BRIEF COMMUNICATIONS

DETERMINATION OF HEAT TRANSFER COEFFICIENTS IN A FLUIDIZED BED BY THE METHOD OF THERMAL RELAXATION OF PARTICLES

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In the experimental investigation of thermal relaxation time of particles [1], the heat transfer coefficients in a fluidized bed have been calculated from data on heating of an individual particle immersed in the bed. The temperature was measured with the aid of a differential thermocouple whose junction was embedded in a granule of the material being examined. The values of heat transfer coefficient obtained differ from the true values, since the efflux of heat along the thermocouple wires has an appreciable influence on the heating of the particles. The effect of the lead-out wires may be allowed for through the formula obtained in [2]:*

$$\alpha_{\text{meas}} = \alpha_{\text{true}} + \frac{\pi\sqrt{2}}{S}\sum_{n=1}^{N}\sqrt{(\alpha_1 \lambda_W r_1^3)_n}\,. \qquad (1)$$

The number of thermocouple wires is two in the given case.

Since the coefficient of heat transfer, d_1, from the thermocouples wires to the bed was determined very approximately in [1], this value should be improved in the following way. By writing a thermal balance equation for the thermocouple wires and integrating it (similar to the determination of the coefficient of heat transfer from the particles to the gas, as described in [1]), we obtain the following expression:

$$\alpha_1 = \frac{(\gamma_1 c_1 + \gamma_2 c_2) r_1}{4\tau_n} \ln \frac{t_b - t_0}{t_b - t_n}\,. \qquad (2)$$

Since the heat transfer is determined to a considerable extent by the motion of the wires connected to the particle being studied, it is expedient, in determining the current temperature of the wires, t_n, to use the values of temperature obtained during the tests [1]. Thus, it is supposed that the whole of the wire located in the fluidized bed is heated in the same way as the thermocouple junction embedded in the granule. This is quite permissible, since the over-all insulation of the wires is close to the thermal resistance of a granule equal in size to the diameter of the particles used in the tests.

*An error occurred in this formula in [2]. In the denominator of the second term on the right the quantity α_{true} should not be there.

Improved values of the "true" heat transfer coefficients, i.e., those calculated from the experimental data, were determined according to (1), making use of (2), but allowing for flow of some of the heat along the thermocouple wires (see the table).

The error, as was shown in [1], is a maximum for the smallest particle diameter. The value of the maximum error is close to that calculated previously [1]. The value of the error may be taken into account in calculating the heat transfer coefficient, by computing the value of $\Delta\alpha$.

The size of the error may be considerably reduced, if, instead of a copper thermocouple wire, we use, for example, a wire of manganin, whose thermal conductivity is about a factor of 15 less than that of copper. This appreciably reduces the flow of heat along the thermocouple wires. The error may be further reduced by reducing the diameter of the wires. The table gives values of $\Delta\alpha = \alpha_{\text{meas}} - \alpha_{\text{true}}$ in the case where a manganin-constantan thermocouple is used, as well as when this thermocouple is used with wires that are a factor of two less in diameter, 0.5×10^{-4} m, thus reducing the value of $\Delta\alpha_{\max}$ from 72.0 to 9.93 W/m²·degree. It should be noted that reduction of the diameter of the wires allows maximum reduction in the influence of the thermocouple wires on the motion of the particle with the junction and, therefore, on its heat exchange with the medium.

Calculation of the Bi number from the values of the heat transfer coefficient α_{true}, as computed from the experimental data, shows that Bi is close to 1, and there is therefore no appreciable temperature gradient over the section of a particle.

Thus, with the technique described it is possible to determine the heat transfer coefficient in a fluidized bed on the basis of measurement of thermal relaxation time of particles, taking account of the error due to the thermocouple wires.

NOTATION

t_b is the temperature of the bed; t_0 is the initial temperature of the particles; R is the particle radius; α_{meas} and α_{true} are respectively, the measured and true (allowing for the error due to the thermocouple) values of heat transfer coefficients in the fluidized bed; $\text{Bi} = \alpha_{\text{true}} R/\lambda_M$ is the Biot number; λ_M and λ_W are respectively, the thermal conductivities of the material of the particles and of the thermocouple wire;

Values of the Heat Transfer Coefficients, α, W/m² · degree in a Fluidized Bed ($\Delta\alpha$ in W/m² · degree, $\delta\alpha$ in %)

material and particle size, m	α_{meas}	α_1	$\Delta\alpha$*	α_{true}	$\delta\alpha$	$\Delta\alpha$**	$\Delta\alpha$***
silica-gel $3.3\cdot10^{-3}$	108.1	38.16	18.2	89.9	20.2	7.12	2.51
MSN $4.5\cdot10^{-3}$	503	30.73	8.78	494.22	1.78	3.43	1.21
MSN $2.45\cdot10^{-3}$	252	32.93	31.0	221.0	14	11.97	4.23
MSN $1.73\cdot10^{-3}$	262	45.33	72.0	190.0	37.9	28.1	9.93

* For λ_1 = 389 W/m·degree, λ_2 = 22.5 W/m·degree, $r_1 = 0.1\cdot10^{-3}$ m.

** For $\lambda_1 = \lambda_2$ = 22.5 W/m·degree, $r_1 = 0.1\cdot10^{-3}$ m.

*** For $\lambda_1 = \lambda_2$ = 22.5 W/m·degree, $r_1 = 0.5\cdot10^{-4}$ m.

**** MSN-polystyrene copolymer.

α_1 is the coefficient of heat transfer between the bed and the thermocouple wire; r_1 is the radius of the thermocouple wire; $S = \pi R^2$ is the surface area of a particle; N is the number of thermocouple wires; $\Delta\alpha = \alpha_{meas} - \alpha_{true}$ is the absolute error of measurement of heat transfer coefficients; $\delta\alpha = (\Delta\alpha/\alpha_{true}) \cdot 100$ is the relative error of measurement of heat transfer coefficients; t_n is the temperature of the wires at time τ_n; γ_1, γ_2 are the densities of copper and of constantan; c_1, c_2 are the specific heat of copper and of constantan.

REFERENCES

1. N. A. Shakhova and A. G. Gorelik, IFZh, [Journal of Engineering Physics], 9, no. 4, 1965.
2. M. A. Kaganov and I. S. Lisker, IFZh, 6, no. 9, 1963.

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