CERTAIN CHARACTERISTICS OF THE MONODISPERSE DISINTEGRATION OF A LIQUID JET

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We examine the process of the monodisperse disintegration of a capillary jet of water in the presence of transverse oscillations of the outlet orifice. We have determined the values of the parameters at which this process begins; we demonstrate the effect of individual factors on the form of the discrete disintegration of the jet.

The theory of the discrete disintegration of a liquid jet was developed by Rayleigh [1] who demonstrated that a moving jet of an inviscid liquid is unstable with respect to rotational-symmetric perturbations, if the wavelength of this perturbation is greater than the cross-sectional perimeter of the jet, and the perturbation that is most favorable for the formation of drops is achieved when $\lambda/d = 4.42$. In our investigation the discrete disintegration of a jet of water is brought about by the forced latter oscillations of the outlet orifice, and these are produced by placing a hollow rod over the core of a 600 watt voice coil of a dynamic loudspeaker. The investigation was performed as a jet of water was discharged through three different outlet orifices into an air medium at atmospheric pressure: the diameter of the first orifice was 0.5025 mm; that of the second was 0.2165 mm; and that of the third, 0.072 mm.

We determined the conditions for the discrete disintegration of the jet in a range of force frequencies from 500 to 10^4 Hz. This process was observed by means of stroboscopic illumination, it was photographed at an exposure of $0.7 \cdot 10^{-6}$ sec, and the photography was carried out with a high-speed motion-picture camera at a filming speed of 4000 frames/sec.

The discrete disintegration of the jet under specific conditions occurs over completely equal parts that are separated from each other through identical distances.

The diameters of the drops that are formed, with a high degree of accuracy, are equal to

$$A = 1.145 v^{1/3} d^{2/3} \nu^{-1/3}.$$

Such monodisperse disintegration of the jet occurs over the entire range of frequencies employed, if $\lambda/d = 3.2$-10 and the oscillation amplitude δ varies from 4 to 23 μm. When $\lambda/d > 10$ or $\delta > 25$ μm, the jet disintegrates with formation of satellite drops, or with the formation of a cocurrent flow. When $\lambda/d < 3.2$, the disruption of the monodispersity results from the merging of individual pulsating drops (see Fig. 1).

In a regime in which the jets being investigated experience monodisperse disintegration, the diameters of the drops that are formed ranged from 125 to 1240 μm and the frequency of drop formation reached 10^4 per second. In the presence of cocurrent flows, the diameters for the smaller drops may be 30 μm and smaller.

As a result of these investigations, we can draw the following conclusions:

1. Monodisperse disintegration is possible when $10 > \lambda/d > 4.5$. This fact is not considered in the Rayleigh theory. At these values of λ/d, the discrete disintegration of the continuous portion begins simultaneously at several points along the wavelength. Because the amplitudes of the force oscillations are primarily on the increase, monodisperse disintegration of the jet continues. As soon as the perturbations reach their maximum, there is a simultaneous disruption of the monodispersity of the disintegration.

2. In the case of lateral forced oscillations of the outlet orifice, the jet disintegrates in discrete fashion because of an increase in the amplitudes of the rotational-symmetric perturbations of the continuous

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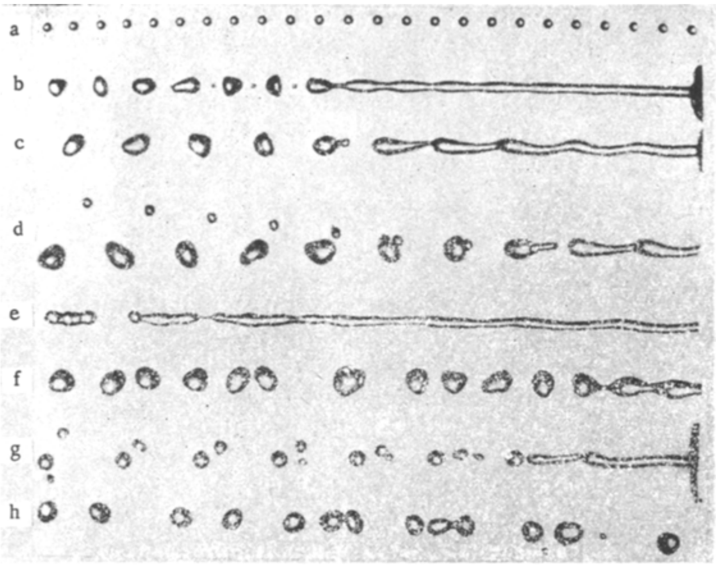

Fig. 1. The effect of λ/d and δ on the disintegration of a capillary jet: a) monodisperse flow of drops 125 μm in diameter, $\lambda/d = 3.25$; b) disintegration of jet for $\lambda/d = 4.35$, $\delta = 5$ μm; c) the same, for $\lambda/d = 5.56$, $\delta = 20$ μm; d) formation of a cocurrent flow for $\lambda/d = 5.56$, $\delta = 26$ μm; e) disintegration of jet when $\lambda/d = 9.1$, $\delta = 18\mu$m; f) disruption of monodispersity when $\lambda/d = 3.1$; g) the same, when $\lambda/d = 11.7$; h) the same, for $\delta < 4$ μm.

portion of the jet. With greater values for the amplitudes of the forced oscillations, substantial wavelike "oscillations" appear in the continuous portion of the jet, but the disintegration of the jet is a consequence of the increase in the amplitude of the rotational-symmetric perturbations.

3. In the presence of wave-like "oscillations" in the continuous portion of the jet, in addition to the usual pulsations of the drops that are being formed, we find that the drops are additionally rotated at a frequency of several score rotations per second.

NOTATION

λ is the perturbation wavelength;
d is the jet diameter;
v is the jet velocity;
ν is the oscillation frequency;
δ is the oscillation amplitude;
A is the drop diameter.

LITERATURE CITED

1. Lord Rayleigh, Proc. Roy. Soc., 29, 71.
2. D. Y. Ryley and M. R. Wood, J. Sci. Instrum., 40 (1963).