Identification of transport and clogging parameters of porous media

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Abstract: In this work, the process of solute transport through a porous medium is experimentally studied. The experimental setup is constructed from a copper tube filled with a porous medium. Glass balls are used as porous filler. Distilled water is pumped through the tube, pumping is carried out with a constant initial pressure drop between the inlet and outlet. A pumping of constant concentration NaCl solution starts in initial time moment. Simultaneously, the measurement of NaCl concentration and mixture flow rate at the outlet begins. The measurement is carried out continuously until the registration zero concentration and constant flow rate. To estimate the transport parameters of the medium, a one-dimensional problem of the solute transport was solved numerically. It was assumed that the permeability is an unambiguous function of the porosity of the medium. To model this dependence, the Kozeny-Karman relation was used. The solute transport was modeled within the MIM approach. It was assumed that in this case the porosity of the medium decreases in proportion to the volume concentration of the adsorbed solute. Based on the comparison of the experimental data with the data obtained in the course of numerical simulation, we solve inverse problem of identifying the transport parameters of the medium. The work was supported by the Russian Science Foundation (Grant No. 20-11-20125)

Experimental setup

1- Mariotte’s bottle, the constant pressure drop δp=pgΔΔ
2- Manometric tubes
3- Working domain with porous media, porosity 0.365, length L=392 mm, diameter 15.6mm
4- The outlet container

The experiment

The salt water with mass m=27g and salt concentration C0 is injected to saturated porous medium during the time t'. After time t' the concentration of salt becomes 0. The salt concentration and mass flux is measured at outlet.

MIM approach with clogging

\[ \text{div} \, \mathbf{u} = 0, \quad \mathbf{u} = \frac{\alpha(v)}{\eta} \nabla p, \]

\[ \frac{\partial (\alpha(v) \mathbf{v})}{\partial t} = -\mathbf{u} \cdot \nabla v + D \nabla^2 (\alpha(v) \mathbf{v}). \]

\[ \frac{\partial \alpha(v)}{\partial t} = a(v, q) - k \cdot \alpha(v), \]

\[ \varphi = \varphi_0, \quad \alpha(v) = K \left( \frac{v}{v_0} \right), \]

\[ \varphi - \text{porosity}, \quad \varphi_0 - \text{porosity of clean media}, \]

\[ K - \text{Carman-Kozeny constant}, \]

\[ w - \text{filtration velocity}, \quad p - \text{pressure} \]

\[ c, q - \text{mobile and immobile concentrations}, \]

\[ \alpha - \text{permeability}, \quad D - \text{diffusivity}, \]

\[ a, b - \text{adsorption and desorption rates}, \]

\[ q_s - \text{saturation of immobile concentration}. \]

Weak clogging assumption (1D problem)

\[ \frac{\partial (\alpha(v) \mathbf{v})}{\partial t} = -\mathbf{u} \cdot \nabla v + D \nabla^2 (\alpha(v) \mathbf{v}). \]

\[ \frac{\partial \alpha(v)}{\partial t} = a(v, q) - k \cdot \alpha(v), \]

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Test of inverse problem

\[ \text{min} E \text{ obtained by BFGS method} \]

where \[ \nabla E = \frac{\partial E}{\partial a} \frac{\partial E}{\partial b} \frac{\partial E}{\partial D} \frac{\partial E}{\partial z} \]

is calculated by adjoint state [2]

test of inverse algorithm is presented in plot red curve - generated data (instead of experimental) black curve - data calculated for n-th iteration of BFGS method

Inverse problem

The modelling of 1D transport and inverse problem

The modelling of experiment

The identification of experiment parameters

\[ \delta p = 130 \text{ Pa} \]

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\[ a, b, D, c, z \]

\[ \alpha, \beta, \gamma, \delta, \epsilon, \theta, \zeta \]

\[ \varphi_0, \varphi, \alpha, K, w, c, q, \]

\[ q_s - \text{saturation of immobile concentration}. \]