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SCATTER OF SPECIFIC HEAT AND DENSITY OF FILLED MATERIALS IN SAMPLES OF FINITE DIMENSION

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UDC 536.21

The probability of obtaining values of the specific heat and density of filled samples that differ from the mean is considered.

In experimental determinations of the specific heat and density of small samples, it is necessary to estimate the possible deviation of the properties of the given sample from the mean values. Such a deviation may occur because, when the sample is small, the number of filler particles that the considered volume contains is a random variable, and hence characteristics such as the specific heat and density of the sample are also random variables.

Let c be the specific heat of the considered filled material. For simplicity, we shall consider a composite of no more than two materials. Since

$$c = c_1 P_{1\,\mathrm{gr}} + c_2 P_{2\,\mathrm{gr}} \tag{1}$$

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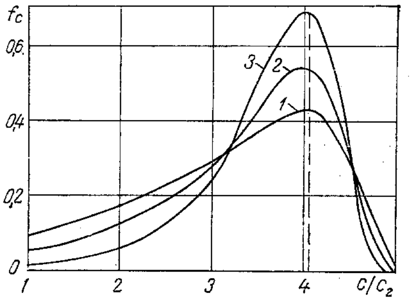

Fig. 1

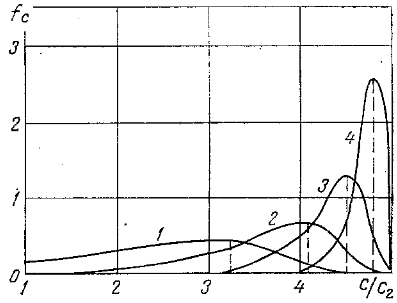

Fig. 2

Fig. 1. Normalized probability of obtaining various values of the specific heat for a degree of filling of 0.4. Volume: 1) $5a^3$; 2) $7a^3$; 3) $10a^3$.

Fig. 2. Normalized probability of obtaining various values of the specific heat in a volume $10a^3$. Degree of filling: 1) 0.2; 2) 0.4; 3) 0.6; 4) 0.8.

and

$$P_{1\,\mathrm{gr}} = \frac{P_1}{P_1 + (1 - P_1)\dfrac{\gamma_2}{\gamma_1}}, \tag{2}$$

then

$$c = c_1 \frac{P_1 + (1 - P_1)\dfrac{\gamma_2}{\gamma_1} \cdot \dfrac{c_2}{c_1}}{P_1 + (1 - P_1)\dfrac{\gamma_2}{\gamma_1}}. \tag{3}$$

For a sample of finite dimensions the degree of filling is itself a random variable depending on the number of filler particles contained within the considered volume. We assume that the filler particles are cubes of side a. Hence the volume of one cube is a^3. We divide the volume V into n cells, where $n = V/a^3$. In the total volume V, the proportion of filler particles is $ma^3/V = P_1$, where m is the number of filler particles contained in the given volume. We consider the probability that the volume V will contain m particles. If ν is the mean number of particles in unit volume, then νa^3 is the probability that a particle will occupy a cell, and $1-\nu a^3$ is the probability that the cell is empty [1]. Hence the probability that the volume V will contain exactly m particles is

$$F_m = C_n^m \left(\frac{\nu V}{n}\right)^m \left(1 - \frac{\nu V}{n}\right)^{n-m}, \tag{4}$$

where νV is the mean number of particles in the volume V,

$$F_m = C_n^m \left(\nu V \frac{a^3}{V}\right)^m \left(1 - \nu V \frac{a^3}{V}\right)^{n-m} = C_n^m (\nu a^3)^m (1 - \nu a^3)^{n-m} = C_n^m P^m (1 - P)^{n-m}. \tag{5}$$

Here P is the mean degree of filling (by volume) of the material.

Using Eq. (5), we can calculate the probability that a volume V will contain m particles, and hence the probability of obtaining a different number c, since $P_1 = ma^3/V$, and c and P_1 are related by Eq. (3).

As an example, Fig. 1 shows the normalized probability of obtaining various values c/c_2 for volumes $5a^3$, $7a^3$, and $10a^3$, when $\gamma_1/\gamma_2 = 5$ and $c_1/c_2 = 5$. As is evident, increase in volume is accompanied by a sharp decrease in the probability of obtaining values of the specific heat greatly different from the mean.

In Fig. 2, the normalized probability of obtaining various values of c/c_2 is shown for different degrees of filling in the same volume ($10a^3$). The dashed lines indicate the mean values of the specific heat. The calculated curves show that increase in the degree of filling is associated with decrease in the probability of obtaining a value of the specific heat that differs sharply from the mean.

Replacing c, c_1, and c_2 by γ, γ_1, and γ_2 in Eq. (3) gives an expression for the density:

$$\gamma = \gamma_1 \frac{P_1 + (1 - P_1)\left(\dfrac{\gamma_2}{\gamma_1}\right)^2}{P_1 + (1 - P_1)\dfrac{\gamma_2}{\gamma_1}}. \tag{6}$$

Using Eqs. (3) and (6), together with Eq. (5), it is possible to calculate the probability of any values of specific heat and density, given the degree of filling and volume. This is of particular importance in situations which involve very small samples, for example, in carrying out experiments in microcalorimeters or in the differential thermal analysis of materials.

NOTATION

P_{igr}, fraction by weight; P_i, fraction by volume; γ_i, density; c_i, specific heat of i-th component; P, mean degree of filling (by volume); C_n^m, number of combinations of m elements from a set of n.

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ENERGY SEPARATION IN TWO-PHASE FLOWS

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A new, essentially nondissipative effect of energy separation in steady two-phase flows is discussed.

The separation of gas molecules by energies in gravitational and centrifugal force fields (the Rank effect) is very widely known. Recently, several thermodynamically more favorable methods of energy separation in gaseous media have been discovered, for example, by means of pulsing gas columns and in cryptosteady motion. Common to these effects is a redistribution of internal mechanical energy and the accompanying thermal energy among the individual particles of initially homogeneous continuous media under the effect of an external mechanical perturbation.

The present work gives theoretical and experimental results regarding a new, fundamentally different energy-separation effect, which takes place in a two-phase, initially homogeneous medium moving at high velocities; after deceleration and separation of the two phases, their temperatures are found to be significantly different.

§ 1. Essentially, the physical basis of the effect is as follows. In an adiabatic flow of ideal gas, the relation between the absolute deceleration temperature T_0 and the static temperature T is given by the specific-heat equation in the form

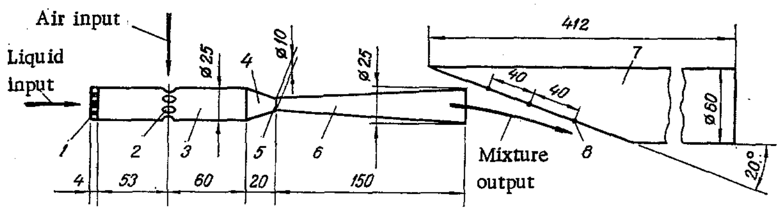

Fig. 1. Experimental nozzle—separator system: 1) atomizer (10 holes, diameter 0.8 mm); 2) air inlet (6 holes, diameter 6 mm); 3) mixer; 4) tapering section of nozzle; 5) neck; 6) broadening section of nozzle; 7) separator; 8) thermocouples (aligned along principal axes of ellipse: one at the center, two on the minor and two on the major axes, respectively, 15 and 40 mm from the center).

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