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УДК 556.34

ОЦЕНКА ДИНАМИКИ ГИДРОЛИТОСФЕРНОГО ПРОЦЕССА ПРИ ИЗМЕНЕНИИ РАДИУСА «КОЛОДЦА»

ASSESSMENT OF DYNAMICS OF HYDROLITHOSPHERIC PROCESS AT CHANGE OF RADIUS OF "WELL"

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В статье рассмотрена разработка метода адаптации параметров регулятора, зависящих от изменения радиуса «колодца», вызывающего изменение динамики процесса добычи гидроминеральных ресурсов.

Ключевые слова: радиус «колодца», гидроминеральная база, математические методы, метод адаптации, параметры регулятора.

The article discusses the development of a method for adapting the parameters of the regulator, depending on changes in the radius of the "well", causing a change in the dynamics of the process of producing hydro-mineral resources.

Key words: radius of "well", hydromineral base, mathematical methods, adaptation method, regulator parameters.

Introduction. Today, an important problem for mankind remains a negative impact on the environment, leading to environmental degradation. Polluting the environment, soil poisoning occurs, which entails pollution of the groundwater aquifer, which in the future can greatly affect the composition of water and our health. The annual increase in precipitation leads to a dilution of the mineral composition of narzan. The relevance of the study is to preserve the hydromineral resources of the KMV region. The use of modern mathematical methods, the introduction of water production process control systems will allow the rational use of the hydromineral base.

The purpose and objectives of the study. The aim of the study is to develop a method for adapting the parameters of the regulator when the radius of the "well" changes, causing a significant change in the dynamics of the production of hydro-mineral raw materials.

To achieve this goal, it is necessary to carry out:

1) Analysis of the mathematical model of mineral water deposits.

2) Synthesis of a field management system formed during
adaptation of the control system when changing the radius of the "well".

3) Investigate transients of a closed-loop control system.

The novelty of the results is determined by the fact that in the work:

1) The relationship of the radius of the "well" with the coefficient K.

2) The influence of the coefficient K (radius of the "well") on the parameters of the controller is investigated.

The practical significance of the results is determined by the possibility of improving methods for the synthesis of control systems for hydrolyte-sphere processes.

The paper studies the practical results of the synthesis of the KMV field management system. The task of synthesizing the control system of the Kislovodsk field is set. A model layer of the field is considered, a closed control system is built, taking into account the change in the radius of the "well".

The mathematical description of the control object

Ground water

$$\frac{\Delta H_1(x,y,z,\tau)}{\Delta\tau} = k_{1,x} * \frac{\Delta^2 h_1(x,y,z,\tau)}{\Delta x^2} + k_{1,y} * \frac{\Delta^2 h_1(x,y,z,\tau)}{\Delta y^2} + k_{1,z} * \frac{\Delta^2 h_1(x,y,z,\tau)}{\Delta z_1^2}) \quad (1)$$

$$0 < x < L_x; 0 < y < L_y; 0 < z < L_{z_1}$$

Пласт

$$\frac{\Delta H_2(x,y,z,\tau)}{\Delta\tau} = \frac{1}{\eta_2} * (k_{2,x} * \frac{\Delta^2 H_2(x,y,z,\tau)}{\Delta x^2} + k_{2,y} * \frac{\Delta^2 H_2(x,y,z,\tau)}{\Delta y^2} + k_{2,z} * \frac{\Delta^2 H_2(x,y,z,\tau)}{\Delta z_2^2}) + V(\tau) * \frac{\Delta H_2(x,y,z,\tau)}{\Delta x} \quad (2)$$

$$0 < x < L_x; 0 < y < L_y; 0 < z < L_{z_3}$$

where: h1 – pressure in the groundwater horizon;

H3 – pressure in the studied aquifer;

$k_{i,x}, k_{i,y}\ k_{i,z}$ – filtering coefficients according to the corresponding coordinates;

ηi = 0.00101 / m – is the elastic capacity of the layer;
V (τ) – pressure drop caused by the impact of the production well.

$$V(\tau) = Q*K \tag{3}$$

where Q – is the production rate of the producing well;
K – is the gain;
δ (x0, y0, z0) is a function equal to unity if x = x0, y = y0, z = z0, and equal to zero in other cases;
x, y, z – spatial coordinates;
τ – time.

Boundary conditions (Darcy conditions) between the layers are set in the form:
Groundwater - Plast

$$h_1(x,y,L_{z_1},\tau) = h_1(x,y,L_{z_1},\tau) + b_1 \cdot (H_2(x,y,0,\tau) - h_1(x,y,L_{z_1},\tau)),$$
$$H_2(x,y,0,\tau) = H_2(x,y,0,\tau) - b_1 \cdot (H_2(x,y,0,\tau) - h_1(x,y,L_{z_1},\tau))$$

where b1 = 0.00003 $days^{-1}$ is the overflow parameter.

Lower boundary of the reservoir

$$\partial H_3(x,y,L_z,\tau)/\partial z = 0$$

Side faces

$$h_1(0,y,z,\tau) = h_{1,0}; H_2(0,y,z,\tau) = H_{2,0},$$
$$\partial h_1(L_x,y,z,\tau)/\partial x = 0; \partial H_2(L_x,y,z,\tau)/\partial x = 0.$$

Forming the boundary conditions along the y coordinate, we assume that the thickness of the layers is such that disturbances from the intake wells do not affect the state of the formation at the boundary points:

$$h_1(x,0,z,\tau) = h_1(x,L_y,z,\tau) = h_{1,0},$$
$$H_2(x,0,z,\tau) = H_2(x,L_y,z,\tau) = H_{2,0}$$

We carry out a procedure for studying the static and dynamic characteristics of an object to determine static and dynamic coefficients, using different coefficients, depending on changes in the radius of the "well" [3]. Several options are to be considered, including different well radius, a study will be conducted for three different values of the well radius, with three different coefficients depending on the radius change.

Imagine there is one producing well [5]. The decrease in level (H_y) at the location of the production well, at a given flow rate (Q), is described by the dependence:

$$H_y = \frac{Q}{4\pi km} Ln\left(\frac{2{,}25 \cdot a*}{r^2}\right) + \frac{Q}{4\pi km} Ln(t_{\text{пр}}) \tag{4}$$

where $Ln(t_{\text{пр}}) = Ln(\tau) - Ln(1+1{,}78 \cdot b \cdot \tau/\mu^*) = Ln(t) - (Ln(\tau) + Ln(1/\tau + 1{,}78 \cdot b^*/\mu^*))$

or $Ln(t_{\text{пр}}) = -Ln(1/\tau + 1{,}78 \cdot b^*/\mu^*)$

where τ – is the current time from the start of the well disturbance (0 << τ);
a * – is the reservoir conductivity;
km – reservoir conductivity;
b * – is the overflow parameter;
r – is the radius of the "well" (Fig. 1);
μ * – reservoir fluid loss.

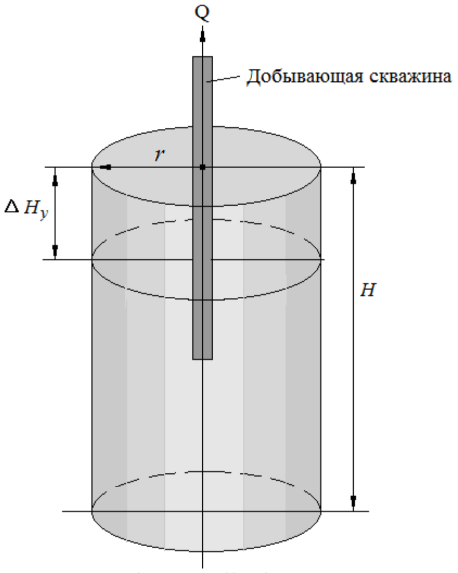

Fig. 1. Well scheme

With a sufficiently large τ, the dependence is converted to the form:

$$H_y = K_y \cdot Q,\ K_y = \frac{1}{4\pi km}\left(Ln\left(\frac{2{,}25 \cdot a^*}{r^2}\right) - Ln(1{,}78 \cdot b^* / \mu^*)\right) \quad (5)$$

Assuming *km* = 201,33 m2 / day;

a^*/r^2 = 110 day^{-1};

μ* = 0,00008;

b^* = 0,000059 day^{-1},

We get K_{r1} =0,001914, K_{r10} =0,0011613, K_{r30} =0,0003871.

If in the time Δτ the flow rate changed by ΔQ, then in the stationary mode the pressure drop caused by the action of the j-th production well (V4 (yj, τ)) can be written in the form $V_4(y_j) = \Delta H_y = K_y \cdot \Delta Q$ [1]. For the above physical properties of the aquifer (ΔHy = 2 m), in the steady state flow rate

ΔQ = $\Delta H_y / K_y$= 2/0.001914 = 2612.33 m3 / day

Consider the first case with a transmission coefficient depending on the value of the radius of the "well" equal to unity [6]. At this stage, we conduct research in a static mode, setting a constant flow rate of 100 m3. We carry out verification by accepting a coefficient equal to 0.001914827 (Fig. 2).

Fig. 2. Determining the value of lowering the level of a real well

The resulting value is 0.7, the accepted value is 0.6. It is necessary to determine how many times it is required to increase (decrease) the coefficient. The coefficient value is 0.857. During verification, we increase the correction factor at 0.857.

We will re-verify to confirm the correct calculation of the coefficients (Fig. 3).

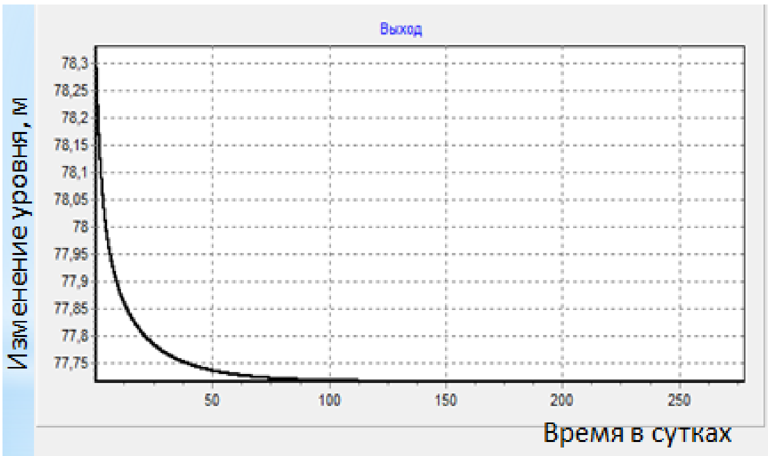

Fig. 3. Verification of verification results

From here we determine the value of K1 for the first well, equal to 605.013.

Next, we examine the dynamic system. For this, it is necessary to add a sinusoidal effect (Fig. 4) [7].

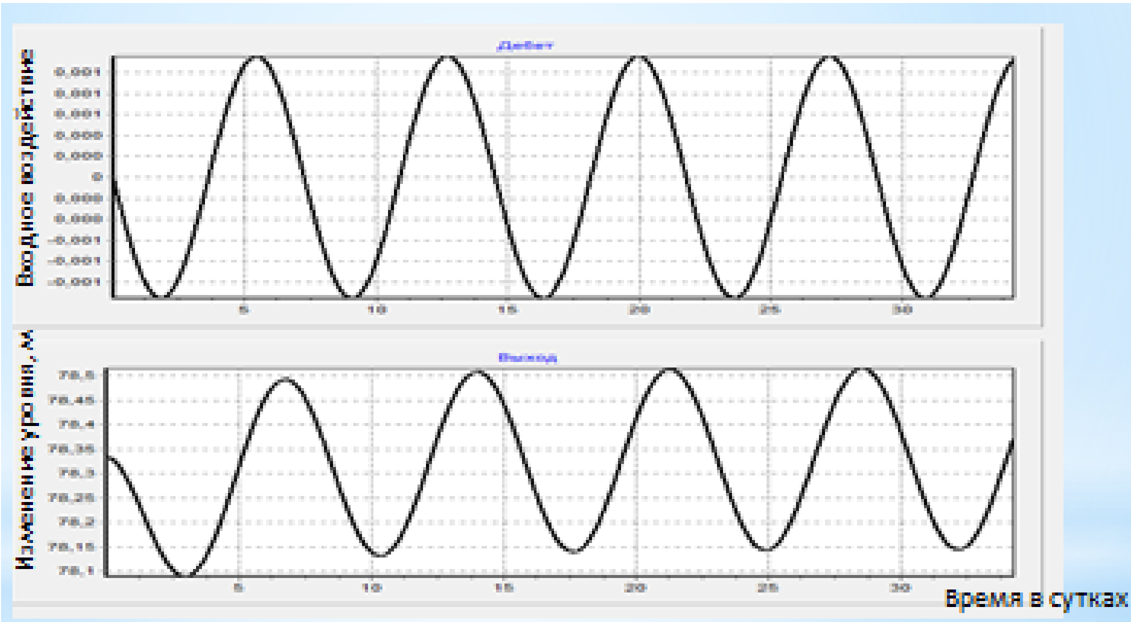

Fig. 4. Determination of the phase value

Consider the second case with a transmission coefficient that depends on the value of the radius of the "well" equal to ten. At this stage, we conduct research in static mode, setting a constant flow rate of 100 m3. We carry out verification by accepting a coefficient equal to 0.0011613.

The resulting value is 0.45, the accepted value is 0.6. It is necessary to determine how many times it is required to increase (decrease) the coefficient. The coefficient value is 1.333. During verification, we increase the correction factor in 1.333.

We will re-verify to confirm the correct calculation of the coefficients.

From here we determine the value of K1 for the first well, equal to 388.937.

Consider the third case with a transmission coefficient depending on the value of the radius of the “well” equal to thirty. At this stage, we conduct research in a static mode, setting a constant flow rate of 100 m3. We carry out verification by accepting a coefficient equal to 0,0003871.

The resulting value is 0.14, the accepted value is 0.6. It is necessary to determine how many times it is required to increase (decrease) the coefficient. The value of the coefficient is 4.2857. During verification, we increase the correction factor in 4.2857.

We will re-verify to confirm the correct calculation of the coefficients [4].

So, we determine the value of K1 for the first well, equal to 361.664.

Next, we examine the dynamic system. For this, a sinusoidal effect must be added.

During verification and determining the response of the system to the selected spatial modes, the following values of the coefficients K1 and phase Δφ, are obtained, which are presented in Table. 1 and the following graph is constructed, which determines the nonlinear dependence of K (R) on R_0.

Table 1

The resulting values of the coefficients

Static Mode			Dynamic Mode		
Coefficient value 0.001914 with R = 1	Coefficient value 0.0011613 with R = 10	Coefficient value 0,0003871 with R = 30	Coefficient value 0,001914 with R = 1	Coefficient value 0,0011613 with R = 10	Coefficient value 0,0003871 with R = 30
K_1	K_1	K_1	φ	φ	φ
605,013	388,937	361,664	-1,102	-1,102	-1,102

To plot the dependence, we apply the Lagrange interpolation polynomial [2] in the form of Newton:

$$K_1\ (R) = K_0 + (R - R_0) * \frac{K_1 - K_0}{R_1 - R_0} + (R - R_0) * (R - R_1) * \frac{\frac{K_2 - K_1}{R_2 - R_1} - \frac{K_1 - K_0}{R_1 - R_0}}{R_2 - R_1} \quad (6)$$

$$K_1\ (R) = 1{,}1322R^2 - 36{,}463R + 640{,}3434$$

when R_0 = 1; R1 = 10; R2 = 30;

K0 = 605.013; K1 = 388.937; K2 = 361.664.

In fig. 6, the following graph is constructed, which determines the nonlinear dependence of K(R_n) on R_0.

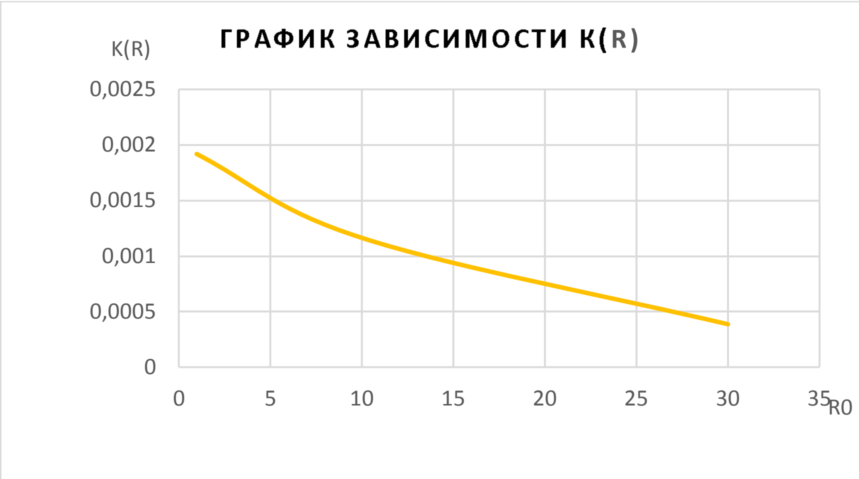

Fig. 6. Nonlinear dependence of K (R_n) от R_n

Conclusion. The description of the reaction of the system to a change in the radius of the well is considered. Applying the Lagrange interpolation polynomial in Newton's form, we obtain a graph of the nonlinear dependence of K (Rn) on Rn.

The obtained dependences allow us to develop an adaptive procedure for determining the parameters of the controller depending on changes in the radius of the "well".

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Дата поступления в редакцию: 25.11.2019
После рецензирования: 23.02.2020
Дата принятия к публикации: 03.03.2020