 450 | 0.7 | 110.3|
|                         | 27248| DW   | 146 | 201 | 481 | 1   | 64 |
|                         | 59071| DW   | 114 | 303 | 461 | 1   | 22 |
| Traditional hydraulic fracturing | 27261| DW   | 168 | 903 | 529 | 2   | 34 |
|                         | 32582| VW   | 168 | 911 | 529 | 22.5| 42.5|
|                         | 27404| DW   | 146 | 1   | 476 | 28.3| 127 |

In order to analyze the clustered data of the correct sample, an algorithm for constructing approximating functions by types of WI was used. Stages of the algorithm for constructing a family of approximating functions are:

- checking the correct data for uniformity and, if necessary, correcting it;
- selecting the type of approximating functions and calculating its coefficients;
- verification of the coefficients significance: if the corresponding coefficients are considered significant, they remain in the approximating function;
if the coefficients are not significant, another type of approximating function is constructed for this sample, in which the coefficients are recalculated and checked for significance;
• calculation of the Fisher criterion for evaluating the adequacy of the obtained approximating functions and making a decision on its use.

Based on the results of testing the algorithm for constructing a family of approximating functions [4] for a control sample by type of WI for the reporting period from 2009 to 2017, a table of 3 approximating functions was obtained.

Table 3. Summary table of approximate functions of WI after clustering on the oil flow rate

| Type of WI                  | Profile/diameter/oilfield/horizon | Approximating function     | Model quality ($r/R^2$) |
|-----------------------------|-----------------------------------|-----------------------------|-------------------------|
| Gas-dynamic fracturing      | (DW/146/294/296)                  | $y = 114.26\ln(t) - 7.8832$| 0.89/0.94               |
| Salt-acid treatment         | (DW/146/293/475)                  | $y = 25.621\ln(t) + 0.4049$| 0.65/0.81               |
| Traditional hydraulic fracturing | (DW/146/250/475)                  | $y = -41.1\ln(t) + 251.41$ | 0.65/0.81               |

4. Conclusion
As a result of this work, the most significant geological and technical interventions were identified on wells with different technical characteristics using statistical methods. The proposed method allows evaluating the effectiveness of WI and implementing their planning.

References
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