THE ATOMIZATION OF A LIQUID BY A RAPID GAS FLOW

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In calculating the sedimentation of dust on the drops formed by the atomization of a liquid in a rapid gas flow, the most probable drop size $2r_m$ should be used rather than the Sauter diameter D_0.

In considering the coagulation of solid particles with drops of liquid – a question which arises when designing or investigating systems for removing dust from gases, such as Venturi tubes – it is essential to know the character of the distribution function describing the behavior of the drops formed in the atomization of a liquid by a rapid gas flow. The drop-size distribution function used at the present time [1, 2] is

$$f(r)\,dr = ar^p \exp(-br^q)\,dr. \tag{1}$$

However, the use of a function of this kind for an exact solution of the coagulation problem involves complex calculations; when solving such problems it is therefore customary to consider the interaction of solid particles with drops of one specific diameter. The drop diameter universally chosen [3-6] is that of Sauter

$$D_0 = \frac{\int\limits_0^\infty d^3 f(d)\,dd}{\int\limits_0^\infty d^2 f(d)\,dd}, \tag{2}$$

this is related to the relative velocity of the gas and the liquid injected into it and to the specific consumption of water in the following manner [1]:

$$D_0 = 10^{-6}\left(\frac{4810}{|v_g^0 - v_d^0|} + 28.8\, m_d^{0^{1,5}}\right). \tag{3}$$

The solution of the problem on the basis of one characteristic size is justified by the fact that the drop distribution function has a sharp maximum; however, the choice of the Sauter diameter to represent this characteristic size for computing purposes is inappropriate. Actually, at the point D_0, it is not the function (1) which takes a maximum value, but the drop-mass distribution, and then only for $q = 1$, whereas in calculations of the coagulation process the size for which the drop-size distribution function (1) reaches a maximum value ought strictly to be used.

It is clear that the size of the drops most prevalent in the distribution may be found from the condition

$$\frac{\partial f(r_m)}{\partial r} = 0. \tag{4}$$

In order to determine the value of r_m in terms of v_g^0, v_d^0, and m_d^0 we first find the relation between these quantities and the parameters of the function (1).

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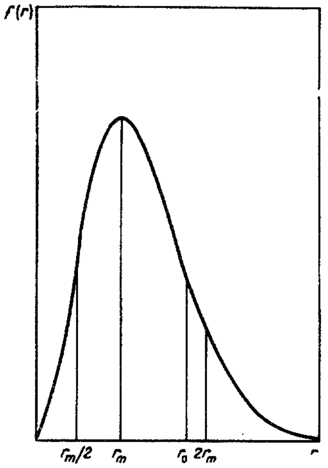

Fig. 1

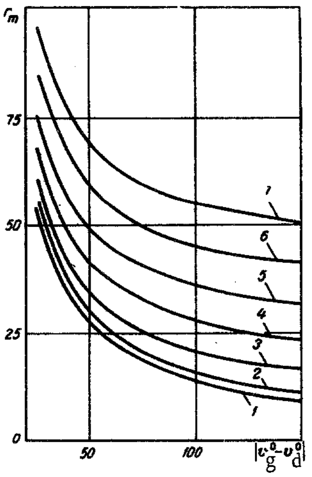

Fig. 2

Fig. 1. Drop-size distribution function according to the formula $f(r) = ar^2 \exp(-br^{1.5})$.

Fig. 2. Dependence of the most probable drop radius r_m (μ) on the relative velocity of the gas and drops $|v_g^0 - v_d^0|$ (m/sec) and the specific flow of water m_d^0 (kg/m³): 1) $m_d^0 \leq 0.25$; 2) $m_d^0 = 0.5$; 3) 1; 4) 1.5; 5) 2; 6) 2.5; 7) 3..

Calculating (2) we may write down the expression for

$$b = \left(\frac{2\Gamma\left(\frac{p+4}{q}\right)}{\Gamma\left(\frac{p+3}{q}\right) D_0} \right)^q \tag{5}$$

and then, using the normalization condition

$$\frac{4}{3} \pi a \int_0^\infty r^{p+3} \exp(-br^q)\, dr = m_d^0, \tag{6}$$

we determine

$$a = \frac{3m_d^0 q b^{\frac{p+4}{q}}}{4\pi\rho\Gamma\left(\frac{p+4}{q}\right)} \tag{7}$$

and the concentration of the drops

$$N = \frac{a\Gamma\left(\frac{p+1}{q}\right)}{qb^{\frac{p+1}{q}}}. \tag{8}$$

Using Eq. (5) we now find the following from Eq. (4):

$$r_m = \left(\frac{p}{bq}\right)^{1/q} = \left(\frac{p}{q}\right)^{1/q} \frac{\Gamma\left(\frac{p+3}{q}\right)}{2\Gamma\left(\frac{p+4}{q}\right)} D_0. \tag{9}$$

It is usually considered that p = 2; regarding the value of q, opinions differ, but the most likely value is q = 1.5-1.8 [7].

Taking q = 1.5 for subsequent calculations, from (5), (7), (8), and (9) we obtain

$$b = \frac{9}{D_0^{3/2}}, \quad a = \frac{3m_d^0 b^4}{16\pi\rho}, \quad N = \frac{2a}{3b^2}, \quad r_m = 0.28\,D_0 \equiv 0.56\,r_0. \tag{10}$$

It may be shown that the size of the overwhelming majority of the drops formed by the atomization of the liquid in a fast-moving gas flow lies within the range $\int_{\frac{r_m}{2}}^{2r_m} f(r)\,dr \approx 0.8$, i.e., 80% of all the drops have a size differing from r_m by less than a factor of two, the number of drops with $r < r_m/2$ being only 8% and that with $r > 2r_m$, 12%. Yet the value of $D_0/2 = 1.8\,r_m$, which is used at the present time, lies almost at the edge of this range (Fig. 1).

The value of r_m appropriate for use in coagulation calculations may be determined from Eqs. (9) and (3).

The relationship for p = 2 and q = 1.5 is given in Fig. 2.

NOTATION

r and d	radius and diameter of the drop respectively;
f(r)	drop-size distribution function;
$r_0 = D_0/2$	half the Sauter diameter;
r_m	most probable drop radius;
Γ	gamma function;
N	drop concentration;
ρ	density of the liquid;
m_d^0	mass of liquid introduced into 1 m^3 of gas;
v_g^0 and v_d^0	initial velocities of gas and drops respectively.

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