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SOME ASPECTS FOR DIFFUSIVE TRANSFERENCE OF HEAT AND MASS IN THERMODYNAMICS HEAT-RESISTANT SYSTEMS*

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The physics-mathematical models for diffusive transference of thermal energy and mass of components are considered for the heat-resistant systems at accordance with positions of thermodynamics of irreversible processes. It is executed modeling of diffusive transference at cross effects in these systems.

Keywords: heat-resistant systems, physics-mathematical models, diffusive transference, thermodynamics of irreversible processes

Thermodynamics of irretrievable processes for transference of energy and matter mass is the special scientific areas [1-3], where there are examine equation of the second principle of thermodynamics as starting mathematical model for balance of energy and matter mass in the elementary volume of the thermodynamics system during her co-operation with an environment.

A task consists in transformation of equation

$$dS = \frac{1}{T} dU + \frac{1}{T} P\, dV - \frac{1}{T} \sum_{k=1}^{n} \mu_k \, dM_k \ , \tag{1}$$

where dS is a full differential of the thermal state for the thermodynamics system; dU, dV are accordingly charge of internal energy and volume of the system; P, T are accordingly pressure and temperature in the system; μ_k is chemical potential of k component for the system; dM_k is an increase for mass k component of the system, – on substation interpretation.

The functions of the state in equation (1) attribute to mass unit of the system (M) get

$$dS_V = \frac{1}{T} dU_V + \frac{\rho \cdot P}{T} \, dV_m - \frac{1}{T} \sum_{k=1}^{n} \mu_k \, dM_k \ . \tag{2}$$

For the irretrievable processes equation (3) in the substation interpretation it is possible to write down as

$$\frac{dS_V}{d\tau} = \frac{1}{T} \cdot \frac{dU_V}{d\tau} + \frac{\rho \cdot P}{T} \cdot \frac{dV}{d\tau} - \frac{1}{T} \cdot \sum_{k=1}^{n} \mu_k \cdot \frac{d\rho_k}{d\tau} \ , \tag{3}$$

where τ is time.

For diffusive transference of thermal energy of equation of transference (3)

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presents a kind:

$$\frac{dS_V}{d\tau} = -\frac{1}{T} \cdot \text{div}\ J_U\ . \qquad (4)$$

Using the known correlation $\text{div}(y \cdot \vec{x}) = y \cdot \text{div}\,\vec{x} + \vec{x} \cdot \nabla\, y$, and considering that $y = \frac{1}{T} = -\frac{1}{T^2} \cdot \nabla\, T$ and $\vec{x} = \vec{J}_U$, and also proceeding from a theorem about making of entropy, it is possible to write down:

$$\frac{\partial S_V}{\partial \tau} \cdot T = -\dot{J}_U \cdot \frac{1}{T} \cdot \nabla\, T = J_U \cdot X_U\ . \qquad (5)$$

On the basis of linearness principle a stream of internal energy in the system, that examine, is determined by correlation

$$\dot{J}_U = -\frac{L_U}{T} \cdot \nabla\, T\ , \qquad (6)$$

where L_U is a kinetic coefficient of transference of internal energy.

Entering denotation $-\frac{L_U}{T} = \lambda$ and putting got correlation to equation (4), write down

$$\frac{\partial U_V}{\partial \tau} = -\text{div}\ \dot{J}_U = \lambda \cdot \text{div} \nabla\ T = \lambda \cdot \nabla^2 T\ . \qquad (7)$$

where $U_V = C_V \cdot T \cdot \rho$, $\tilde{N}_V$ is a specific mass heat capacity of the system.

At $\rho, C_V \neq f(\tau)$ and $\lambda / C_V \cdot \rho = a$ have

$$\frac{\partial T}{\partial \tau} = a \cdot \nabla^2 T\ . \qquad (8)$$

In the case of diffusive transference of mass on condition of transfer of one component of equation (3) looks like

$$\frac{\partial S_m}{\partial \tau} = -\frac{\mu}{T} \cdot \frac{\partial \rho}{\partial \tau}\ . \qquad (9)$$

Using correlation which is known from a vectorial analysis, have

$$\rho \cdot \frac{dS_m}{d\tau} = \text{div}\left[\frac{\mu}{T} \cdot \dot{J}_D\right] - \dot{J}_D \cdot \nabla \left(\frac{\mu}{T}\right)\ . \qquad (10)$$

From a theorem about making of entropy (10) it is got X_D.

On the basis of phenomenological principle of linearness differential equation of mass conductivity at diffusive transference of one component in the system:

$$\frac{\partial \rho}{\partial \tau} = D \cdot \nabla^2 \mu\ . \qquad (11)$$

The streams of thermal energy and matter mass at cross effects are determined accordingly by correlations:

$$\dot{J}_q = -L_{qq} \cdot \frac{\nabla T}{T} - \sum_{k=1}^{n-1} L_{qk} \cdot T \cdot \nabla \left(\frac{\mu_k - \mu_n}{T}\right)\ ; \qquad (12)$$

$$\dot{J}_m = -L_{iu} \cdot \frac{\nabla T}{T} - \sum_{k=1}^{n-1} L_{mk} \cdot T \cdot \nabla \left(\frac{\mu_k - \mu_n}{T} \right) , \quad (13)$$

where L_{qi}, L_{qk}, L_{mi}, L_{mk} are kinetic coefficients of transference.

Including of denotation: $\partial\mu_1/\partial\rho_{10} = \mu_1'$; $L_{qq}/T = \lambda_1$; $L_{11} \cdot \mu_1'/\rho_{20} = D$; $L_{q1} \cdot \mu_1'/\rho_{20} = \lambda_{q1}$; $L_{iq}/T = D_{1q}$, it is got:

$$\dot{J}_q = -\lambda \cdot \frac{\nabla T}{T} - \left(\lambda_{qi} \cdot \nabla \rho_1 \right) ; \quad (14)$$

$$\dot{J}_D = \left(D_{iiq} \cdot \frac{\nabla T}{T} \right) - D \cdot \nabla \rho_1 . \quad (15)$$

In accordance with Umov equation it is possible to write down:

$$\frac{\partial T}{\partial \tau} = -\frac{1}{C \cdot \rho} \cdot \operatorname{div} \dot{J}_q ; \quad (16)$$

$$\rho \cdot \frac{\partial \rho_{10}}{\partial \tau} = -\operatorname{div} \dot{J}_D . \quad (17)$$

After $\lambda = \text{const}$ and $\lambda_{q1} = \text{const}$ equation (16) and (17) look like:

$$\frac{\partial T}{\partial \tau} = a \cdot \nabla^2 T + \frac{a}{C_{mq}} \cdot \nabla^2 \rho_1 . \quad (18)$$

$$\frac{\partial \rho_1}{\partial \tau} = D_{iq} \cdot \nabla^2 T + D \cdot \nabla^2 \rho_1 . \quad (19)$$

Conclusions. The physics-mathematical models of diffusive transference for thermal energy and mass of components are considered and also them cross effects for the heat-resistant system from positions of thermodynamics of irretrievable processes.

LIST OF LITERATURE

1. Хаазе, Р. Термодинамика необратимых процессв [Текст] : пер. с нем. ; под ред. А. В. Лыкова. – М. : Мир, 1967. – 544 с. – Библиография в конце каждого раздела.
2. Кубо, Р. Термодинамика [Текст] : пер. с англ. ; под ред. Д. Н. Зубарева и Н. М. Плакиды. – М. : Мир, 1970. – 304 с. – Библиография в конце каждого раздела
3. Лыков, А. В. Теория тепло- и массопереноса [Текст] / А. В. Лыков, Ю. А. Михайлов. – М. : Л. : Энергия, 1063. – 536 с. – Библиогр. : с. 527-535.