Systematic Approach to Compare Technologies for the Enhanced Oil Recovery

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Abstract. The article deals with methodical approach to compare technologies of enhanced oil recovery on the basis of summarizing data of their implementation. The result of comparison is a ranking of technologies in decreasing order of technological and economic attractiveness. The recommendations for their definition are given. We discuss the features of attractiveness indicators under the conditions of PJSC Tatneft. It is shown that the technologies that are best for economic attractiveness do not turn out the best for the technological appeal. Recommendations are given on the preparation of data for calculation. The results of the ranking are described for a group of technologies designed to address one of the most common problems for the oil deposit development. It seems appropriate to compare technologies on the basis of a deeper evaluation of activities than is reflected in the statements.

Keywords: technologies of enhanced oil recovery, technological and economic attractiveness, attractiveness indicators, ranking of technologies.

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PJSC Tatneft has a wide range of different technologies to increase oil recovery performed through injection and production wells. The choice of technologies to be used is largely determined by information on previous experiences with their implementation, stored in Dll.dbf database of TatASU LLC for each activity. The aim of this work is to streamline the methodological approach to the comparison of technologies (characterized by average results of combined events) from these data. The approach is also valid in the case of own estimates of the outcome measures.

To compare the performance characteristics and to determine the best technologies we suggest using indicators of technological attractiveness (more justified in the aspect of providing more current oil production) and economic attractiveness (more interesting in the aspect of providing a given return on investment). Economic attractiveness is less strict, since in its assessment additional data are used with their own error in determining (cost of the activity, additional oil production for the timing of the effect, depending on the duration of the effect, which, in turn, is not free from the obligation to implement the investment program). Selection of the appeal depends on analyzing the problem to be solved.

Technological attractiveness indicator is calculated using the formula (1):

$$П_Т = Н \cdot К_{ТУ} \cdot \log М_Т , \quad (1)$$

where $П_Т$ – indicator of technological attractiveness, units; H – relative increase in oil production due to the activity, units; $К_{ТУ}$ – rate of technological success, unit; $\log М_Т$ – logarithm of the number of events considered for determining the technological attractiveness, units.

Technological success factor is calculated using the formula (2):

$$К_{ТУ} = \frac{М_Д}{М_Т} , \quad (2)$$

where $К_{ТУ}$ – technological success factor, units; $М_Д$ – number of activities with a relative increase in oil production in excess of the threshold, units; $М_Т$ – the total number of activities considered for determining the technological attractiveness, units.

The indicator of economic attractiveness is calculated using the formula (3):

$$П_Э = Р \cdot К_{ЭУ} \cdot \ln М_Э , \quad (3)$$

where $П_Э$ – indicator of economic attractiveness, units; P – profitability of activities, %; $П_{ЭУ}$ – factor of economic success, units; $\ln М_Э$ – the natural logarithm of the number of activities considered for determining the economic attractiveness, units

Economic success factor is calculated using the formula (4):

$$К_{ЭУ} = \frac{М_Р}{М_Э} , \quad (4)$$

where $К_{ЭУ}$ – factor of economic success, units; $М_Р$ – number of activities with profitability greater than the threshold, units; $М_Э$ – the total number of measures considered for determining the economic attractiveness, units.

Profitability, used as the main indicator of economic efficiency is determined by the commonly known procedure.

The cost of activities for the last years are reduced to the nomination of the year of analysis according to the formula (5):

$$З = З_t \cdot I_{t_М+1} \cdot I_{t_М+2} \cdot ... \cdot I_{t_А} , \quad (5)$$

where З – costs for the activity given to the year of analysis, rubles; $t_М$ – year of ; $t_А$ – year of analysis; $З_t$ – costs for the activities in the year of its implementation, rubles; I – average inflation indices, units.

Technologies are ranked according to the attractiveness indicator.

The procedure for the formation of generalized notions of technological processes efficiency for reporting data is as follows.

Initially additional processing and preparation of database information is performed. Activities with questionable composition of reagents, physically incorrect data on the flow

rate and water cut are eliminated of the array of data on the interested technologies.

For more adequately characterization of the technology objects (sites, wells) are excluded from consideration with a too short period of manifestation of the effect (effect is not yet fully emerged) and too long term of manifestation of the effect (the accuracy of determining the end is getting worse with time elapsed from the date of the activity). From the experience: 6-24 months on activities through production wells, 12-48 months on activities through injection wells. For the remaining activities control testing is carried out for accounting changes in pump performance during the activity (the amount of oil flow before the exposure and the average for the period of existence of oil flow growth should not exceed the flow rate prior to exposure).

In addition, by exposure through injection wells activities are derived from a consideration, characterized by the highest additional oil production for the following reasons. For activities through injection wells TatASU calculated the exposure by the accumulated operating parameters of wells with the use of two-parameter approximating functions. Usually a convex or concave curved 'path of points' in the background of the activity (roughly – 'arch') is replaced by a straight line. This predetermines systematically introduced mistake in predicting, respectively, in favor of or against the effect of the exposure.

In the latter case it is mathematically possible to obtain a negative value of the calculated effect, which, however, is not indicated in the report (zero is stated). Therefore, it is necessary to eliminate approximately the same number of events with the largest effect in order to compensate in the formation of activity selection to determine the average characteristics of the activities.

To describe the process average values are used for the set of indicators of the activities. They are liquid flow rate prior to exposure; oil flow rate prior to exposure; water cut before exposure; the duration of manifestation of the effect; additionally produced oil; costs of action (taking into account inflation over time); number of agents used in exposure (in the case of matching technology with similar composition used). Key features of the application of activities are the relative increase in the average daily oil flow rate (taking into account the above mentioned revisions) and the profitability of the activity application.

Let us note that the first one is a little more objective, since the main uncertainty in the technological efficiency is brought by the manifestation duration of the effect. Whereas the objective of the second indicator is deteriorating not only for the manifestation duration, but also for the difference in the inflation coefficients at different times of the activities included in the technology selection.

Calculation of indicators of technologies comparison is performed in the following order.

A list of compared technologies is defined. For each technology average growth of oil production rate, duration of effect, additional oil production, profitability are determined; technological success, economic success are calculated. By itself, economic success does not represent a serious interest, so the rigidity requirement of compliance of economic data to current economic conditions at the time of the analysis may not be overly restrictive. It is important to perform the mutual ratio of the economic success of technologies to determine the ranking of a particular technology in the general list of close technologies for a particular type of work. Based on these indicators, taking into account the representativeness, technology attractiveness indices are calculated, and their ranks are determined in the list of the considered technologies.

The presented approach to the comparison of methods is illustrated with examples of technologies comparison designed to solve the same task with several different ways (mainly used with reagents). In this paper, in order to avoid conflict of interests, titles of technologies are encoded though the indicators of activity applications are real.

The source of information is the statistical reporting database of TatASU – Dll.dbf. Database as of 01.01.2016 contains information about 8475 activities in total of 62 considered technologies.

The control testing is performed of indicators of the reporting on the application of activities:

- On the composition of reagents used to detect and reject activities, sharply differing in purpose (there is no reason to believe that the basic functional problem is solved in the technologies group – 397 activities);
- Under the terms of the exposure implementation to detect and reject activities, sharply differing in purpose – 164 activities with water cut of 20%, for the 68 activities water cut is not indicated;
- By the method of evaluation of exposure results to detect and reject activities whose results are distorted by errors – for 2646 activities change of the pump performance is not considered; for 214 activities the duration of the effect is more than 60 months.

In addition, for the above reasons 44 activities were rejected with duration of the effect less than 4 months or unspecified duration; 18 activities for other reasons.

Thus, for further consideration 5133 activities are left.

Results for ranking technologies by technological attractiveness are given in Table 1. Technologies with the number of activities less than 20 were considered insufficiently representative and were not ranked.

The ranking results on economic attractiveness are shown in Table 2.

The tables show that the best technologies on the economic attractiveness are not the best in the technological appeal. This should be taken in addressing issues of selecting technologies. Tables 1 and 2 show that the top of the ranking places technologies with codes 3122221524, 3121114282, 3122111752, widely used at present.

It should be noted that the above approach to assessing the effectiveness of activities has its own scope of applicability and is not free from principle drawbacks, mainly relating to the procedure for evaluation of technological activities and the procedure for calculating the economic efficiency of activities.

Regarding the use of materials of Dll.dbf database let us point out the following features.

First of all, it is the lack of consideration of the remaining completely out of sight changes in water intake, which is essential for water limit technologies, and it is very important for stimulation and displacement technologies.

Furthermore, in some instances, doubts are raised for correct forecast 'base' for a period exceeding the approximation interval (which is usually not prolonged).

Technology code	Number of activities	Rank	Ratio of water cut after and before exposure, un.	Relative increase in oil production of well, un.	Technological success, un.	Technological attractiveness, un.
3122221524	131	1	0,87	8,4	0,9	16,3
3121114282	757	2	0,89	5,5	0,9	14,9
3122111752	332	3	0,91	5,1	0,9	11,0
3122212713	65	4	0,90	6,8	0,8	10,5
3122117592	341	5	0,93	3,6	0,9	8,2
3122229244	294	6	0,88	3,5	0,9	8,0
3122114862	516	7	0,93	3,2	0,8	7,3
3122228994	34	8	0,91	4,8	1,0	7,2
3122111792	17	9	0,85	5,9	0,9	6,5
3122119752	70	10	0,90	3,9	0,9	6,3
3122117392	77	11	0,96	4,0	0,8	6,0
3121118962	410	12	0,92	2,7	0,8	6,0
3122111572	22	13	0,90	4,6	1,0	6,0
3122118372	182	14	0,94	3,2	0,8	5,8
3122118632	79	15	0,91	3,3	0,9	5,5
3122118822	158	16	0,92	3,0	0,8	5,3
…	…	…	…	…	…	…

Table 1. The ranking results of technologies for technological attractiveness.

Technology code	Number of activities	Rank	Ratio of water cut after and before exposure, un.	Profitability of activities, %	Economic success, un.	Economic attractiveness, un.
3121111992	48	1	0,93	39	0,88	1,34
3122229794	31	2	0,81	38	0,90	1,20
3122111572	22	3	0,90	29	0,86	0,79
3122117592	341	4	0,93	18	0,71	0,76
3121114282	757	5	0,89	16	0,69	0,73
3122229244	294	6	0,88	16	0,70	0,66
3122111752	332	7	0,91	13	0,67	0,50
3122221524	131	8	0,87	11	0,68	0,37
3122211953	44	9	0,92	12	0,68	0,30
3122111792	17	10	0,85	15	0,71	0,30
3122119302	31	11	0,90	12	0,68	0,28
3121111632	17	12	0,93	17	0,59	0,28
3122212713	65	13	0,90	8	0,71	0,25
3122111662	24	14	0,91	9	0,75	0,22
3122227124	138	15	0,86	5	0,59	0,16
3122228994	34	16	0,91	6	0,56	0,13
…	…	…	…	…	…	…

Table 2. The ranking results of technologies for economic attractiveness.

In perspective it seems appropriate to carry out a comparison of technologies based on a deeper assessment of the results of activities.

Conclusions

1. To compare technologies according to their applications we suggest using indicators of technological attractiveness (more justified in the aspect of providing additional current oil production) and economic attractiveness (more interesting in the aspect of providing a given return on investment).

2. It is shown that the best technologies on the economic attractiveness do not turn out the best in the technological appeal.

3. The above approach to assessing the effectiveness of activities is not free from drawbacks, mainly relating to the procedure for evaluation of technological activities and the procedure for calculating the economic efficiency of activities.

4. It is advisable to carry out a comparison of technologies on the basis of a deeper assessment of activities than is reflected in the report.

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