EVAPORATION OF LIQUID DURING ITS ATOMIZATION ON A ROTATING DISK

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The article suggests an approximate method of determining the evaporation rate of a liquid film moving diametrically over the surface of a rotating disk. The results of experiments and of calculations by the suggested method were similar.

In technology and in scientific research, liquids atomized by rotating atomizers, e.g., a rotating disk, are used. During the process, the liquid, moving as a thin film over the surface of the rotating disk from its axis to the circumference, evaporates. It is often essential to take this evaporation into account.

For instance, in laboratory practice, generators of monodisperse aerosols of the type of rotating disk are used [1]. With the aid of these generators, a liquid can be divided into drops of approximately the same radius that is controllable within wide limits (e.g., with the aid of the generator "Volchok" with pneumatically driven rotor, within the limits 3-30 μm). If smaller drops have to be obtained, the investigated liquid with low volatility, mixed with a volatile diluent, is atomized; the diluent quickly evaporates, and in the air there remain drops with a radius \( r < 3 \mu m \) containing hardly any diluent. However, the diluent may evaporate chiefly while the liquid film still moves over the surface of the rotating disk, i.e., prematurely, before drops are formed; in that case, in the evaporation of the mixture, the radius of the drops \( r \) would be the same as in atomization of the investigated liquid (without diluting it with a volatile diluent), i.e., the method of obtaining drops with \( r < 3 \mu m \) would be unsuitable. Obviously, this is one of the cases when it is necessary to take the evaporation of the liquid over the surface of a rotating disk in the form of a thin film into account. Below we examine in particular this case, but the results are naturally of wider significance.

To reduce \( r \) substantially by the evaporation of the volatile diluent, two conditions must be fulfilled: the rate of evaporation of the film \( I \) has to be low compared with the flow rate \( G \) of the liquid

\[
K_1 = IG^{-1} \ll 1, \tag{1}
\]

and the rate of evaporation of the mixture has to be sufficiently high for the bulk of the diluent to evaporate at the time the drops are in a state of suspension

\[
K_2 = \tau VH^{-1} \ll 1. \tag{2}
\]

In the evaporation of the bulk of the volatile diluent, a drop of the diluted solution behaves approximately in the same way as a drop of pure diluent [2], i.e., in the case of small drops slowly settling in air, the evaporation time of the bulk of the diluent can be approximately determined by the formula [3]*

*When this formula is used for \( \tau \), we assume that the initial concentration of diluent in the drop is high, and that the accelerated evaporation at the time of braking of the drop, thrust from the circumference of the disk at high initial speed relative to the air, need not be taken into account. The first assumption is due to the fact that for substantial reduction in size of the drop by evaporation of the volatile diluent it is necessary that its initial concentration in the drop be high; e.g., to reduce the drop size in this way by one half, the concentration of the diluent has to be 87.5%. The second assumption is based on the fact that though the high initial speed of the drop relative to the air substantially accelerates evaporation, the period of braking of the small drops that are here under consideration is extremely short, therefore the degree of evaporation of the drop at the time of its accelerated evaporation is negligible; this was proved by the numerical solution of the system of equations of motion and evaporation of a drop under analogous conditions obtained in the "kinematic" regime of evaporation of a drop in a turbulent air stream [4].

TABLE 1. Characteristics of Disks Used in the Experiments

<table>
<thead>
<tr>
<th>Disk No.</th>
<th>Radius, cm</th>
<th>Material</th>
<th>Weight, g</th>
<th>Heat capacity, cal/deg</th>
<th>Thermal conductivity of material, cal/cm·sec·deg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.5</td>
<td>Organic glass</td>
<td>8.6</td>
<td>3.1</td>
<td>0.0056</td>
</tr>
<tr>
<td>2</td>
<td>5.0</td>
<td>»</td>
<td>24.5</td>
<td>8.8</td>
<td>»</td>
</tr>
<tr>
<td>3</td>
<td>10.0</td>
<td>»</td>
<td>102.0</td>
<td>36.7</td>
<td>»</td>
</tr>
<tr>
<td>4</td>
<td>5.15</td>
<td>Glass</td>
<td>57.5</td>
<td>5.8</td>
<td>0.0020</td>
</tr>
<tr>
<td>5</td>
<td>7.8</td>
<td></td>
<td>216.0</td>
<td>21.6</td>
<td>»</td>
</tr>
<tr>
<td>6</td>
<td>15.0</td>
<td>Duralumin</td>
<td>235.0</td>
<td>49.2</td>
<td>0.48</td>
</tr>
<tr>
<td>7</td>
<td>22.5</td>
<td>»</td>
<td>650.0</td>
<td>136.5</td>
<td>»</td>
</tr>
</tbody>
</table>

Fig. 1. Diagram of the experimental device.

\[ \tau \approx \frac{\rho r_0^2}{2D (c_0 - c_\omega)}. \]

The initial radius of the drops in the first monodisperse regime of evaporation of liquid by a rotating disk is determined by the formula [1]

\[ r_0 = \frac{C}{\omega} \sqrt{\frac{\sigma}{\rho K}}. \]

For water and mineral oils, \( C \approx 2.9 \).

The settling rate of drops after Stokes at the beginning of evaporation is

\[ V = \frac{2}{9} \frac{\rho g r_0^2}{\eta}. \]

As evaporation proceeds \( r < r_0 \), \( V \) decreases.

We substitute \( \tau \), \( r_0 \), and \( V \) into the inequality (2) and write it as follows:

\[ K_2 = \frac{1}{9} \frac{C \omega^2 g}{DH (c_0 - c_\omega) R^2 \omega^2} \ll 1. \] (2a)

All the magnitudes on the left-hand side of this inequality are known, and it can be used for approximately determining \( K_2 \).