HEAT TRANSFER OF AROMATIC HYDROCARBONS IN A DOWNWARD FLOW AT SUPERCRITICAL PRESSURE

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UDC 536.24

This paper gives the results of experimental heat-transfer investigations on a downward flow of liquid at supercritical pressure.

The heat-transfer media used were toluene and benzene, which have the following critical parameters, respectively: p_{cr} = 4.2358 MPa, t_{cr} = 320.8°C and p_{cr} = 4.942 MPa, t_{cr} = 289.45°C.

Plots of $t_w = f(q)$ obtained for a turbulent flow of toluene and benzene from the readings of thermocouples located at approximately the same distance from the tube entrance and with π = 1.416 show that, when $t_w < t_m$, t_w increases linearly with increase in heat flux density (Fig. 1a, b). When t_w of the investigated substances reaches t_m the behavior of the temperature curve changes. As the heat flux density increases, the wall temperature remains approximately constant (t_w varies around t_m). At large values of q there is an increase in t_w.

*All-Union Institute of Scientific–Technical Information.

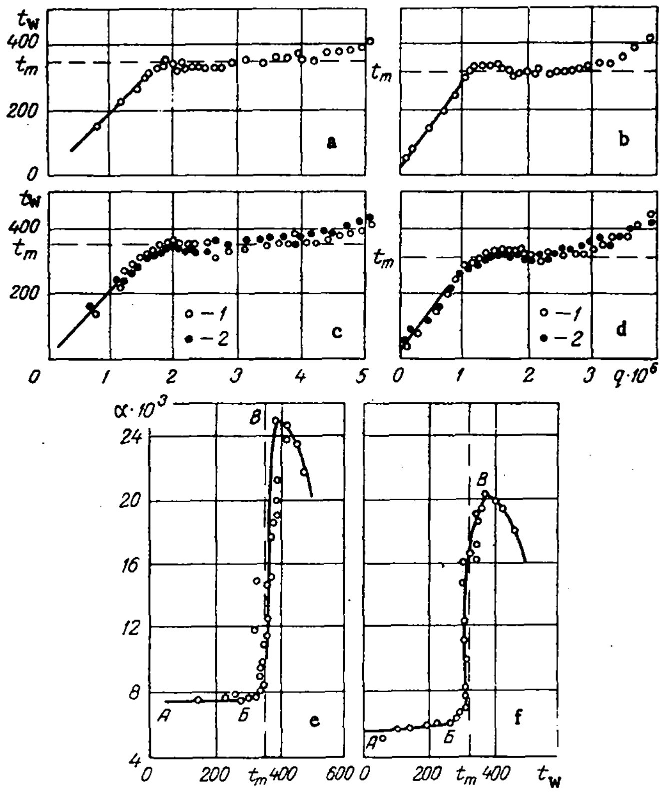

Fig. 1. Relations $t_w = f(q)$ and $\alpha = f(t_w)$ in case of a downward flow of toluene and benzene with π = 1.416 for ρw = 3440 and 2040 kg/(m^2 · sec), respectively, t_L^{in} = 25°C: a) toluene, x/d = 35; b) benzene, x/d = 33.3; c) toluene; 1) x/d = 19.3; 2) 65.0; d) benzene; 1) x/d = 19.0; 2) 62.0; e) toluene, x/d = 81.7; benzene, x/d = 76.2.

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In experiments with turbulent downward flow of toluene and benzene an improvement in heat transfer is obtained when $t_w \approx t_m$ and $q/\rho w \approx 0.6 \cdot 10^3$ J/kg. Plots of $t_w = f(q)$, obtained from readings of two thermocouples located at a distance of $x/d \approx 19$ and $x/d \approx 63$ from the tube entrance and with $\pi = 1.416$ indicate that in the case of a turbulent downward flow of liquid in a round tube the heat-transfer coefficient in any part of the flow is improved when $t_w \approx t_m$ (Fig. 1c, d).

Plots of $\alpha = f(t_w)$ for a turbulent downward flow of toluene and benzene (Fig. 1e, f) show that when $t_w < t_m$ the relation $\alpha = f(t_w)$ is the same as in the case of ordinary convective heat transfer, and when $t_w \approx t_m$ the heat transfer coefficient increases sharply with increase in heat flux density. The heat-transfer coefficient has a maximum value at point B. An analysis of the experimental data indicates that the above results are valid for tubes of any cross section.

NOTATION

t_w	is the wall temperature, °C;
t_L^{in}	is the liquid temperature at tube entrance, °C;
p	is the pressure, MPa;
p_{cr}	is the critical pressure, MPa;
t_{cr}	is the critical temperatures, °C;
q	is the heat flux density, W/m^2;
ρw	is the mass velocity, kg/(m^2 · sec);
t_m	is the pseudocritical temperature (temperature corresponding to maximum specific heat when $p > p_{cr}$), °C;
α_B	is the heat-transfer coefficient in normal conditions, W/(m^2 · °C);
α_C	is the maximum value of heat transfer coefficient in improved regime near pseudocritical temperature, W/(m^2 · °C).

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EFFECT OF NONUNIFORMITY OF HEAT FLUX DENSITY DISTRIBUTION ON CHARACTERISTICS OF AN ANISOTROPIC THERMOELEMENT

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UDC 621.382.2

Heat flux transducers often operate in conditions where the heat flux being measured is distributed nonuniformly over the receiving area of the transducer. The relation between the transducer, signal and the mean integral heat flux is usually based on the assumption that nonuniformity of the heat flux distribution has little effect. The nonuniformity of the heat flow density, however, leads to a direct error of measurement. In the case of a position-sensitive transducer the effect of nonuniformity on the transducer signal is of decisive importance.

In this paper the effect of nonuniformity of the heat flux density on the thermo-emf of an isotropic thermoelement is analyzed.

Assumptions of constancy of the physical properties of the thermoelement and the negligibility of the thermal effects of eddy currents on the temperature distribution, substantiated in [1, 4], reduce the problem to separate determination of the fields of temperature and electrochemical potential. The corresponding boundary-value problems are solved by the method of finite integral transforms. The solution gives an expression for the transducer thermo-emf in the following form:

$$E = -(\alpha_{11} - \alpha_k)\,(T(L, y) - T(0, y)) - \alpha_{12}\int_0^L \frac{\partial T}{\partial y}\,dx + \Phi_0(L, y) - \Phi_0(0, y).$$

The obtained formulas can be used to determine the thermo-emf for any relation q(x) between the heat flux density and the coordinate, but direct calculation from them is uneconomical. In view of this, calculations were made for the special case

$$q(x) = \begin{cases} 0, & \xi < x \\ 1, & \xi \geqslant x \end{cases}.$$

This result, in conjunction with the superposition principle, can be used to evaluate the thermo-emf of the thermoelement for any function q(x).

An analysis of the solution showed that the thermoelement thermo-emf is linearly related to the irradiated area in a wide range and, hence, an anisotropic thermoelement can be used as a transducer for the boundary of an irradiated region.

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MEASUREMENT OF SURFACE TEMPERATURE FIELDS BY A SET OF THERMOINDICATORS

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UDC 536.522.3

Temperature determination by means of thermoindicators is based on the change in the state of these materials at specific temperatures. The measurement of temperature fields is a more complex problem that requires a standard method of placement of the set of thermoindicators on the investigated surface.

The proposed method of placement of thermoindicators is essentially as follows. The expected temperature range $T_{max} - T_{min}$ is divided into temperature intervals ΔT by a set of thermoindicators, which gives a temperature error $\sigma = \Delta T/2$.

Since the set of thermoindicators placed on the surface occupies a certain area there is a spatial error L. The minimum spatial error corresponds to the minimum diameter l of the thermoindicator spots and possibly to their closer arrangement. The relation between the spatial error and the shape of the spots is analyzed.

For spots in the form of squares of side l the set of thermoindicators is arranged in a square of side L. Since the square includes all the thermoindicators of the set, its side is

$$L = l\sqrt{\frac{T_{max} - T_{min}}{\Delta T} + 1} = l\sqrt{\frac{T_{max} - T_{min}}{2\sigma} + 1}.$$

When the number of thermoindicators is large the relation between the spatial and temperature errors can be put in the form of an error relation

$$L^2\sigma = l^2\left(\frac{T_{max} - T_{min}}{2}\right).$$

The proposed method gives the most accurate results when the temperature gradient ∇T satisfies the condition $\nabla T \leq \Delta T/L$. If the condition is not satisfied, some isotherms are absent and the determination of the temperature field is less accurate. A repeat experiment, reducing the temperature range for each of the squares, can significantly reduce the spatial error and increase the accuracy of measurement.

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TEMPERATURE DEPENDENCE OF THERMAL CONDUCTIVITY OF PROUSTITE IN SOLID AND LIQUID STATES

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UDC 53.096:536.21/22:549.354.11

This paper gives an account of the technique and results of measurement of the thermal conductivity of proustite, Ag_3AsS_3, in the temperature range 250-650°C.

In previous investigations [1, 2] the thermal conductivity of proustite was determined only at room temperature. Since proustite decomposes and interacts with atmospheric oxygen when it is heated, the most suitable method of measuring the thermal conductivity is the "tube method" [3]. The idea of this method consists in the use of a three-layered cylindrical wall model on the assumption that the isothermic surfaces of the heat field are also cylindrical and coaxial with this three-layered "tube."

The theoretical formula for the thermal conductivity of proustite has the form

$$\lambda_{Pr} = \lambda_{23} = k_s \frac{P}{2\pi h} \frac{\ln(d_3/d_2)}{\Delta t_{14} - (\Delta t_{12} + \Delta t_{34})},$$

where $k_s = 1/(1 + 0.5 d_1/h)$ is a coefficient that takes into account the scattering of heat through the tube ends; $\Delta t_{14} = t_1 - t_4$ is the temperature drop between the inner and outer walls of the three-layered tube; Δt_{12} and Δt_{34} are the temperature drops on the 1st and 3rd walls; d_3 and d_2 are the internal diameters of the 3rd and 2nd walls, P is the total heat scattered by the heater. The 1st and 3rd walls of the three-layered tube are made of fused quartz, whose thermal conductivity has been well investigated and can be taken as a standard [4], then

$$\Delta t_{12} + \Delta t_{34} = \frac{k_s P}{2\pi h \lambda} \ln \frac{d_2 d_4}{d_1 d_3},$$

where h is the tube height (the ratio $h : d_{max}$ should be more than 4:1).

The proustite tube is contained in an evacuated cavity formed by the cylindrical optical-quartz wells. The inner quartz tube contains a miniature electric heater. To even out the temperatures over the height of the investigated specimen and for reliable thermal contact the space between the walls is filled with fused tin. The measurement cell was situated in a dry nitrogen atmosphere. The initial proustite, submerged in the apparatus, contained about 0.4-0.5% Ag_7AsS_6 (billingsleyite) and $AgAsS_2$ (amithite) as impurities.

An investigation of the temperature dependence of the thermal conductivity of proustite provided a series of curves $\lambda_{Pr} = f(t)$ for the solid phase and a curve for the melt (Fig. 1). The maximum spread of the experimental points from the envelope for each curve did not exceed ±8% with the absolute error of the method equal to 14.7%. The difference between the curves $\lambda_{Pr} = f(t)$ at the start of the temperature range of measurement did not exceed 20%, increased with increase in temperature, and near the melting point reached a value of 40-50%. Such a large difference is probably due to the effect of the structure of the polycrystalline ingot formed by spontaneous crystallization from a supercooled melt. The obtained values of the thermal conductivity of proustite are close to the experimental data of other authors. A consideration of the spectral transmission of proustite can be used to calculate the corrections for radiative heat transfer (curves 1' and 2'). The thermal conductivity curve for the solid phase has a maximum at a temperature of approximately 457°C, and the curve

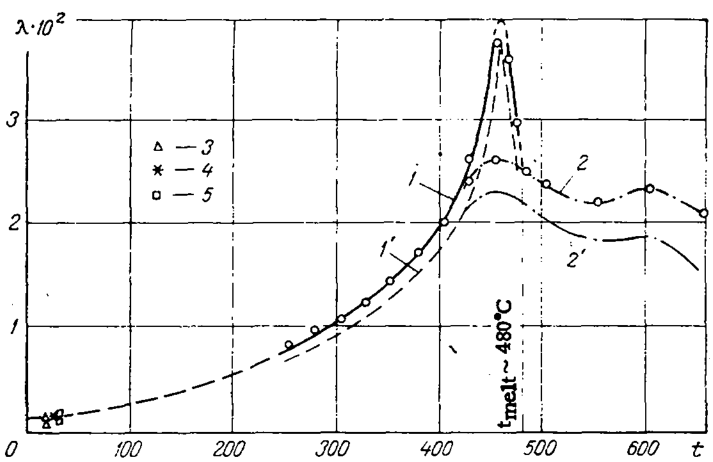

Fig. 1. Temperature dependence of thermal conductivity of proustite: 1) Solid phase; 1') solid phase with correction for radiative heat transfer; 2) liquid phase; 2') liquid phase with correction for radiative heat transfer; 3) from data of [1]; 4) [2]; 5) calculation. $\lambda \cdot 10^2$, $W \cdot cm^{-1} \cdot deg^{-1}$; t, °C.

for the melt has two maxima in the investigated temperature range: at 457°C and at 600-605°C. The presence of the maxima is probably due to structural changes according in the solid phase in the premelting state and in the melt itself.

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POROUS COOLING OF A POLYGONAL SYMMETRIC WEDGE WITH AN INCISION

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UDC 532.526.2

One of the most important characteristics of the heat transfer accompanying porous cooling is the temperature field in the filtration region. The aim of the work was to obtain an analytical solution of the pressure and temperature fields in a polygonal porous wedge with an incision in the case of power-law filtration of the incompressible fluid.

When the hypothesis of constancy of the thermophysical properties of a porous body—coolant system in the considered temperature range is adopted only the effect of motion of the coolant on the temperature field is considered and the reverse effect can be neglected, i.e., the dynamic and thermal problems can be solved separately.

The problem of power-law filtration of an incompressible fluid in a wedge-shaped porous body with an incision is reduced in Chaplygin coordinates to a mixed boundary-value problem for the Helmholtz equation

$$\frac{\partial^2 Q}{\partial \tau^2} + \frac{\partial^2 Q}{\partial \beta^2} - \frac{n^2}{4(n+1)} Q = 0, \quad (1)$$

where Q is a function of pressure; τ, β, are Chaplygin variables; and n is the degree of filtration (when n = 0 filtration is linear). The filtration region in the indicated coordinates is represented by an infinite strip with a longitudinal incision; in view of the symmetry of the problem only the upper half of the strip, where the function Q is one-sheeted, is considered.

The analytical solution, obtained by using the generalized integral Fourier transform and the Wiener–Hopf method, makes it possible to construct the pressure field and to consider the energy equation, which contains the pressure as an independent variable:

$$\frac{\partial}{\partial P}\left(\varkappa \frac{\partial T}{\partial P}\right) + \frac{\partial}{\partial \psi}\left(\frac{1}{\varkappa} \frac{\partial T}{\partial \psi}\right) + \frac{C_p}{\lambda} \frac{\partial T}{\partial P} = 0. \quad (2)$$

Here P is the pressure; ψ, the stream function, T, the temperature, $\varkappa = v^n \mu/\alpha$; v, the filtration rate; μ, the dynamic viscosity coefficient; α, the permeability coefficient; C_p, the specific heat of the coolant; and λ_{ef}, the effective thermal conductivity.

The additional assumption of linearity of filtration allows the conversion of (2) to a Helmholtz equation for the temperature. If the impermeable boundary of the porous body does not conduct heat, the filtration region in coordinates P = P and $\psi = -\psi\mu/\alpha$ is an infinite strip on whose boundaries the values of the sought function are known. An analytical solution of the indicated problem is obtained for the case where temperature and pressure are constant on the coolant entrance surface, the pressure is constant on the exit surface, and the temperature is a known function of the coordinates. Conversion to physical coordinates is effected by relations given in the paper.

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DETERMINATION OF OPTICAL PROPERTIES OF SEMITRANSPARENT LIGHT-SCATTERING MATERIALS

V. A. Tovstonog

UDC 536.3

The extensive use of semitransparent materials in various branches of engineering is arousing more and more interest in the problem of determination of the optical properties of such materials. This paper describes how the optical properties of light-scattering materials can be determined by a method based on the solution of the radiation transport equation by the method of moments.

1. Radiative transfer is considered in a plane layer of scattering medium bounded by surfaces with arbitrary laws of reflection and transmission of radiation. The method of moments [1] is used to obtain relations connecting the photometric characteristics of the layer – the reflection coefficient R and transmission coefficient T with the values of the optical constants of the material – the absorption coefficient and the specific scattering coefficient $\gamma = \sigma/\varkappa$

$$R = R(\varkappa, \gamma), \quad T = T(\varkappa, \gamma). \quad (1)$$

Relations (1) are regarded as a system of equations for $\varkappa$ and γ for known (experimentally determined) photometric characterization of the specimens and solutions of it in a two- or four-term approximation are obtained by the method of moments.

2. The errors of the method of determining the optical constants are determined by treatment of the results of accurate calculations: The initial data are exact values of R and T for prescribed γ_0 and $\tau_0 = \varkappa_0 h(1 + \gamma_0)$, where h is the layer thickness, and the expounded method is used to determine the value of γ and $\tau' =$

$\varkappa h(1+\gamma)$ and the errors $\varepsilon_\gamma = (\gamma-\gamma_0)/\gamma_0$, $\varepsilon_\tau = (\tau'-\tau_0')\tau_0'$ in a wide range of variation of γ_0 and τ_0'. The investigations show that the use of the four-term approximation of the method of moments in the region $\gamma \gtrsim 2$ gives an error not exceeding 5%.

3. The role of boundary reflection is investigated by the example of determination of the optical constants of a scattering material with specularly reflecting (according to the Fresnel formulas) boundaries. It is shown that in the range of probable values of the refractive index of solid materials ($n = 1.4$-1.8) the optical constants can differ by a factor of more than 2-5 from the corresponding values obtained with no correction for the effect of boundary reflection.

4. The application of the derived method is illustrated by data for the optical properties of STEF-20 glass textolite, and their accuracy is confirmed by comparison of results of experiments and theoretical calculations of heat transfer in STEF-20 heated by the radiant flux from a DKSTV-15000 source with a known emission spectrum.

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TEMPERATURE FIELDS IN A SYSTEM OF THIN, DIATHERMICALLY SEPARATED AND PARTIALLY CONTACTING CYLINDRICAL WALLS

A. A. Berezovskii and L. M. Berezovskaya

UDC 517.946.9

This paper considers the problem of determination of the temperature field in a system of two thin cylindrical walls separated by a diathermic medium and in partial contact along the ρ axis in n equally-spaced regions (Fig. 1). The surface $\rho = R_1$ receives a heat flux q that is uniform with respect to φ. On the surface $\rho = R_4$ heat transfer occurs in accordance with Newton's law, and in the diathermic cavity between the walls and contacts radiative heat transfer occurs.

An accurate treatment entails consideration of the boundary-value problem for the two-dimensional steady heat-conduction equation with discontinuous thermal conductivity λ and nonlocal nonlinear coupling conditions reflecting radiative heat transfer.

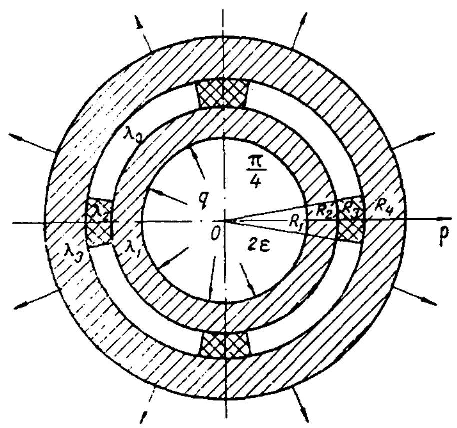

Fig. 1. Heat-transmitting system of two partially contacting cylindrical walls.

An analysis of the thermophysical process in such a heat-transmitting system allowed considerable simplification of the problem and conversion to a consideration of the field of the average (with respect to ρ) temperatures of the cylindrical walls $\bar{u}_1(\varphi)$ and $\bar{u}_3(\varphi)$. For the latter a system of nonlinear boundary-value problems was obtained for ordinary differential equations with discontinuous coefficients and containing the specially introduced equivalent thermal conductivity

$$\lambda_0(\bar{u}_1, \bar{u}_3) = \frac{R_2 R_3 \varepsilon_1 \varepsilon_3 \sigma}{R_2 \varepsilon_3 + R_2 \varepsilon_1 (1 - \varepsilon_3)} \ln \frac{R_3}{R_2} \frac{\bar{u}_3^4(\varphi) - \bar{u}_1^4(\varphi)}{\bar{u}_3(\varphi) - \bar{u}_1(\varphi)},$$

where ε_1 and ε_3 are absorption coefficients; $\sigma = 5.67 \cdot 10^{-8}$ W/m$^2 \cdot$K^4 is the Stefan–Boltzmann constant.

An analysis of the range of variation of $\lambda_0(\bar{u}_1, \bar{u}_3)$ allowed linearization of the obtained system in the region of low and moderate temperatures. The solutions of the linearized problems are given in explicit form and are illustrated by graphs of numerical calculations of control examples.

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TEMPERATURE FIELDS IN SPACE WITH A SYMMETRIC CAVITY

V. N. Dogotar' and M. P. Lenyuk

UDC 517.946

The problem of the structure of the true (dynamic) temperature fields in a homogeneous isotropic space with a symmetric cavity reduces mathematically to the solution in the region

$$D = [0, t_1] \times \Omega = \{(t, r),\ 0 \leqslant t \leqslant t_1,\ R \leqslant r < \infty\}$$

of the equation [1]

$$b_0^2 \frac{\partial^2 T}{\partial t^2} + b_1^2 \frac{\partial T}{\partial t} - \left(\frac{\partial^2 T}{\partial r^2} + \frac{2\alpha + 1}{r} \frac{\partial T}{\partial r} \right) = f(t, r) \tag{1}$$

with initial boundary conditions

$$T|_{t=0} = \varphi_1(r), \qquad \left. \frac{\partial T}{\partial t} \right|_{t=0} = \varphi_2(r), \tag{2}$$

$$\left[-\frac{\partial}{\partial r} + \beta_1 h \left(1 + \beta_2 \tau_r \frac{\partial}{\partial t} \right) \right] T|_{r=R} = h \left(1 + \beta_2 \tau_r \frac{\partial}{\partial t} \right) \varphi_3(t),$$
$$\lim_{r \to \infty} (r^{\alpha + 1/2} T) = 0. \tag{3}$$

Here $b_0^2 = W_r^{-2}$, $b_1^2 = a^{-1}$, β_k (k = 1, 2) are the coefficients of connectivity of the boundary conditions. The other quantities in problem (1)-(3) are as usual [1].

With natural limitations on the data of the problem it is shown that the structure of the sought temperature field in the region D is given by the function

$$T(r, t) = \int_0^t \int_R^\infty \mathscr{E}(r, \rho, t - \tau) f(\rho, \tau) \rho^{2\alpha+1} d\rho d\tau + \int_R^\infty \mathscr{E}(r, \rho, t) [b_1^2 \varphi_1(\rho) + b_0^2 \varphi_2(\rho)] \rho^{2\alpha+1} d\rho +$$
$$+ \int_0^t W(r, t - \tau) \psi(\tau) d\tau + b_0^2 \frac{\partial}{\partial t} \int_R^\infty \mathscr{E}(r, \rho, t) \varphi_1(\rho) \rho^{2\alpha+1} d\rho. \tag{4}$$

An analysis of W and ε led to the need to consider small t and to obtain a formula suitable for engineering calculation of temperatures in this case. Parameters h, β_1, β_2, and τ_r provide a means of separating the dynamic and quasistatic ($\tau_r \to 0$) temperature fields in the considered space with the assignment on the cavity boundary of any of the conditions of kind I ($h \to \infty$, $\beta_2 = 0$, $\beta_1 = 1$), II ($\beta_1 = 0$, $\beta_2 = 1$), or III ($\beta_1 = \beta_2 = 1$).

As an example, temperature fields resulting from an instantaneous "thermal shock" on the cavity boundary were investigated.

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INVESTIGATION OF THERMOELASTIC FIELDS IN CASE OF FINITE VELOCITY OF PROPAGATION OF HEAT

K. V. Lakusta

UDC 539.377

A plane-parallel elastic homogeneous isotropic layer of finite thickness m with stress-free boundaries, occupying the region $0 \leq x \leq m$, $-\infty < y$, $z < \infty$ is considered. Through the surface $x = 0$ of the layer there occurs heat exchange with the external medium, whose temperature changes at the initial instant from T_0 to T_c, and subsequently remains (for simplicity) constant, while the surface $x = m$ is maintained at temperature T_0. When $t = 0$ the layer temperature is T_0 and the heating rate is assumed equal to zero.

The system of differential equations representing the distribution of the thermoelastic fields in the layer has, in the one-dimensional formulation, the form

$$\frac{\partial^2\sigma_x}{\partial\xi^2} = \frac{\partial^2\sigma_x}{\partial f^2} - \frac{\partial^2\Theta}{\partial f^2},$$

with initial conditions

$$\sigma_x(\xi, f)|_{f=0} = \frac{\partial\sigma_x(\xi, f)}{\partial f}\bigg|_{f=0} = 0$$

and boundary conditions

$$\sigma_x(\xi, f) = 0 \text{ when } \xi = 0 \text{ and } \xi = \xi_0,$$

where Θ is the dimensionless temperature, which is determined from the problem

$$\frac{\partial^2\Theta}{\partial\xi^2} = \frac{\partial\Theta}{\partial f} + M^2\frac{\partial^2\Theta}{\partial f^2},$$

$$\Theta(\xi, f)|_{\xi=0} = 1, \quad \Theta(\xi, f)|_{\xi=\xi_0} = 0,$$

$$\Theta(\xi, f) = \frac{\partial\Theta(\xi, f)}{\partial f} = 0 \text{ when } f = 0.$$

Here $\Theta = (T-T_0)/(T_c-T_0)$; $\sigma_x = \sigma_{xx}(1-2\mu)/E\alpha(T_c-T_0)$; $\xi = c_1x/a$; $f = c_1^2t/a$; $M = c_1/c_q$; $\xi_0 = c_1m/a$, where c_1 is the velocity of propagation of the elastic wave; c_q is the velocity of heat propagation; μ, α, a are, respectively, the Poisson ratio, linear expansion coefficient, and thermal diffusivity; E is Young's modulus; σ_x, ξ, and f are the dimensionless normal stress tensor component, coordinate, and time.

By replacing the derivatives with respect to the coordinate and time in the equations and conditions by the corresponding difference ratios a finite-difference analog of the system is obtained.

The results of calculation of the stress fields and their analysis for various values of M^2 are given.

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HEAT-CONDUCTION PROBLEM IN GEOMETRICALLY HETEROGENEOUS ROTATION SHELLS WITH NONIDEAL THERMAL CONTACT IN THE COUPLING ZONE

A. M. Makarov and V. R. Romanovskii

UDC 536.24

The investigation of problems of coupled heat transfer in composite regions has a bearing on actual problems of heat-conduction theory. Their solution requires the use of special methods that take into account the discontinuous nature of the differential operators and the existence of matching conditions for the sought quantities characterizing the heat transfer of contiguous bodies. Problems of heat transfer in structures composed of a finite number of mutually nonintersecting geometrically homogeneous regions with discontinuity surfaces consisting of coordinate surfaces of the same family, each of which belongs only to adjacent regions, have been investigated fairly thoroughly in the literature. In this case the matching conditions for the sought functions are independent of the number and kind of contiguous surfaces, as, for instance, the condition of ideal contact for a multilayer region

$$u^{(i+1)}-u^{(i)}=0,\quad p^{(i+1)}\frac{\partial u^{(i+1)}}{\partial \nu_i}-p^{(i)}\frac{\partial u^{(i)}}{\partial \nu_i}=0,\quad i=\overline{1,\,N-1},\tag{1}$$

where $p^{(i)}$ are prescribed parameters; ν_i is the direction of the normal to the interface of the media.

Of definite interest for practical applications are problems involving the investigation of heat-conduction equations with differential operators written in different coordinate surfaces (geometrically heterogeneous regions). In this case conditions (1) undergo some changes in correspondence with the thermophysical properties of contact and shape of the contiguous regions, which can be taken into account phenomenologically in matching conditions of the form

$$\begin{gathered}n_{1,1}^{(1)}u^{(1)}+n_{1,2}^{(1)}\frac{\partial u^{(1)}}{\partial \nu_1}=n_{1,1}^{(i+1)}u^{(i+1)}+n_{1,2}^{(i+1)}\frac{\partial u^{(i+1)}}{\partial \nu_{i+1}}+\Psi^{(i)},\ i=\overline{1,\,N-1}\\ \sum_{i=1}^{N}\left(n_{2,1}^{(i)}u^{(i)}+n_{2,2}^{(i)}\frac{\partial u^{(i)}}{\partial \nu_i}\right)=\chi.\end{gathered}\tag{2}$$

Here $\psi^{(i)}$ and χ are prescribed functions that depend on the density of the heat sources located at the junction; $n_{j,k}^{i}$ (j, k = 1, 2) are known constants characterizing the structural and physical contact parameters.

The paper considers the unsteady problem of heat conduction with the structure of a space, formed by a region of variation of independent variables, consisting of a composite axisymmetric canonical form with a node consisting of a cylindrical shell nonideally coupled with axisymmetric plates

$$\Omega=\bigcup_i \Omega_\varphi^{(i)},\ \Omega_\varphi^{(i)}=\{(z,\,\rho,\,\varphi): z\in(0,\,a_1),\ i=1;\\ \rho\in(a,\,a_2),\ i=2;\ \rho\in(0,\,a),\ i=3;\ \varphi\in(0,\,2\pi)\}.$$

The problem is solved by constructing a finite integral transform on a nonideally coupled geometrically heterogeneous branching complex. Characteristic features of determination of this class of integral transforms are indicated. By the application of the operational calculus generated by this transform the initial problem for the transformant of the sought functions reduces to integration of a simpler differential equation.

Integral transforms on a geometric branching complex allow the consideration of theoretical models of a complex structure: in the presence of a finite number of nodes at each of which the matching conditions (2) correspond to specific thermophysical processes, which in turn increases the potential of linear thermoelasticity for a description of real structural elements and combinations of them.

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TEMPERATURE FIELD OF A SEMIINFINITE BODY WITH VARIABLE COEFFICIENTS AND A BOUNDARY CONDITION OF THE FIRST KIND

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The heat-conduction

$$c_0 c(\theta)\frac{\partial\theta}{\partial\tau} = \lambda_0 \frac{\partial}{\partial x}\lambda(\theta)\frac{\partial\theta}{\partial x} \tag{1}$$

with boundary conditions

$$\theta(x, 0) = 0; \quad \theta(0, \tau) = \theta_K; \quad \theta(\infty, \tau) = 0. \tag{2}$$

is solved. After introduction of the Boltzmann and Kirchoff substitutions

$$\xi = \frac{x}{\sqrt{2a_0\tau}}; \quad \Phi = \int_0^\theta \lambda(\theta)\, d\theta \tag{3}$$

Eq. (1) can be written in the form

$$-\frac{d\Phi}{d\xi}\frac{\xi}{a(\theta)} = \frac{d^2\Phi}{d\xi^2}. \tag{4}$$

The relation $a(\theta)$ is approximated by a relation $a(\Phi)$, or $a(\Phi)$ is obtained by direct treatment of the experimental data. Then, the solution of the equation

$$-\frac{d\Phi}{d\xi}\frac{\xi}{a[\Phi(\xi)]} = \frac{d^2\Phi}{d\xi^2} \tag{5}$$

with boundary conditions

$$\Phi(0) = \Phi_K, \quad \Phi(\infty) = 0 \tag{6}$$

gives

$$\Phi = \Phi_K - \frac{\Phi_K}{Q}\int_0^\xi \exp\left(-\int \frac{\xi d\xi}{a[\Phi(\xi)]}\right) d\xi, \tag{7}$$

where

$$Q = \int_0^\infty \exp\left(-\int \frac{\xi d\xi}{a[\Phi(\xi)]}\right) d\xi. \tag{8}$$

We write the integrand as a power series

$$\frac{\xi}{a[\Phi(\xi)]} = \sum_{n=0}^{\infty} k_n \xi^n \tag{9}$$

and put series (9) in (7). The coefficients k_n are found from the identity after substitution of the solution (7) in (9). For the case $a(\Phi) = 1 + b\Phi$ we have $k_0 = 0$; $k_1 = (1 + b\Phi_k)^{-1}$; $k_2 = gk_1$; $k_3 = gk_2$; $k_4 = g(k_3 - 1/6k_1^2)$ and so on, where $g = b\Phi_k Q^{-1}(1 + b\Phi_k)^{-1}$.

The paper gives the first 11 values of the coefficients k_n. In the calculations Q is taken as 1 in the first approximation, the values of k_n are found, and Q is determined more accurately from (8). For bodies with a weak relation $a(\Phi)$ one approximation is sufficient in engineering calculations. When b = 0 solution (7) becomes the known solution with constant coefficients.

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EFFICIENCY OF TRAPPING OF DUST PARTICLES IN A VENTURI SCRUBBER

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The efficiency of a Venturi scrubber for the trapping of particles more than 0.1 μm in diameter is usually calculated from the formula [1]

$$\eta = 1 - \exp(-Km\,\mathrm{Stk}^{1/2}), \tag{1}$$

where $\mathrm{Stk} = d_p^2 v_g \rho_p C_d / 18\mu_g d_d$ is the Stokes number (inertial parameter), and the coefficient K depends on the path length of the drops is the active region of the Venturi tube and their surface.

If inertial precipitation of particles on a sphere in a potential flow is regarded as the main mechanism of dust trapping in a Venturi scrubber the efficiency for Stk > 0.1 can be estimated from the formula [2]

$$\eta = \mathrm{Stk}^2/(\mathrm{Stk} + 0{,}35)^2. \tag{2}$$

The fractional efficiency of a Venturi scrubber for the trapping of polydisperse dust in the ferroalloy industry with $m \approx 2.2 \cdot 10^{-3}$ m³/m³ was investigated.

The results of the experimental investigations and theoretical calculations are given in Fig. 1 in the form of a plot of the efficiency of dust trapping in a Venturi scrubber against Stk. Curve 1 is obtained from formula (2), curve 2 corresponds to experimental data, and curve 3 is obtained from formula (1) with K = 1.56 [3].

The data presented in Fig. 1 confirm that that an exploratory calculation of the efficiency of particle precipitation in a Venturi scrubber can be based on the theoretical relations characterizing their deposition on a sphere. The increase in the practical efficiency of the apparatus when Stk < 20 can be attributed to the larger number of deposition surfaces (drops). Curve 3 indicates that the calculated values of the dust-trapping efficiency are overestimates for the value of K recommended in [3].

The mathematical treatment of the experimental data led to the empirical formula

$$\eta - 1 - 0.15\,\mathrm{Stk}^{1.24}, \tag{3}$$

which can be used in the range 1 ≤ Stk ≤ 170 for calculation of the dust-trapping efficiency in a Venturi scrubber at relatively high values of m (of the order of $2 \cdot 10^{-3}$ m³/m³).

At small values of m (up to $0.6 \cdot 10^{-3}$ m³/m³) it is better to use formula (2).

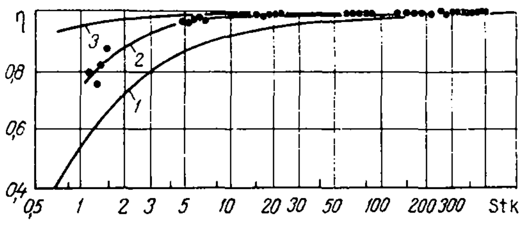

Fig. 1. Trapping efficiency for dust particles as function of Stokes number (the dots are the experimental data).

NOTATION

η is the dust-trapping efficiency;
m is the specific spraying;
d_p is the particle diameter;
v_g is the relative velocity of gases in throat of Venturi tube;
ρ_p is the density of particle;
C_c is the Cunningham – Milliken correction;
μ_g is the dynamic viscosity of gases;
d_d is the drop diameter.

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MODELING OF ABSORPTION PROCESS BY USE OF HEAT AND MASS TRANSFER EQUATIONS

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The paper proposes a mathematical model of hydrocarbon absorption that takes the kinetic relations into account. Attention is concentrated on a description of the interphase transfer of matter accompanied by heat transfer. The mathematical model is based on a system of differential equations, including the equations of mass transfer in the gas and liquid phases for multicomponent mixtures, the equations of mass balance, heat balance for the phase interface, phase equilibrium, and heat balance for the two phases. Integration was performed by the Euler method. For calculation of a real plate a sectional model was used.

The mathematical model was used to calculate the absorber in the Korobkovskii gas-processing factory (GPF) with 30 real plates, whose investigation gave fairly full data on the material balance and operating conditions. Corrections were made to the model.

To determine the suitability of this model the results were compared with results obtained by calculation for real and theoretical plates. The comparison showed that the accuracy of the model had no significant effect on the profile of the gas and liquid flows over the height of the column, but the profiles of the component concentrations and the temperatures for the compared models differ very appreciably.

An analysis of the temperature changes over the height of the column indicated that the dry gas leaving the apparatus is supercooled. This leads to precipitation of condensate in the outlet gas pipes and the separating tank, which was confirmed by operating data for the industrial absorber in the Korobkovskii GPF.

The supercooling of the gas can be attributed to the fact that when it interacts with the cold absorbent at the top of the column the rate of heat transfer is higher than that of absorption.

Calculations based on the model revealed that the influx of cold moist gas can cause supercooling of the absorbent at the bottom of the column and promote reduction of the methane content in the saturated absorbent. Such a change in methane concentration very greatly affects the operation of the absorption – steam column following the absorber.

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