OSCILLATORY MODES OF ADSORPTION IN THE FLOW OF MULTICOMPONENT SYSTEMS

Liana Kovaleva, Marat Mavletov
Bashkir State University, Frunze 32, 450074, Russia, Liana@ic.bashedu.ru

Summary A system of equations describing flow of multicomponent mixtures in a porous medium, taking into account the phenomena of competing adsorption is formulated. An equation of sorption kinetics, which describes a series of oscillatory modes for certain of the original parameters, is suggested. A quantitative and qualitative numerical analysis is carried out for formulated problem. A qualitative comparison of the results of calculations and experimental data is given.

Experimental investigations of adsorption phenomena in multicomponent systems show the presence of competing effects, which lead to a non-monotonic distribution of adsorbents on the surface of a solid. A mutual influence of the components on the degree of adsorption of each of them is observed [1]. A system of equations describing flow of multicomponent mixtures in a porous medium includes equation of material balance, sorption kinetics equation, relaxation equation, Darcy's law and piezoconductivity equation [2]. The relaxation equation taking into accounts a non-equilibrium nature o the sorption process. The sorption kinetics equation taking into accounts influence of the components on the degree of adsorption on the surface of a solid.

The formulated initial-boundary-value problem in the special case of two-component sorption was solved numerically by a difference method and using the checkerboard scheme. All the results obtained can be divided into two classes: (1) solutions of the traveling concentration wave type, and (2) solutions corresponding to the various oscillatory processes. Solutions of the first class occur in cases when one of the components clearly predominates over the others either in speed, or in degree of adsorption activity on the surface of the skeleton of the porous medium. Solutions of the second class are if the greatest interest from the point of view of confirming the competitive of the adsorption. Various types of oscillations are possible in the concentration distributions as was shown by the numerical experiment.

The solutions of the problem depend very much on the sorption kinetics equation. In this connection, the stability of the systems of equations of sorption kinetics was analyses for the case of two simultaneously adsorbing components. Region of existence solutions (1) and (2) was founded numerically by the Runge-Kutta method for a wide range of values of its coefficients. An insignificant change in the values of some parameters substantially changes the nature of the process from decaying oscillations, which is due to the presence of singular point of the stable focus, to chaotic oscillations (Fig. 1), connected with occurrence of singular points of the unstable focus type and limiting cycles. Oscillations in the distribution of concentration of adsorbents (a_1, a_2) on the surface of a solid raise the oscillation in the distribution of concentration of components in a moving phase (c_1, c_2).

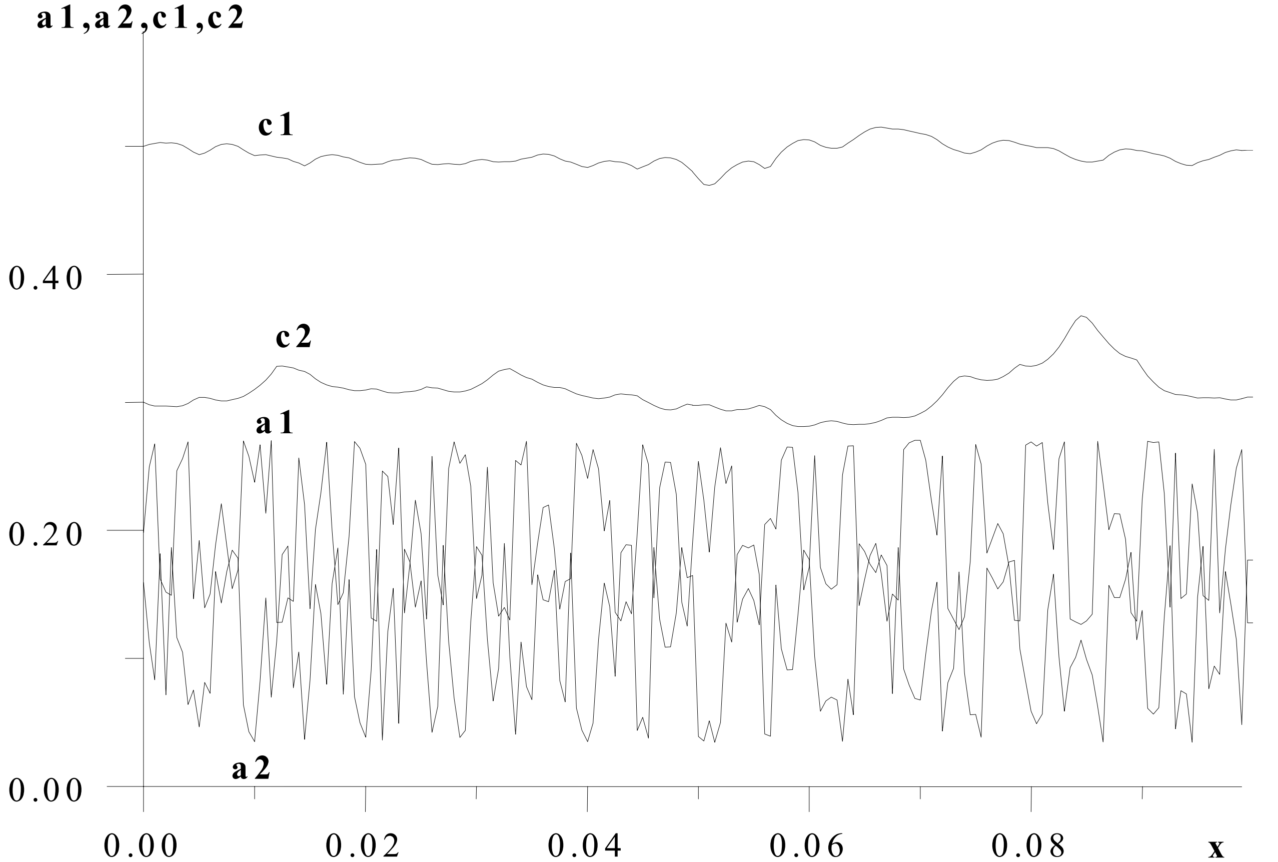

Fig. 1

Phase diagrams in the (c_1, c_2) plane (Fig. 2) show the presence of strange attractor.

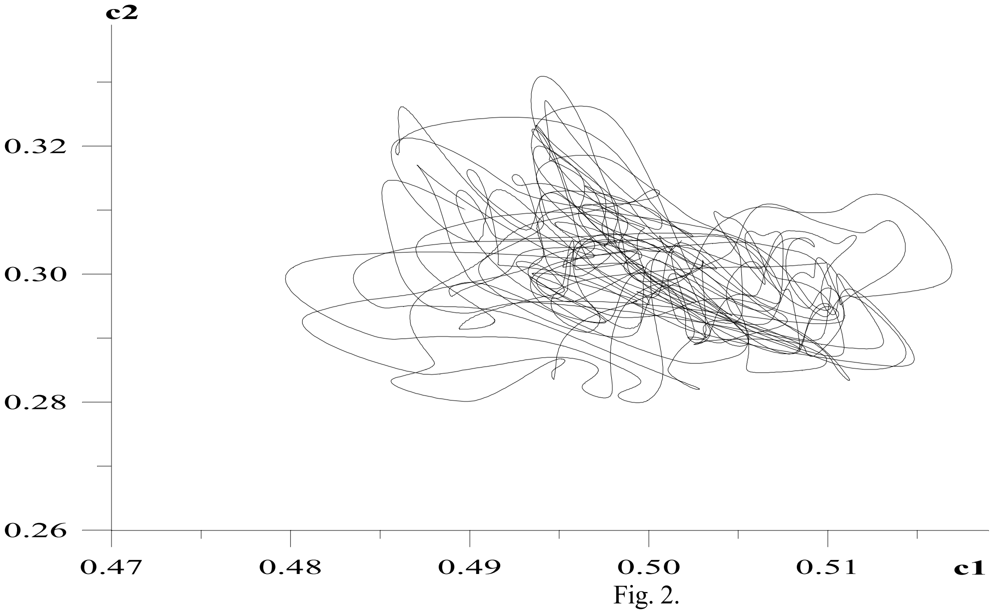

Fig. 2.

The correlation dimension of this attractor is 2.603. This confirms chaotic nature of distribution of adsorbents on the surface of a solid.

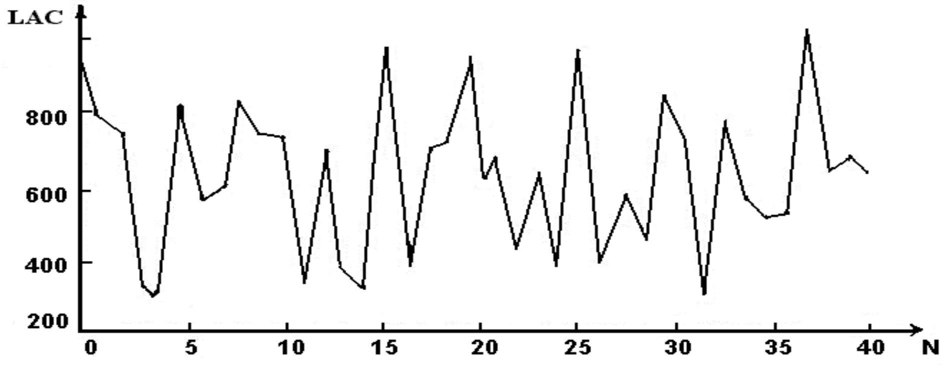

Fig. 3.

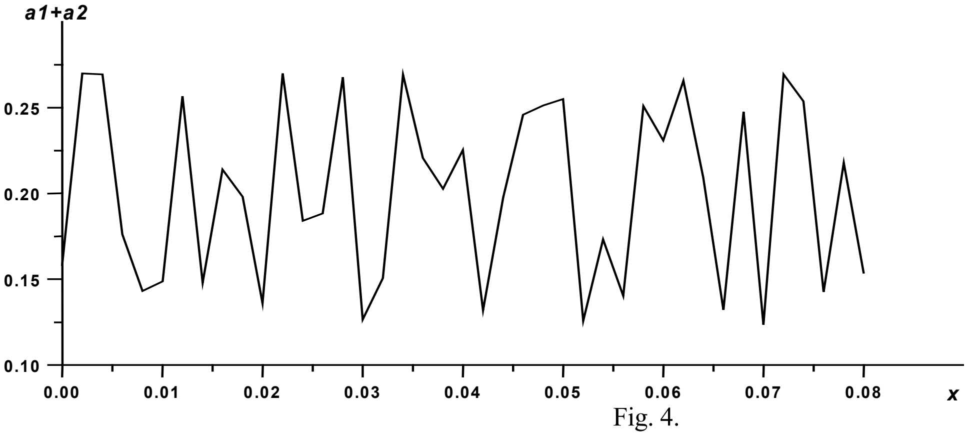

Fig. 4.

The conclusions on the behaviour of the parameters of multicomponent sorption, obtained on the basis of the mathematical model, agree completely with the results of specially conducted experiments [3]. The longitudinal distribution of light adsorption coefficient, which quantitatively characterizes the content of the adsorbent residue, along the model of porous medium was found to be non-linear. The results obtained show good qualitative similarity between the experimental data (Fig. 4) and the numerical calculations (Fig. 3) and the oscillatory nature of the competing adsorption processes.

References

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