and j to two other states. The time intervals and mass-transfer coefficients obtained on samples of the composites analogous to that corresponding to the tomogram in Fig. 1 are considered. It follows from Fig. 3 that: assuming the best material has the least tortuosity, the most acceptable is that in which the layers are characterized by the same properties with respect to moisture migration. In this case, ε is a minimum, and depends only on the ratio \( L_x/L_y \). With a purely diffusional process, \( L_y = 0 \), and hence ε is not determined. Increase in the difference between \( t_i^j \) leads to increase in ε. As shown by calculations, moisture migration characterized by the tortuosity is determined basically by the times \( t_i^j \) and is practically independent of \( \delta_i \). The results obtained may be extended to any number of layers.

Thus, the tortuosity factor of pores has been estimated as a random parameter of moisture absorption in composites. In the present case, it characterizes the pore space of the material over its whole volume and may be used in mathematical models of moisture transfer.

NOTATION

\( n \), number of layers in material; \( \bar{t}_k \), mean residence time in k-th state in Fig. 2, taking no account of internal diffusion; \( L_x, L_y \), mass-transfer coefficients along x and y axes, respectively.

LITERATURE CITED


NONSTEADY TRANSFER AND DISPERSIONAL EFFECTS IN HETEROGENEOUS MEDIA

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A single transport equation taking account of the dispersion of effective conductivities and interphase exchange due to relaxation effects, as well as the inhomogeneity of the corresponding fields, is obtained in Laplace transforms. The asymptotes of this equation are considered.

The problem of adequate description of heat and mass transfer in heterogeneous and, in particular, granular media has been under intensive study for several decades now. Methods of engineering calculation based on semiempirical models have been proposed, leading to completely satisfactory results in many situations; see the review [1], for example. However, as yet there is no general theory indicating the regions of validity of these methods and models and extending them to processes in which nonsteady effects, sources, and sinks due to phase and chemical transformations and diverse nonlinear phenomena are of fundamental importance [2]. In practice, as before, the phenomenological model based on the concept of parallel transport in the two phases of a heterogeneous medium is most often used; this model leads to a system of two linear equations with constant coefficients [1, 3, 4] or to a single equivalent transport equation, which may be formally obtained from this system [5, 6].

The applicability of these equations is limited to processes which are very close to steady state. Generalization to a situation which is very unsteady is difficult in that...
several relaxation processes with comparable (generally speaking) relaxation times occur simultaneously in the system and dispersional phenomena associated both with transit through the heterogeneous medium and with transfer between its phases are present simultaneously [7]. The dispersion of the interphase flux was considered recently under the assumption that only relaxation of the temperature or concentration field within the particles of disperse phase in practically homogeneous conditions has the determining role [8, 9]. This leads directly to the explanation of a series of generally observed effects. Results of similar significance were obtained recently for polydisperse media, taking account of some nonlinear phenomena at the phase interface [10, 11]. In all cases, nonsteady behavior of the phase-transfer coefficient leads to a nonlocal (in time) equivalent equation containing integral hereditary terms [7-11]. Analogous equations with a series of simplifying assumptions were obtained earlier in filtration theory in cracked porous media, the mathematical formulation of which has much in common with that of the problem of heat and mass transfer [12-15]. In the present work, for the example of heat transfer in a granular medium, in the absence of contact heat conduction through the grain body, the dispersion of both interphase transfer and effective heat flux is taken into account, as well as the inhomogeneity of the temperature field.

2. Bearing in mind that, as in [8, 9], the dynamics of temperature-field variation within an individual particle must be considered, taking account of the temperature relaxation and inhomogeneity outside the particle, the same transfer theory as in [7, 16] is used, on the basis of the method of ensemble averaging and the concepts of self-consistent field theory. According to this theory, the effective heat fluxes in a granular medium and interphase heat transfer are expressed as integrals, the integrands of which depend on the distribution of the mean temperature in a single (trial) particle. It is convenient to introduce dimensionless coordinates $r$ with the scale $a$ and time $\tau_0$ with the scale $a^2/\kappa_2$ and to apply at once Laplace transformation with respect to the time with parameter $p$. This yields the equations

\[
\frac{\kappa_2}{a^2} \frac{\partial^2 \tau_1}{\partial r^2} = -\frac{1}{a} \nabla q + H, \quad \frac{\kappa_2}{a^2} \rho \frac{\partial \tau_2}{\partial r} = -H, \tag{1}
\]

where

\[
q(R) = -\frac{\lambda_1}{a} \nabla \tau - (\lambda_2 - \lambda_1) \frac{3p}{4a} \int_{|R-R'| \leq 1} \nabla R^\tau (R|R') dR',
\]

\[
H(R) = -\frac{3p\lambda_2}{4a^2} \int_{|R-R'| \leq 1} \Delta R^\tau (R|R') dR', \quad \tau = \tau_1 + \rho \tau_2,
\tag{2}
\]

and the integration is taken over the radius vector $R'$ of the trial particle (here and below, the functions and their Laplace transforms are denoted by the same symbols). In addition, the following formulas may be written for $q$ and $H$

\[
q = -\frac{\lambda_1}{a} \beta \nabla \tau, \quad H = -\frac{\lambda_2}{a^2} \rho \mu \tau, \tag{3}
\]

where $\beta$ and $\mu$ are unknown functions of the parameters of the medium and $p$; the dependence on $p$ determines the dispersion of the effective thermal conductivity $\lambda_1 \beta$ and also the interphase heat transfer.

Using Eq. (3), Eq. (1) is written in the form

\[
s^2 \tau = \Delta \tau, \quad \tau_1 = (1 - \rho \mu) \tau, \quad \tau_2 = \mu \tau,
\]

\[
s^2 = \frac{\kappa_2}{\kappa_1} \left[ 1 + \rho \left( \frac{c_2}{c_1} - 1 \right) \mu \right] \frac{p}{\beta}, \tag{4}
\]

and hence it follows, in particular, that the transforms of the mean temperatures of the phases are expressed in terms of the transform of the mean temperature of the medium as a whole.

Assuming, for the sake of simplicity, that the mean temperatures depend on only a single Cartesian coordinate $z = r \cos \phi$, $r = R - R'$ (it may be shown that this does not limit the generality of the theory), $\tau(R)$ is written as a Taylor expansion...