Simulation of Mass-transfer Process in Porous Media with Complex Shape

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1 Introduction

Some rare minerals and metals are extracted by underground leaching method. Thus sorption extraction of minerals on mass-transfer devices with ionite resines is the widespread method. The sorber which scheme is sketched in Fig. 1 makes wide use on practice.

![Fig. 1 Scheme of sorption column](image)

The sorber represents a cylindrical column, which height is H and diameter – D. The sorber is filled by a layer of ionite sorbents in the form of spherical porous granules in diameter d. The solution with sorbing mineral is pumped over through a column with the certain velocity. The charge (or average velocity) of solution defined from kinetic parameters of sorption. A cone barrier located in front of pipe is intended for achievement of uniform distribution of a solution across a column. Sorption proceeds until output concentration of a mineral does not become below some limiting value.

2 The formulation of a problem

It is supposed that filtration of passive solution in sorption column is described by the equations of fluid dynamics in a granular layer [1]

\[ \text{div} \vec{V} = 0, \quad \alpha \vec{V} = -\nabla (P/\rho + zg), \]  

(1)
Simulation of Masschange Process

\[ \alpha = \frac{633 \nu r}{d^2}, \quad \tau + \varepsilon = 1, \]  

(2)

where \( \nu \) - velocity of solution, \( P \) - pressure in porous media, \( \rho \) - density of solution, \( z \) - vertical coordinate in cylindrical system of coordinates, \( g \) - gravity acceleration, \( \nu \) - kinematic viscosity of solution, \( d \) - diameter of granules, \( \tau \) - volumetric concentration of granules, \( \varepsilon \) - porosity of layer filled by granules. Mineral sorption process in a reactor is described by the following non-stationary equations

\[
\begin{aligned}
\frac{\partial C}{\partial t} + \vec{V} \cdot \nabla C &= -\frac{\rho}{\varepsilon} \frac{\partial \bar{C}}{\partial t} + \text{div}(D \nabla C), \\
\rho \frac{\partial \bar{C}}{\partial t} &= \beta \left( C - \frac{\bar{C}}{K_d} \right),
\end{aligned}
\]

(3)

(4)

where \( C \) - volumetric concentration of a mineral in a solution, \( \bar{C} \) - mass concentration of a mineral in firm granules, \( \beta \) - velocity of transition of a mineral between dissolved and firm phases, \( K_d \) - coefficient of equilibrium, \( D \) - tensor of diffusions with nonzero diagonal coefficients. In computation it is accepted, that, \( D_y = D_u + \delta \nu \cdot D_r = D_u + \delta \nu \cdot \delta_r = 1.8 d \cdot \delta_r = 0.7 d \cdot D_u \) - coefficient of molecular diffusion, \( d = 0.5 \text{ mm}, \varepsilon = 0.4 \). Volumetric concentration of a mineral at an input in a solution is 0.136 g/l. Admissible volumetric concentration of mineral on an output is no more 0.057 g/l. Boundary condition on wall:

\[ \vec{V} \cdot \vec{n} = 0, \quad \frac{\partial C}{\partial n} = 0 \]

(5)

Fluid velocity and volumetric concentration of a mineral in a solution on inlet of sorber are set:

\[ \vec{V} = u_0, \quad C = C_0 \]

(6)

At the initial time the column is filled by a solution and sorbent which is not containing a mineral:

\[ C = 0 \]

(7)

The system of the nonlinear equations (1) - (4) with these boundary and initial conditions (5) - (7) is solved with application of numerical methods. The fictitious domain method [2] is used for simulation the solution filtration in a column with complex geometry. Kinetic parameters of mineral sorption \( \beta \) and \( K_d \) are defined by comparison of computations results with data of physical experiment [2]. In experiment of filtration and sorption processes are as much as possible approached to 1D case. On fig. 2 comparison of the received results of a mineral concentration in a solution with experimental data on different distances from an input in a column is shown. At values of parameters and \( \beta = 1500 \text{ kg/(m}^3\text{s}) \) and \( K_d = 400 \text{ m} \) available the satisfactory consent of

![Fig. 2 Comparison of the received results on sorption kinetics with experimental data](image)

settlement data with experimental data.
3 Results

Numerical results for distribution of pressure shown on Fig. 3. And for isoline of mass concentration of a firm phase shown on Fig. 4, that it with different values in the left half (the right half is mirror symmetric, i.e. axisymmetric) of column cut on a vertical.

References
