HYDROMECHANICS

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Fig. 1

Figure 1: Fig. 1

Abstract

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ON THE EVAPORATION OF SPHERES OF SOLIDS IN A GAS FLOW

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Numerous works have been devoted to the process of evaporation of droplets. Considerably less attention has been paid to the evaporation of spheres of solids in a gas flow. Meanwhile, the study of the kinetics of evaporation of solid bodies, in particular spheres, is not only of independent interest, but also has great significance for the study of the laws of evaporation of a liquid. Indeed, a liquid droplet, upon evaporation, retains its spherical shape, regardless of how evaporation proceeds from different parts of its surface. In the case of a sphere made of a solid volatile substance, evaporation proceeds more intensively on the side from which the sphere is blown by the gas; the size of the sphere decreases more rapidly there, and therefore the shape of the body obtained as a result of evaporation may indicate the distribution of evaporation rates over the surface of the body swept by the flow.

Fig. 1

On the question of evaporation from different parts of a sphere when it is swept by a gas flow, there is as yet no unified point of view. L. S. Leibenzon (^{1}) believes that evaporation from the rear part occurs, but that it is significantly less than evaporation from the front part and is difficult to determine. A. S. Irisov (^{2}) denies altogether the existence of evaporation from the rear part; on the contrary, V. G. Levich (^{3}) shows that evaporation from the rear part can be taken into account and that it is comparable with evaporation from the front part.

The author set himself the goal of investigating the rate of evaporation in different parts of a sphere swept by a flow. For this purpose, spheres were used –

naphthalene and camphor spheres, which evaporate relatively easily when blown by a stream at ordinary temperatures.

Fig. 2

Figure 2: Fig. 2

Fig. 3

Figure 3: Fig. 3

Frössling used a naphthalene sphere for the purpose of studying evaporation kinetics (4). The spheres were prepared from molten naphthalene or camphor and, by means of a suspension, were fastened at the base of the tube creating the gas stream. At certain time intervals the spheres were photographed, and the photographs were used to determine the evaporation rates in different parts of the sphere. To determine the total amount of substance evaporating per unit time from the entire surface, the sphere was weighed at the same time intervals on a balance with an accuracy of up to 1 mg. In the experiments the stream velocity varied from 0.5 to 10 m/sec, and the temperature from 15 to 100–120°, so that the naphthalene also evaporated in the liquid phase.

Fig. 2

The investigations carried out showed that in the evaporation kinetics of naphthalene in the liquid and solid phases there is no difference. The loss of substance per unit time is different in these cases, but qualitatively the process proceeds in the same way. This enabled us to consider the evaporation of the substance in the rear and in the front parts, as well as at the places of least evaporation.

Fig. 3

In Fig. 1 are shown successive contours of an evaporating naphthalene sphere of diameter 2 mm at a temperature of 45° and a stream velocity of 7 m/sec, taken at time intervals from 1 to 2 min. In Fig. 2 it is clearly seen that evaporation of the sphere does not proceed uniformly over the entire surface—there is a zone of least evaporation, which divides the surface of the sphere into front and rear parts. The zone of least evaporation is located at the place where the jets of the blowing stream separate. This zone forms an angle of 200° with the center of the sphere, which does not fully correspond to the value of the angle calculated by L. S. Leibenzon (1).

The shape of the naphthalene sphere proved similar to the shape obtained by G. A. Akselrod (5) in experiments on the dissolution of salt spheres in a liquid stream.

Investigation of the shape of the front and rear parts shows that these parts evaporate at different, but quite comparable, rates. Both the front and the rear parts of the surface retain, to a first approximation, sphericity; only the radius of the sphere changes. This observation fully agrees with the conclusions of V. G. Levich (3), according to which evaporation from the rear part of the sphere is not only comparable with evaporation from the front part, but in certain cases may be greater than the latter. At the same time, the decrease in evaporation from the surface of the sphere from the point where the stream impinges to the place where the jets separate qualitatively confirms the character of the change in the diffusion flux over the surface of the sphere, calculated by V. G. Levich (^{3}) on the basis of hydrodynamic concepts.

Having calculated, from the radii of the spheres, the surfaces of the front and rear parts, we found that the dependence of their change on time is linear, and moreover

corresponds to a straight line with a greater angle of inclination, i.e., a higher rate of evaporation. Thus, since the change in the surface of each of the hemispheres of the naphthalene sphere being blown over occurs linearly in time, one may write $dS/dt = \text{const}$. This is known as Sreznevsky' s law ^{6}. Usually (in the evaporation of drops) it is applied to the entire surface of the evaporating spheroid (drop). In our case, both the front and the rear hemispheres obey Sreznevsky' s law, so that for the entire sphere as a whole one may write:

$$\frac{(dS/dt)_{\text{front}} + (dS/dt)_{\text{rear}}}{2} = \text{const}.$$

The greater the flow velocity, the greater the evaporation from the front and rear parts, but the character of the change of the surface in time remains the same.

The temperature of the flow by which the sphere is blown has an even greater influence on the evaporation rate of the sphere.

Having calculated the change in the quantity dS/dt during evaporation of a naphthalene sphere for various flow temperatures and represented it graphically, we obtained the curve shown in Fig. 3. The fact that this curve is completely analogous to the curve of the change in vapor elasticity as a function of temperature indicates the diffusion character of the evaporation and the substantial influence on the evaporation rate of the layer consisting of saturated vapors of the evaporating substance. It is precisely with this layer that the flow blowing over the sphere interacts.

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Note: Figure translations are in progress. See original paper for figures.

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