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Modeling the task of optimal planning of wells repair and renewal operations

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Abstract: The article considers the task of optimal planning of repair and renewal operations (RRO). A graphical description of the change in well stock is given. The solution of the task is described as the Markov process; the well can only be in three possible states, while the time is continuous, since the transition from one state to another can occur at any time. The problem of selecting a well for repair is considered.

1. Introduction

The operating time of the well is divided into three periods: operation, waiting for repair and repair itself. Emergency shutdown of the well affects both the volume of oil production and the entire operation of the deposit. Therefore, the task of optimal planning of the RRO is relevant today.

2. Research

To improve the efficiency of the well, it is necessary to take into account both technical and economic factors:

- the number of new wells placed on production;
- the number of repair/drilling crews;
- operation life (quality of construction and repair of wells);
- period of well repair.

Then the task sounds as follows: for a given oil production plan, it is necessary to determine the amount of work of the drilling and repair crews at the maximum profit of the enterprise.

The problem of optimal planning of repairs at wells can be described as a linear programming task. [1]

It is required to find the maximum of the objective function

$$F = D - 3 \to \max, \tag{1}$$

under the following restrictions

$$\begin{cases} Q \geq Q_{pl} \\ K \leq K_{\max} \\ Z \leq Z_{\max} \\ K,\ Z > 0 \end{cases}, \tag{2}$$

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$$Q = q_1 \int_0^t x_1(t)dt + q_2 \int_0^t X_2(t)dt$$

where

D – enterprise total revenue;

$З$ –overall costs of the enterprise;

Q_{pl} – planned oil production;

Z_{max} – maximum number of drilling crews;

K_{max} – maximum number of repair crews.

The costs can be calculated using the following formula

$$З = З_1 + З_2 + З_3 + З_4, \quad (3)$$

where $З_1$, $З_2$, $З_3$, $З_4$ – expenses for maintenance and construction of wells, maintenance of repair and drilling crews.

Wherein

$$З_1 = C_r \cdot \frac{K}{T_r} \cdot T, \quad З_2 = C_m \cdot K \cdot T, \quad З_3 = C_c \cdot \frac{Z}{T_c} \cdot T, \quad З_4 = C_d \cdot Z \cdot T,$$

where

C_r – the average cost of repair of one well, rub.;

C_m – the average cost of maintaining one repair crew, rub./day;

C_c – the average cost of construction of one well, rub.;

C_d – the average cost of maintaining one drilling crew, rub./day.

The income can be calculated according to the following formula

$$D = C\left(Q - q_2 \int_0^{T'} x_3(t)\,dt\right) \quad (4)$$

where

q_1 – the average volume of production of a working well, t/day;

q_2 – the average volume of production of the well waiting for repairs, t/day;

T – planning period (1 year).

3. Results and discussion

3.1. The task of optimal planning of drilling and repair works.

Since the number of working wells is constantly changing, the dynamics of changes in the well stock can be considered as the Markov process; the well can only be in three possible states, while the time is continuous, since the transition from one state to another can occur at any time.

In this case, we denote:

$X_1(t)$, $X_2(t)$ and $X_3(t)$ – the average number of wells that are in normal operation, stopped for queuing for repairs and under repair;

$T_м$, $T_о$ and $T_р$ – the average overhaul period of the well, the time in line for setting for repair and the time of the repair itself;

$\lambda_{12} = \frac{1}{T_м}$ – the intensity of the transition from the working state to the repair queue,

$\lambda_{31} = \frac{1}{T_r}$ – the intensity of the transition from repair to operational state of failure of wells and exit from repair.

Set the initial value of the operating well stock $N_0 = x_1(0) + x_2(0) + x_3(0)$. [2]

The number of crews in idle $K_m = K - X_3(t)$.

The change in the well stock is described in Figure 1.

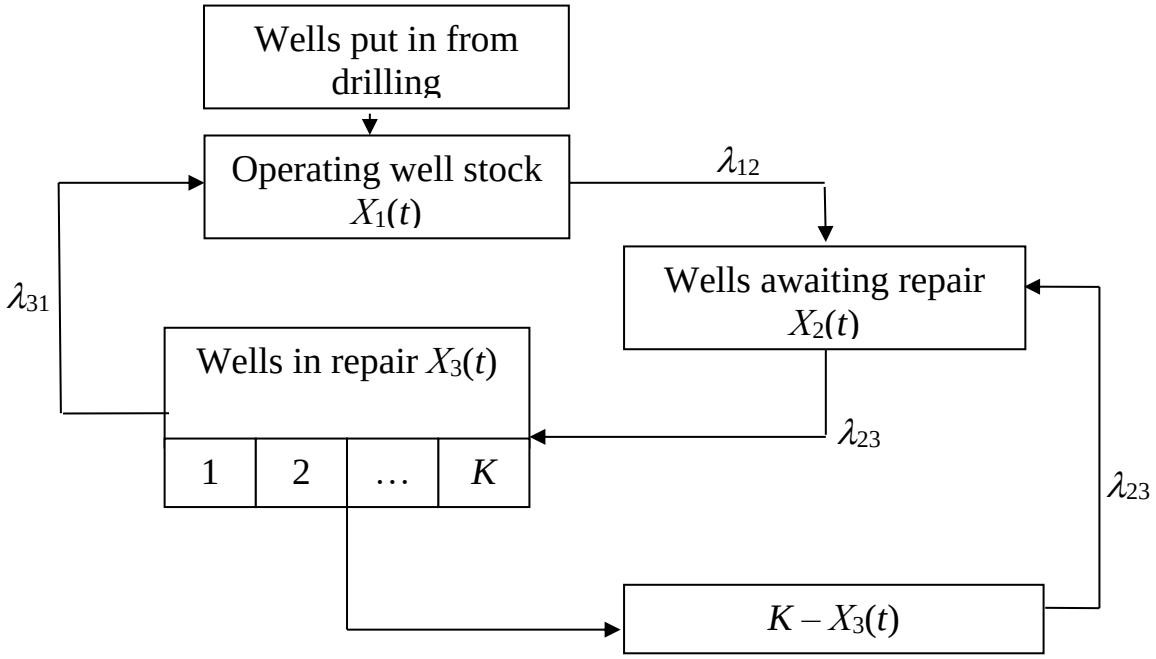


Figure 1. Change in the stock of wells and repair crews.

For Figure 1, we form the Kolmogorov equations with regard to the average numbers of states:

$$\left.\begin{aligned} \frac{dX_1}{dt} &= -\lambda_{12}X_1 + \lambda_{31}X_3 + \delta \\ \frac{dX_2}{dt} &= -\lambda_{23}X_2 + \lambda_{12}X_1 \\ \frac{dX_3}{dt} &= -\lambda_{31}X_3 + \lambda_{23}X_2 \end{aligned}\right\}. \quad (5)$$

Instead of the last equation, we use the equation of material balance at time *t*:

$$N = N_0 + \delta \cdot t,$$

or

$$X_1(t) + X_2(t) + X_3(t) = N_0 + \delta \cdot t.$$

Thus, substituting X_3 into (5), we obtain a system of three equations with three unknowns:

$$\left.\begin{aligned} \frac{dX_1}{dt} &= -\lambda_{12}X_1 + \lambda_{31}X_3 + \delta \\ \frac{dX_2}{dt} &= -\lambda_{23}X_2 + \lambda_{12}X_1 \\ X_3(t) &= N_0 + \delta \cdot t - X_1(t) - X_2(t) \end{aligned}\right\}. \quad (6)$$

The obtained model of the well stock dynamics is modified taking into account the intensity of the flows λ_{12}, λ_{23} and λ_{31}, and the intensity of wells input from drilling $\delta = \frac{Z}{T_c}$. These flows depend on the overhaul period, the number of repair crews *K*, and the quality of well repair.

The objective function (1), taking into account the function of costs and income from the sale of extracted oil, or under constraints (2), completely determines the task of optimal planning of the repair works volume. In this case, the dynamics $X_1(t)$, $X_2(t)$ and $X_3(t)$, obtained as a result of the solution, as well as K_{opt} give the optimal trajectory of the oil and gas production management. Any changes in the number of $X_1(t)$, $X_2(t)$, $X_3(t)$ will deviate from the optimal trajectory, and therefore it is desirable to eliminate these deviations (in particular, for deviations $X_1(t)$ and $X_3(t)$).

3.2. The task of planning repair work at wells.

Having determined the volume of repair and drilling operations, it is necessary to solve one of the main tasks of efficient use of the well stock - the task of choosing a well for repair [3].

With a limited number of repair crews, there may be a situation where several wells need to be repaired simultaneously. Then the criterion for the order of repair can be, for example, the priority of high-output wells or the repair time, or the cost of repairs, etc. can be considered an important factor.

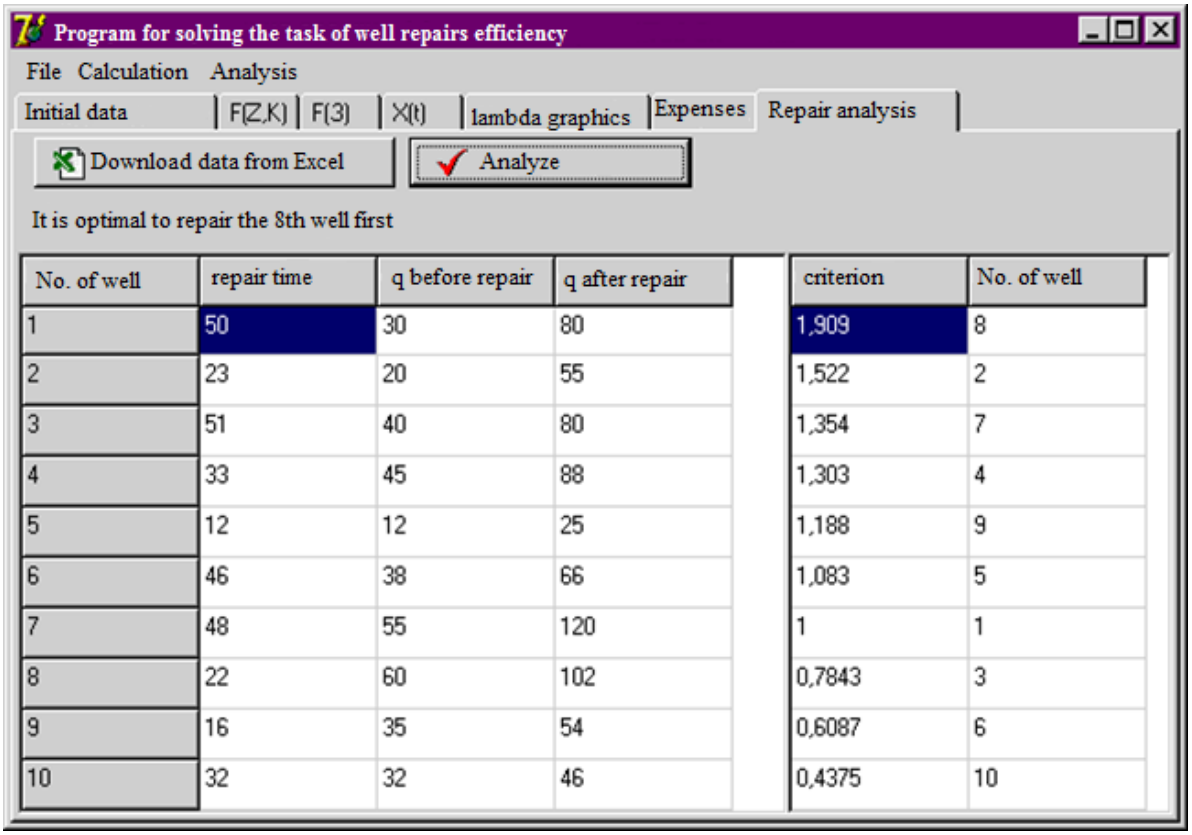
However, for the best planning, it is recommended to take into account several most important criteria at once, for example, the overhaul period, the time spent for repairs and the planned profit due to repair and renewal operations.

Overhaul period characterizes the duration of the well operation between the date of bringing the well on to stable production and the date of its shutdown, due to the failure of the deep pumping equipment, the underground part of the mechanized well stock facilities. The calculation is carried out according to the operating mechanized well stock [4].

Repair time is divided into two parts: repair and tripping. The most labor-intensive and time-consuming operation is tripping. Performing the tripping often takes between 50 and 80% of the total time. Now, it is technically impossible to reduce the time spent on tripping. Often, along with the RRO, various geophysical surveys are carried out inside the well; the time for their implementation, as well as the implementation of other measures, should also be taken into account [5].

When calculating profits, it is necessary to take into account high-output wells, whose production will increase insignificantly after repair, and even a reduction in profits is possible. Hence, in case of emergency on high-output wells, a sharp drop in the average daily production rate takes place. To account for such wells, we offer to conduct a double sampling. First, we sample, without additional conditions, and then we perform internal sorting taking into account only the current production rate. In this case, we avoid possible emergencies on high-output wells, whose downtimes will greatly reduce the average production rate.

In the aggregate of all factors, we calculate the priority criterion. Ranking the criterion in descending order, we get the schedule of the sequence of carrying out repair and renewal operations at the wells, taking into account priority maintenance of high-output wells in Figure 2.



No. of well	repair time	q before repair	q after repair	criterion	No. of well
1	50	30	80	1,909	8
2	23	20	55	1,522	2
3	51	40	80	1,354	7
4	33	45	88	1,303	4
5	12	12	25	1,188	9
6	46	38	66	1,083	5
7	48	55	120	1	1
8	22	60	102	0,7843	3
9	16	35	54	0,6087	6
10	32	32	46	0,4375	10

Figure 2. Distribution of wells for repair and renewal operations.

Figure 2 shows that it is more profitable to repair well № 8 first. Its debit will increase by 1.7 times, while the debit of well № 7 will increase more than 2 times. However, considering that the repair time of these wells differ by almost 2 times, it is recommended to repair the well № 8 first.

4. Conclusion

Thus, a method of optimal planning of repair works was proposed, to stabilize the level of oil production and determine the dynamics of changes in the fund of production wells.

The tasks of effective use of a wells fund are formulated and solved. Criteria of optimality for the selection of wells for repair are determined. Using double sorting in the calculation of profits, high-output wells are taken into account.

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