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RELAXATION DRAWING MODELS

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ABSTRACT

Numerical modeling of inverse problem relaxation filtration of a homogeneous liquid in the porous media
In thispaper pressure-conductivity and relaxation time for pressure gradient are identified by solving of inverse problem. The regularization method is used for perturbed initial data. Effectiveness of first and second order methods is comparatively analyzed.

One of the first works in this direction is [1]. The authors of this work, based on a large number of experimental data, showed a relaxation change in the rate of leakage in the flow of polymer mixtures at a constant pressure difference through the porous medium. This phenomenon is explained by a specific unbalanced leakage current. Based on the kinetic theory, the leakage is structured with a quantitative relationship between cost and time and is well consistent with the experimental results.

[2] considered some one-dimensional non-stationary leakage problems, assuming that the pressure gradient in the elastic mode lags behind the leakage rate. The connection, which takes into account the dependence of the pressure gradient of this nature on the rate of leakage, is made by generalizing the law of the lesson, in the case of a linear connection, this connection has the following form.

$$v = -\frac{k}{\mu}\left(\frac{\partial p}{\partial x} + \lambda \frac{\partial^2 p}{\partial x \partial t}\right), \qquad (1)$$

In this point v – infiltration rate, k – layer permeability, μ – fluid viscosity, $p(x,t)$ – pressure, λ – pressure gradient relaxation time. (1) the physical meaning of the equation (1.1) as shown in the case above, if in a previously calm liquid v_0 with a constant leakage rate set, then the corresponding pressure gradient is not set all at once, but gradually with some delay

$$\frac{\partial p}{\partial x} = -\frac{\mu v_0}{k}\left[1 - \exp\left(-\frac{t}{\lambda}\right)\right]. \qquad (2)$$

(2) as can be seen from, λ parameter does not change v_0 characterizes the rate of setting a constant pressure gradient corresponding to the rate of leakage.

In addition, the following equation of permeability is derived from the general assumptions of the theory of elastic regime [4] using (2).

$$\frac{\partial p}{\partial t} = \chi\left(\frac{\partial^2 p}{\partial x^2} + \lambda \frac{\partial^3 p}{\partial x^2 \partial t}\right), \qquad \chi = \frac{k}{\mu(m\beta_{ж} + \beta_c)}, \qquad (3)$$

In this point χ - pressure permeability coefficient, m - porosity, $\beta_{ж}$, β_c - the coefficients of compressibility of the liquid and the layer, respectively.

[3] The problem of delay in the occurrence of an imbalance between the pressure gradient and the rate of leakage is discussed in the study, the conditions of the study are as follows:

a) velocity inertia and the delay of its values from the values of the pressure gradient;

b) delay of pressure relaxation and pressure gradient values from leakage rate values;

(c) the complex structure of the porous medium and the delay in establishing equilibrium in the micro-pores;

d) delay in particle placement due to changes in porosity, permeability, etc.

In the study, the connection (1) is generalized, taking into account the delay in the rate of leakage

$$v+\lambda_v\frac{\partial v}{\partial t}=-\frac{k}{\mu}\left(\frac{\partial p}{\partial x}+\lambda_p\frac{\partial^2 p}{\partial x\partial t}\right), \qquad (4)$$

In this point λ_v - leakage rate relaxation time.

Similarly, the following nonstationary equation is derived from (3)

$$\frac{\partial p}{\partial t}+\lambda_v\frac{\partial^2 p}{\partial t^2}=\chi\left(\frac{\partial^2 p}{\partial x^2}+\lambda_p\frac{\partial^3 p}{\partial x^2\partial t}\right). \qquad (5)$$

[5] an integral model of unbalanced leakage has been proposed in the study. The proposed model is shown to be well compatible with the experimental data.

The following law can be applied in one-dimensional study of the motion of liquids, taking into account the forces of inertia in a homogeneous porous medium. [13, 14]

$$v+\lambda_v\frac{\partial v}{\partial t}=-\frac{k}{\mu}\cdot\frac{\partial p}{\partial x}. \qquad (6)$$

Given λ_v and λ_p the parameters are in the form of some variables in (1), (4), (6), which are determined by the viscosity of the fluid, the elasticity of the porous medium blocks, and the fluid exchange between the blocks and cracks. $$m+\lambda_c\frac{\partial m}{\partial t}=m_0+\beta_c\left(p-p_0\right), \qquad (7)$$

In this point m, m_0 - current and initial porosity, β_c - coefficient of volumetric elasticity of the layer, λ_c - porosity relaxation time.

If we take the law of gravity in the form of a balanced lesson law (in one dimension), that is

$$v=-\frac{k}{\mu}\cdot\frac{\partial p}{\partial x}, \qquad (8)$$

In this case, taking into account (7), we obtain this equation of pressure permeability

$$\frac{\partial p}{\partial t}+\lambda_c\left(1-\frac{\beta_c}{\beta^*}\right)\frac{\partial^2 p}{\partial t^2}=\chi\left(\frac{\partial^2 p}{\partial x^2}+\lambda_c\frac{\partial^3 p}{\partial x^2\partial t}\right), \qquad (9)$$

which corresponds to the designation (5).

In [21, 22] the law of leakage is written in the following integral form

$$\vec{v} = -\frac{k}{\mu}\int_{-\infty}^{\infty} K(t-\xi)\nabla G(\xi)d\xi, \qquad (10)$$

In this point $G = p + \rho\varphi$, φ – gravitational potential, $K(t)$ and does not depend on spatial coordinates and satisfies the following conditions:

a) $K(t)$ function (time)$^{-1}$ can be dimensional and generalized;

б) $\int_{-\infty}^{\infty} K(\xi)d\xi = 1$.

To be precise, a subtraction equation is written, which is solved just like a linear operator. In reducing porous media (8) the law of equilibrium is not followed and model (10) must be applied. The pressure gradient relaxation time range was experimentally estimated.

(4) The model is called a two-way relaxation model. In general, it is possible to write its various generalizations in linear differential rheological models of viscous fluids. In particular, polynomial-type differential operators can have the following appearance.

$$P(D)\vec{v} = -\frac{k}{\mu}\text{grad}(Q(D)p), \qquad (11)$$

In this point

$P(D) = 1 + p_1 D + \ldots + p_n D^n$, $Q(D) = 1 + q_1 D + \ldots + q_m D^m$, $D = \partial/\partial t$, $D^i = \partial^i/\partial t^i$,

$\sqrt[i]{p_i}$, $\sqrt[i]{q_i}$ - leakage rate and pressure gradient relaxation times.

It is usually difficult to apply (11) for practical calculations, $\sqrt[i]{p_i}$, $\sqrt[i]{q_i}$ it is extremely difficult to determine relaxation times experimentally. Therefore, model (4) is widely used.

As noted at the beginning of the paragraph, in some cases it is necessary to take into account the relaxing nature of the equation of state. This is true for heavy oils, polymer compounds, drilling fluids and other fluids, as well as other relaxation phenomena. [23] proposed the following relaxation state equation

$$\rho_0\beta_{ж}\left(p + \lambda_1\frac{\partial p}{\partial t}\right) = \rho + \lambda_2\frac{\partial \rho}{\partial t}, \qquad (12)$$

here ρ_0 - initial density, $\beta_{ж}$ - coefficient of volumetric elasticity of the liquid, λ_1, λ_2 - fluid pressure and density relaxation times.

(12) The following equation is obtained for the pressure using the simple Darsi law of the form (8)

$$\frac{\partial p}{\partial t} + \lambda_1\frac{\partial^2 p}{\partial t^2} = \chi\left(\Delta p + \lambda_2\frac{\partial}{\partial t}\Delta p\right), \qquad (13)$$

this is no different from the form of equations (5) and (9).

[23] proposed a hereditary model of leakage of dilatant fluids. Based on the constructed model, the effect of non-monotonic pressure curve recovery (CCR) for heavy oils and the extinction of consumption at constant pressure difference are explained.

It is clear from the data presented that hypothetical relaxation leakage models can be accepted in different ways. However, a common shortcoming of all such models is that they do not depend on the relaxation properties of the relaxation properties of the liquid and the porous medium.

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