MODELING AND NANOTECHNOLOGY

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ON A METHOD OF MODELING THE TEMPERATURE FRONT IN A CIRCULATORY SYSTEM

The dynamics of objects with distributed parameters is described by differential equations in partial derivatives of parabolic type, which with boundary conditions are mathematical models of many nonstationary nonlinear processes. Mathematical model heat and mass transfer in is a system of equations of parabolic type with the same boundary conditions.

Let's assume that the operating time of the circulation system is limited by the time of reaching the temperature front of the production well. Studies [1] have shown that the heat flow from the surrounding massif in real formation conditions does not show a significant effect on the operation of the circulating system at a constant temperature. Therefore, in the calculations of heat flow is neglected. In the production of geothermal energy there is a pressure filtration, in which the value of μ has a value of about 10-6 m-2. In this regard, the system goes into steady state for a short time compared to the time of its operation.

Assuming that the temperature of the liquid changes abruptly from T_{hot} – the temperature of hot water to T_{cold} – the temperature of cold water, the boundary G of the transition from one temperature to another is the temperature front. The filtration coefficient (in the general case can be piecewise constant, ie depending on the coordinates) when crossing the boundary G varies from K_{hot} – hot water filtration coefficient to K_{cold} – cold water filtration coefficient.

The following method is proposed for modeling the motion of the temperature front, based on the continuity of the fluid flow at the boundary G

$$-K_{cold}\left.\frac{\partial H_{cold}}{\partial n}\right|_G = -K_{hot}\left.\frac{\partial H_{hot}}{\partial n}\right|_G .$$

Taking into account all the above and considering the thickness of the layer as a piecewise constant, from the original system of differential equations [2, (1) - (2)] we move on to the next system of equations

$$K_{cold}m\frac{\partial^2 H_{cold}}{\partial x^2} + K_{cold}m\frac{\partial^2 H_{cold}}{\partial y^2} = 0, \quad (1)$$

$$K_{hot}m\frac{\partial^2 H_{hot}}{\partial x^2} + K_{hot}m\frac{\partial^2 H_{hot}}{\partial y^2} = 0. \quad (2)$$

We make a discretization in space of the system of equations (1) and (2) using finite difference schemes**.** Then the system of equations for node i , j in the finite difference form will look like:

$$\frac{K_{cold}m}{h^2}\Big[\left(H_{i+1,j}^{cold} - H_{i,j}^{cold}\right) + \left(H_{i-1,j}^{cold} - H_{i,j}^{cold}\right) +$$
$$+\left(H_{i,j+1}^{cold} - H_{i,j}^{cold}\right) + \left(H_{i,j-1}^{cold} - H_{i,j}^{cold}\right)\Big] = 0;$$
$$\frac{K_{hot}m}{h^2}\Big[\left(H_{i+1,j}^{hot} - H_{i,j}^{hot}\right) + \left(H_{i-1,j}^{hot} - H_{i,j}^{hot}\right) +$$
$$+\left(H_{i,j+1}^{hot} - H_{i,j}^{hot}\right) + \left(H_{i,j-1}^{hot} - H_{i,j}^{hot}\right)\Big] = 0.$$

By introducing the scale $H = K_H U + H_{\min}$ we get

$$\frac{K_{cold}m}{h^2}\left(U_{i+1,j}^{cold} + U_{i-1,j}^{cold} + U_{i,j+1}^{cold} + U_{i,j-1}^{cold} - 4U_{i,j}^{cold}\right) = 0; \quad (3)$$

$$\frac{K_{hot}m}{h^2}\left(U_{i+1,j}^{hot} + U_{i-1,j}^{hot} + U_{i,j+1}^{hot} + U_{i,j-1}^{hot} - 4U_{i,j}^{hot}\right) = 0. \quad (4)$$

Kirchhoff's law for node i , j of the resistive grid is written as follows

$$\frac{1}{R_{cold}}\left(U_{i+1,j}^{cold}+U_{i-1,j}^{cold}+U_{i,j+1}^{cold}+U_{i,j-1}^{cold}-4U_{i,j}^{cold}\right)=0; \quad (5)$$

$$\frac{1}{R_{hot}}\left(U_{i+1,j}^{hot}+U_{i-1,j}^{hot}+U_{i,j+1}^{hot}+U_{i,j-1}^{hot}-4U_{i,j}^{hot}\right)=0. \quad (6)$$

From equations (3)-(6) we can obtain the following expressions for the resistance of the grid and currents simulating the flow of liquid

$$R_{cold}=\frac{K_R}{K_{cold}m},\ R_{гар}=\frac{K_R}{K_{hot}m},\ i=\frac{QU}{HK_{hot}mR_{hot}}.$$

The radial nature of the fluid flow near the wells is taken into account by the additional resistance, which is determined by the formula:

$$R_{add}=R\left(\frac{1}{2\pi}l_n\frac{h}{r_{well}}-\frac{1}{n}ctg\frac{\pi}{n}\right).$$

References:

1. V.I. Lialko & M.M.Mitnik (1976) Issledovanie processov perenosa tepla i veshhestva v zemnoj kore [Research of Heat and Matter Transfer Processes in the Earth's Crust]. Kyiv: “Naukova dumka” [in Russian].
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