EFFECT OF VARIOUS SPRAYING FACTORS ON THE SIZE DISTRIBUTION OF DROPS

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The results of an investigation into the fractional composition and mean size of a system of liquid drops with a wide range of particle size are presented. The drops are produced by means of a centrifugal disc spray.

In recent years considerable interest has arisen in connection with sprays having a wide range of particle (drop) size. In practical calculations and operations based on spraying processes, it is usual to replace the actual system of drops in the jet by one with a single drop size, simply matching the total volumes and total drop surface areas of the two systems [1]. However, any particular mean volume–surface diameter may correspond to a whole range of systems with very different drop-size distributions. This has a major effect when discussing the processes taking place in different pieces of apparatus, since the conditions of evaporation applying to large and small drops differ substantially [2].

In this paper we shall try to discover the effects of various spraying factors on the fractional composition of drop systems and the mean drop size when spraying liquids with a centrifugal disc spray. In our experiments we used a centrifugal disc spray with a pneumatic drive and a disc diameter of 50 mm. The flow of liquid lay within the range 1.5–4.5 kg/h.

The size of the drops was determined by a method based on the mesh (sieve) analysis of solidified drops [3]. The accuracy of the method was increased by washing the residue in the mesh with a water jet. Spraying was carried out with aqueous solutions of the products of chemical interaction between phenol and formaldehyde (thermoreactive phenol–formaldehyde resins) produced by Soviet industry and having a wide range of physicochemical properties. A specific characteristic of the hardened particles of these products is their spherical shape, together with their monolithic or hollow single-cell structure, having no openings in the sides (walls). The method of conducting the experiments and also the results of a study of drop size distribution (for pneumatic spraying of the liquid) as a function of the viscosity of the liquid, the ratio of the flow of liquid to the flow of air, and the air temperature were set out in the first part of our investigation [6].

The experiments with the centrifugal disc spray were aimed at studying the drop spectrum as a function of the viscosity of the liquid, its surface tension, and the angular velocity and output of the disc. The experimental results were analyzed in the same way as in the case of pneumatic spraying, by using the Rosin–Rammler equation for the total volume distribution of systems with a wide spread of drop sizes [4]:

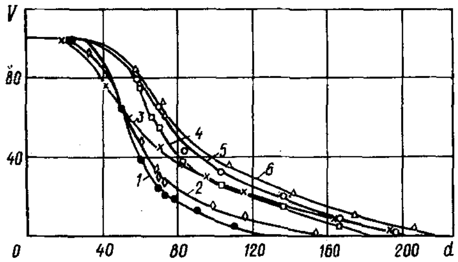

Fig. 1. Total size distribution of the drops on spraying liquid by means of a centrifugal disc: 1) $\mu = 0.09\ \mathrm{N \cdot sec/m^2}$; $\sigma = 0.027\ \mathrm{N/m}$; 2) respectively 0.05 and 0.042; 3) 0.05 and 0.051; 4) 0.75 and 0.030; 5) 2.90 and 0.031; 6) 5.20 and 0.031.

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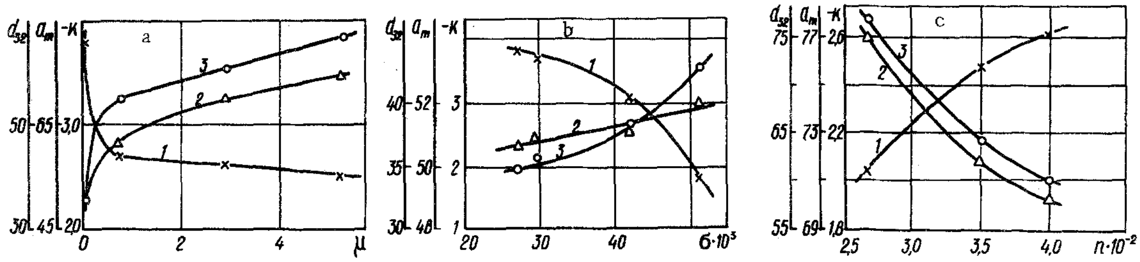

Fig. 2. Coefficients of the total drop distribution equation K (1) and a_m (2) and the mean volume–surface diameter d_{32} (3) as functions of: a) the viscosity of the liquid μ; b) the surface tension of the liquid σ; c) the angular velocity of the disc n.

TABLE 1. Dependence of K, a_m, and d_{32} on the Output G.

$G \cdot 10^3$	$\sigma \cdot 10^3$	K	a_m	d_{32}
0,42	51	−1,80	52,0	42,5
1,25	51	−1,82	65,0	59,4
0,44	27	−3,81	50,6	34,8
0,83	27	−3,70	59,0	47,2

$$V = 100 - \frac{100}{\exp bd^K}, \quad (1)$$

where $b = 1/a_m^K$. The curves derived from the experimental data agree closely with Eq. (1) on making a proper choice of the coefficients K and a_m.

In order to determine the role of the coefficients K and a_m in the drop size spectrum, let us consider the total drop distribution curves obtained for various values of the surface tension and viscosity of the liquid (Fig. 1). Curves 1, 2, 3 reflect the influence of surface tension (varying between 0.027 and 0.051 N/m); curves 4, 5, 6 reflect the influence of viscosity over the range 0.05-5.20 N·sec/m². The laws governing the changes taking place in the coefficients K and a_m of Eq. (1) as a result of changes in the same factors (viscosity and surface tension) varying over the same ranges are illustrated in Fig. 2a, b. On comparing Figs. 1 and 2a, we see that a change in viscosity over the range indicated causes fairly considerable changes in K (2.5-3.81 absolute) and a_m (50.6-74.5).

In the graphical interpretation of the total distribution, this effect appears as a change in the radius of curvature of the curve and also in the distance of the inflection on the curve from the vertical axis (Fig. 1). The physical meaning of the change in the coefficients K and a_m with increasing viscosity of the liquid arises from the fact that the degree of variation in the drop size and also the most probable diameter of a drop both increase.

A slightly different picture is obtained on varying the surface tension of the liquid (Figs. 1 and 2a). A reduction in surface tension from 0.051 to 0.27 N/m causes no appreciable change in a_m (50.6-52.0), but produces a considerable rise in K (1.80-3.81). Graphically, curves 1, 2, 3 are distinguished by the fact that they have different radii of curvature, but almost identical distances of the inflection from the V axis, i.e., as the surface tension diminishes, the drop spectrum approaches the state of being represented by a single particle size, while the most probable drop diameter remains constant.

In order to compare the laws governing the changes which take place in the characteristics of many-size and nominally single-size systems when the properties of the liquids vary, we show in Fig. 2a, b how the coefficients of the distribution equation K and a_m and the mean volume-surface diameter d_{32} vary with μ and σ. As is evident from Fig. 2a, b, the mean diameter of the particles cannot serve as a genuine indicator of the spread in the particle size of a system, since the behavior of the distribution coefficients and the mean volume–surface diameter as functions of one spraying factor or the other is completely different.

The effect of the angular velocity of the disc (267-400 rps) on K, a_m, and d_{32} during the spraying of a highly viscous liquid (dynamic viscosity at 293°K 2.9 N·sec/m²) is indicated in Fig. 2c. We see from Fig. 2c that the rate of rotation of the disc has a considerable influence on the particle-size distribution parameters. The degree of dependence may be estimated quantitatively by examining the equations after their conversion into logarithmic form. On spraying liquid with a viscosity in the range 0.05-5.20 N·sec/m² the equations take the form

$$K = -2.90 \cdot \mu^{-0.091},$$

$$a_m = 64.95 \cdot \mu^{0.084}, \quad (3)$$

$$d_{32} = 53.50 \cdot \mu^{0.132}. \quad (4)$$

In the high-viscosity range (0.75-5.20 N·sec/m^2) the power indices of μ are still lower

$$K = -2.62 \cdot \mu^{-0,030}, \tag{5}$$

$$d_{32} = 56.50 \cdot \mu^{0,096}. \tag{6}$$

The expression for a_m in this range of viscosity coincides with Eq. (3).

The equations relating K, a_m, and d_{32} to the surface tension σ and the number of rotations of the disc take the form

$$K = -49.72 \cdot 10^{-3} \cdot \sigma^{-1,177}, \tag{7}$$

$$a_m = 59.20 \cdot \sigma^{0,043}, \tag{8}$$

$$d_{32} = 133.20 \cdot \sigma^{0,372}, \tag{9}$$

$$K = -50.65 \cdot 10^{-3} \cdot n^{0,658}, \tag{10}$$

$$a_m = 300 \cdot n^{-0,242}, \tag{11}$$

$$d_{32} = 28.15 \cdot 10^{2} \cdot n^{-0,640}. \tag{12}$$

It is well known [5] that the output of the disc has a fairly substantial influence on the size of the drops. The laboratory installation with which we were working enabled us to determine the particle-distribution indices of the drops for a fairly wide range of mass flow of the disc G. The results of these determinations appear in Table 1. The change in the coefficients K and a_m over this range of outputs shows that, with increasing flow of liquid, the most probable diameter of the drops increases, the volumetric proportion of drops of this diameter remaining practically constant.

Generalizing all the foregoing, we may conclude that different physicochemical and technological spraying parameters have different effects on the fractional composition of a system of drops with a wide range of sizes, and also on its mean volume–surface diameter. Of the several factors considered in the present investigation (within the limits already indicated), the surface tension of the liquid and the angular velocity of the disc exert the greatest influence on the dispersion parameters K and a_m.

The foregoing data enable us to make a more reasoned approach to the matter of estimating the effects of various spraying parameters on the drop size spectrum, and may be used in a number of practical connections.

NOTATION

V	is the number of drops with larger dimensions, % of volume;
d	is the diameter of drops, μ;
d_{32}	is the volume–surface diameter of drops, μ;
μ	is the dynamic viscosity of liquid at 293°K;
σ	is the surface tension of liquid at 293°K;
n	is the rate of rotation of disc, sec^{-1};
G	is the output of disc, kg/sec;
K and a_m	are coefficients of the Rosin–Rammler equation.

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