Design of distributed systems of hydrolithospere processes management. Selection of optimal number of extracting wells

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Abstract. The article considers the important issue of designing the distributed systems of hydrolithospere processes management. Control effects on the hydrolithospere processes are implemented by a set of extractive wells. The article shows how to determine the optimal number of extractive wells that provide a distributed control impact on the management object.

1. Introduction

The rational and environmentally safe management of natural resources is a priority. The main parameters of the hydrolithospere processes are known to be described by equations in private derivatives [1-3]. To study the objects in question, one needs to apply the system with distributed parameters, while ensuring that the distributed input is implemented and the distributed output function is measured. The distributed control effect on the control object (see Figure 1) is provided by a collection of extractive wells. The larger the wells, the more precise the distributed effects on the control object can be realized, and consequently, the greater the expenditures on the production and operation of the considered number of wells [2]. The distributed output function can be measured in different ways:

- by the development of a collection of control wells equipped with a suitable set of sensors to measure the current state of the hydrolithospere process;
- by the use of the extractive wells, which is further withed by a set of sensors. The standard management scheme is shown in Figure 1.

![Figure 1. Structural scheme of management system.](image)

At present, one of the promising trends of enhancing a set of service properties of such bronzes is alloying them with superdispersed powders (SDP). Introduction of their small amount into the melt before a crystallization process allows increasing strength propeties of castings [1, 2]. But a
mechanism of interaction with lead-tin-based bronzes, as well as the process regularities of such modification, is not studied profoundly. However, such modification of copper alloys is promising from several points of view.

This paper presents an investigation of the influence of different content of additives of the pre-treated aluminium oxide powder on the structure of lead-tin-base bronze under formation.

2. Selection of optimal number of extracting wells
The definition of the debits of the extractive wells is based on the condition that the aquifer is unrestricted in a plan, isolated in the section and has a power border.

When entering the quasi-steady mode, the lower level in the first extractive wells is determined by the sum of the influence of the $i$-th well, and the influence of all the other extractive wells of the aquifer and the distribution boundary [2]:

$$
H_i = \frac{Q_i}{4\pi km} \ln \left( \frac{2.25 \cdot a^* \cdot \tau}{r_i^2} \right) + \sum_{j=1, j \neq i}^{n} \frac{Q_j}{4\pi km} \ln \left( \frac{2.25 \cdot a^* \cdot \tau}{\rho_{i,j}^2} \right) - \sum_{j=1}^{n} \frac{Q_j}{4\pi km} \ln \left( \frac{2.25 \cdot a^* \cdot \tau}{R_j^2} \right),
$$

where $H_i$ is the lowering level in the well under consideration of $H_0$; $r_i$ - a parameter of $i$-th extractive wells that is determined by using the results of the pilot studies (usually the ratio of $a^*/r_i$); $R_j$ - distance from the distribution line to the $j$-th well; $\tau$ - time; $km$ - the hydroconductivity of the aquifer in question; $a^*$ - piezoconductivity of reservoir; $n$ - number of wells; $Q_i$ - production of $i$-th extractive well; $Q_j$ - production of the $j$-th extractive well; $\rho_{i,j}$ - the distance from the $j$-th extractive well to the $i$-th extractive well.

![Figure 2. Diagram of extracting wells.](image)

In general, the value of $\rho_{i,j}$ is defined from the following ratio:

$$
\rho_{i,j} = \text{abs}(j-i) \cdot \Delta y, \text{ where } \Delta y = Ly/(n+1).
$$

Considering that

$$
C_i = \frac{1}{4\pi km}, \quad \tilde{C}_{i,j} = \ln \left( \frac{2.25 \cdot a^* \cdot \tau}{r_i^2} \right), \quad C_{i,j} = \ln \left( \frac{2.25 \cdot a^* \cdot \tau}{\rho_{i,j}^2} \right) - \ln \left( \frac{2.25 \cdot a^* \cdot \tau}{R_j^2} \right),
$$

equation (1) is rearranged in the following form:
\[ H_i = C_1 \cdot (Q_i \cdot (\tilde{C}_{2,i} - \ln \left( \frac{2.25 \cdot a^* \cdot \tau}{R_i^2} \right)) + \sum_{j=1, j \neq i}^{n} Q_j \cdot C_{i,j}) \]

where \( H_i \) - demotion at the point of the extractive wells.

Let us write equation (2) in a matrix form:

\[
\begin{bmatrix}
H_1 \\
\vdots \\
\vdots \\
H_n
\end{bmatrix} = C_1 \cdot \begin{bmatrix}
\tilde{C}_{3,1}, C_{1,2}, \ldots, C_{1,n} \\
\tilde{C}_{2,1}, \tilde{C}_{3,2}, \ldots, C_{2,4} \\
C_{n,1}, C_{n,2}, \ldots, \tilde{C}_{3,n}
\end{bmatrix} \cdot \begin{bmatrix}
Q_1 \\
\vdots \\
\vdots \\
Q_n
\end{bmatrix}, (3)
\]

where \( \tilde{C}_{3,i} = \tilde{C}_{2,i} - \ln \left( \frac{2.25 \cdot a^* \cdot \tau}{R_i^2} \right) \).

By solving the matrix equation (3), let us define the debits of the extractive wells, with the specified values of the level \( (H_i) \) decrease:

\[
\begin{bmatrix}
Q_1 \\
\vdots \\
\vdots \\
Q_n
\end{bmatrix} = \frac{1}{C_1} \cdot \begin{bmatrix}
\tilde{C}_{3,1}, C_{1,2}, \ldots, C_{1,n} \\
\tilde{C}_{2,1}, \tilde{C}_{3,2}, \ldots, C_{2,4} \\
C_{n,1}, C_{n,2}, \ldots, \tilde{C}_{3,n}
\end{bmatrix}^{-1} \cdot \begin{bmatrix}
H_1 \\
\vdots \\
\vdots \\
H_n
\end{bmatrix}, (4)
\]

Total production rate \( (Q) \) of the extractive wells is determined from the ratio:

\[
Q = \sum_{j=1}^{n} Q_j.
\]

Each field has its own set of geometric \( (R_i, L, r_i) \) and physical parameters. In general, the production conditions of the field are generally set by specified values of the level \( (H_i) \) decrease. Let us select the number of extractors \( (n) \) as a variable parameter. It is known, that the production and operation of each of the producing wells will require some cost. In this case, it is necessary to include different types of taxes in a cost article. The total income is calculated based on the amount of raw material, produced for a certain period, and the cost of its implementation.

The profit is calculated by the difference between the income and the costs.

3. The problem:

For the specified deposit: \( a_i^* = 104 \text{ m}^2/\text{day} \); \( km = 144 \text{ m/day} \); \( H_i = 1 \text{ m} \); \( r_i = 7.53 \text{ m} \); \( R = 240 \text{ m} \); \( L_y = 400 \text{ m} \), let us determine the number of producing wells that provide maximum profit for the 10-year period.

The methodology of the solution is as follows:

1. Using ratio (4), let us determine the total production of the extractive wells, depending on the number of extractive wells. The results of the calculations are shown in Figure 3.
2. Let us define the income part. Assuming that the price of 1 m$^3$ of the extracted raw materials is 300 rub., the total income of 10 years of exploitation of the deposit can be determined from ratio $D=Q(365 \cdot 10 \cdot 300)/1000000$ mln. rub.

3. Let us define the consumables. It is expected that 30 million rub. will be spent on the structure and maintenance during 10 years of each extraction. The tax is 7.5%.

4. Let us select the target function. The target function will be the profit ($P$) for 10 years of operation of the deposit, which is recorded as:

$$P=D-30n-D \cdot 0.075.$$

According to the calculations, Figure 4 shows a schedule for the change of profits, depending on the number of extractive wells.

![Graph of Total Debit](image)

**Figure 3.** Total Debit

The calculated optimal number of wells is 9, and the profit for 10 years of operation will be 436.6 mln. rub. Figure 5 shows the schedule for the profit from the lowering level of the extractive wells based on the results of the calculations [4-11].

![Graph of Profit](image)

**Figure 4.** Profit for 10 years of operation of deposit
As shown in Figure 5, the increase in the lowering level leads to the increase of the debits, and the total income increases significantly, but the weight portion of the costs will be insignificant.

Of course, the example described above is somewhat idealized, but the methodology for determining the optimal number of wells can be applied to other target functions. Using the above-mentioned technique, it is possible to design a distributed input impact on the control object.

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