# ON "SATELLITE-DROPS" FORMED IN THE ATOMIZATION OF A FLUID BY A ROTATING DISK

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The dependence between the relative quantity E and the mean size $d_m$ of satellite-drops formed in fluid atomization by a rotating disk and the parameters of the process is investigated experimentally. Empirical formulas are obtained to permit determination of E and $d_m$ as a function of the rotational velocity and radius of the disk, the viscosity, density and surface tension of the fluid.

It is known [1-2] that at low fluid discharges delivered to the center of a rotating disk as a continuous jet, approximately identical "fundamental" drops and finer "satellite-drops" formed. As the fluid discharge increases, the quantity of satellite-drops grows and of the fundamental drops diminishes. The atomization conditions at which the weight content of satellite-drops reaches 100% and the fundamental drops vanish can be considered the atomization corresponding to the transition from the first mode, characterized by the formation of drops directly on the disk edge, to the second mode. In the second mode, not drops, but liquid filaments which decompose into drops at some distance from the edge [3], are ejected from the edge of the disk. In many cases, not only the size of the fundamental drops, but also the relative quantity and size of the satellite-drops must be estimated in advance. It is as yet impossible to solve this problem theoretically.

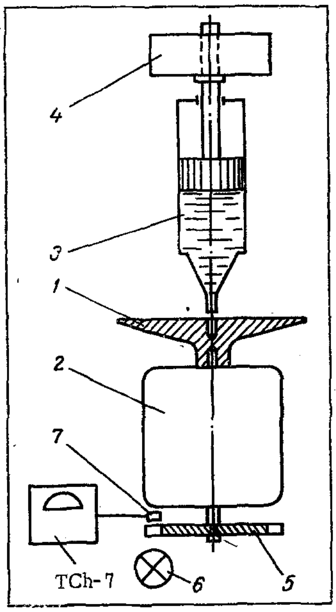


Fig. 1. Diagram of the experimental apparatus.

To obtain the empirical dependences governing the quantity and size of the satellite-drops as a function of the values of the fundamental parameters of the atomization process, experiments were conducted on the setup shown in Fig. 1. A continuous fluid jet from the injector needle 3, whose plunger was loaded by the weight 4, was delivered to the central cylindrical recess of the smooth horizontal disk 1 set into rotation by the collector electric motor 2 ("Omega," N = 18,000 rpm). To measure the angular velocity of the disk 1, a circle 5 with cutouts to interrupt the light flux from the incandescent lamp 6 to the photoresistor 7 was mounted at the lower end of the shaft of the electric motor 2. A frequency meter regulated by a rheostat measured the frequency of the pulses generated by the photoresistor (i.e., the angular velocity of the disk). A horizontal sheet of paper was placed 9 cm below the plane of the disk. The deposited fundamental drops of tinted fluid formed a circular trace of regular shape on the paper. The satellite-drops were deposited principally within this trace. As the fluid discharge increases, the clear ring formed by the fundamental drops lost color (without a change in radius) up to total disappearance, and the spread-out inner ring formed by the satellite-drops became denser.

In order to determine the relative weight of the fundamental drops, the increment in the weight of the paper ring sector on which the ring trace was formed was measured in tests with practically nonvaporizing

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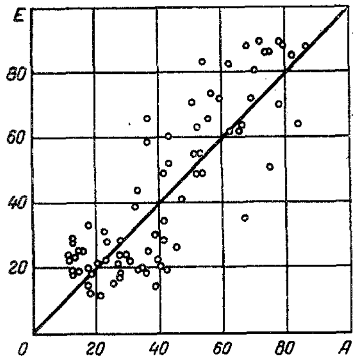


Fig. 2. Dependence of the relative weight quantity of satellite-drops E, % on the quantity $86(\omega^{0.48}\nu^{0.12}/R^{0.30})(\rho Q/\sigma)^{0.62} = A$: curve – empirical formula; points – experiment.

fluids (mineral oils). The relative weight of the fundamental drops $E = \Delta G/G$ was determined by means of the results of weighing and measuring the total quantity of fluid used G. A metal sector with crimps was used in place of the paper sector in tests with water: the quantity of fluid deposited within the ring was determined by colorimetry. As a check the quantity of fluid deposited on the whole area of the checking circle $G_1$ was determined and compared with the quantity G of fluid used.

To determine the size of the satellite-drops, microscope slides were used which had first been coated with a thin layer of silicone oil. The slides were laid out on a horizontal surface along one of the radii of the disk. The simplest slit shutter with slit motion perpendicular to the line of slides was used to limit the duration of the exposure.

The deposited drops were measured and counted under a microscope; they were hence separated into size classes and the area examined was taken into account.

In all 90 tests were conducted in which $\omega$ varied from 31.4-1660 $sec^{-1}$, R between 1 and 11 cm, Q from 0.03-1.7 $cm^3/sec$, $\rho$ from 0.89-1 $g/cm^3$, $\nu$ from 0.01-26.4 $cm^2/sec$, and $\sigma$ from 29-73 $g/sec^2$. The measured values of the deposited drops E were from 8 to 89%, the total degree of deposition of the fluid within the circle checked $E_1 = G_1/G$ varied between 90 and 100% in the majority of tests (except for six tests with the formation of drops less than 100 $\mu$ in size, for which a significant part of the fluid, up to 35%, was deposited outside the limits of the circle checked).

The test results were processed on an electronic computer by least squares in the form of the dependence $E = f(\omega, \nu, R, Q, \sigma, \rho)$. Consequently, an empirical formula governing the relative weight quantity of satellite-drops as a function of parameters of the process was obtained:

$$E = 86\,\frac{\omega^{0.48}\nu^{0.12}}{R^{0.30}}\left(\frac{\rho Q}{\sigma}\right)^{0.62} \leqslant 100\,\%\,. \tag{1}$$

The dependence (1) is compared in Fig. 2 with experimental values of E (points). The relative quantity of satellite-drops grows as the fluid discharge Q, the disk angular velocity $\omega$, and the fluid density $\rho$ increase, depends slightly on the fluid viscosity $\nu$ (grows slowly as the viscosity increases), and diminishes as the fluid surface tension $\sigma$ and the disk radius R increase. Formula (1) can be recommended for approximate practical estimates.

Taking the value E = 100% as the condition for transition from the first to the second mode of atomization, we obtain the following inequality to estimate the values of the parameters corresponding to the first mode

$$0 < 86\,\frac{\omega^{0,48}\nu^{0,12}}{R^{0,30}}\left(\frac{\rho Q}{\sigma}\right)^{0,62} \leqslant 100\,\%\,. \tag{2}$$

The empirical formula

$$d_m = \frac{1,1}{\omega}\left(\frac{\sigma}{R\rho}\right)^{1/2} \tag{3}$$

is obtained for the satellite-drop diameter for the median mass.

Processing of the test results showed that the size distribution of the satellite-drops is defined approximately by a normal distribution law for random variables. The relative magnitude of the root-mean-square deviation $\beta/d_m$ varied between 0.08 and 0.16.

## NOTATION

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| $R, \omega$ | are the disk radius and angular velocity; |
| $\rho, \nu, \sigma, Q$ | are the fluid density, kinematic viscosity, surface tension and discharge; |
| $d_m$ | is the satellite-drop diameter for the median mass; |

$\beta$ is the root-mean-square deviation of the drop diameter from the diameter for the median mass;

E is the relative weight quantity of satellite-drops.

## LITERATURE CITED


1. V. F. Dunskii and N. V. Nikitin, Inzh. Fiz. Zh., 9, No. 1 (1965).
2. W. Walton and W. Pruett, in: Aerosol Application in Agriculture [Russian translation], A. G. Amelin (editor), IL, Moscow (1955).
3. V. F. Dunskii and N. V. Nikitin, Inzh. Fiz. Zh., 17, No. 1 (1969).