EXPERIMENTAL RESEARCH ON EVAPORATION AND ATOMIZATION OF LIQUID BY MEANS OF A ROTATING HEATED DISK

N. Yu. Gubenko and B. I. Leonchik

UDC 532.54

Results are given of experimental research on heating, evaporation and breaking down of a film of liquid which moves over a heated rotating disk.

The flow of liquid over the surface of a smooth rotating disk is characterized by the formation of a film; the heat supplied to it causes nonadiabatic evaporation of liquid and its simultaneous heating.

In order to determine the parameters of the liquid as it descends from the disk, it is necessary to know its temperature. It does not appear possible to do this by means of calculation, since a considerable proportion of the conducted heat is consumed in evaporation.

We carried out an experiment to determine the relationship for calculation of the intensity of heating of the liquid moving over a heated rotating disk in relation to the determining parameters.

Smooth plain disks made from steel Kh18N9T with a diameter of 100, 120, and 150 mm were the object of the investigation. The rotating speed of the disks was regulated smoothly in a range from 2660 to 1200 rpm and it was measured by using a stroboscope of the type ST-5 MÉI. The disk was heated on both faces by means of heat radiation from electric heaters. The density of the transmitted liquid of the thermal flux varied in the limits $(35\text{-}150)\cdot 10^3$ W/m^2. The investigated liquid (aqueous solutions of $NaNO_3$ with initial concentrations of 39 and 19% and distilled water) was supplied to the center of the disk, its discharge varied from 4 to 18 kg/h, and the initial temperature was in the range 20-85°C. The measured parameters of the surrounding air corresponded to those prevailing at room temperature.

In the experiments carried out the concentration of the solution as it descended from the disk and also the temperature of the liquid at the edge of the disk were determined by means of analysis of selected samples. A special device [1] was used for this purpose.

The relative error of determination of the concentration did not exceed ±2%, but the temperature measurement error was 1.5-2°C. Treatment of the experimental data enabled the criterion relationship

$$\frac{r}{c\Delta t} = 0.6\left(\frac{\omega R^2}{\nu}\right)^{0.2}\left(\frac{G_0}{R\nu\gamma}\right)^{0.3}\left(\frac{qR}{r\nu\gamma}\right)^{-0.5}\left(\frac{P}{P_0}\right)^{3.6} \quad (1)$$

to be obtained, which approximated the results of the experiments with an accuracy of ±15%.

Expression (1) represents the relationship between the Kutateladze criterion $K = r/c\,\Delta t$ and the three criteria which have a hydrodynamic nature, the similarity, and the simplex P/P_0, which takes into account the variation of the pressure of the vapors above the solution in comparison with the pressure of the vapors above the pure solvent at the same temperature. The values of all the physical magnitudes which enter the criterion are taken at the initial temperature and concentration of the liquid supplied to the disk.

P_0 = 745 mm Hg column is taken as the determining pressure; P is determined at a temperature of 100°C.

Energy Institute, Moscow. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 20, No. 1. pp. 151-153, January, 1971. Original article submitted January 29, 1970.

In the experiments which were carried out the criterion had the following numerical values: $K = 8.5$–22; $\omega R^2/\nu = (0.78\text{–}2.34)\cdot 10^6$; $G/R\nu\gamma = 12.6\text{–}65.0$; $qR/r\nu\gamma = 0.6\text{–}1.85$; $P/P_0 = 1\text{–}0.81$.

It must be noted that the influence of the parameters of air on the process examined is weak. This is explained by the fact that in the case of nonadiabatic evaporation of the liquid it heats up considerably, as a result of which the vapor pressure above the surface of the liquid considerably exceeds its partial pressure in the surrounding air and the influence of the latter can be neglected.

In addition, the influence of heating and or partial evaporation of the liquid on the disk on the characteristics of the atomizing jet was investigated, for which the degree of dispersion of the atomization was determined by means of microphotography of samples, taken from the lateral cross section of the jet at a distance of 120 mm from the center of the disk, and also the density of the spray, and, correspondingly, the radius of the jet.

The available calculated relationships for determining the diameter of the drops which form during breaking down of the liquid by the disk atomizers are inapplicable in the case examined, since they are obtained for a different range of parameters of the system, or for discs of a different design [2]. Hence the experimental data obtained were generalized in the form of the following relationship:

$$\frac{d_{99}}{R_d} = 2{,}1\cdot 10^3 \left(\frac{\omega R_d^2}{\nu}\right)^{-0{,}85} \left(\frac{G}{\nu\gamma R_d}\right)^{0{,}2} \left(\frac{\sigma}{\gamma R_d^2}\right)^{0{,}3}. \tag{2}$$

The discharge of the liquid, subject to atomization by the heated disk,

$$G = G_0 - \frac{1}{r}\left[qF - \int_0^R G\cdot c\,(t_R - t_0)\,dR\right] \tag{3}$$

or approximately

$$G = G_0 - \frac{1}{r}\,(qF - G_0 c_0 \Delta t). \tag{4}$$

The calculations d_{99} according to (2) and the experimental data corresponding to them show that the heating and partial evaporation of the liquid on the disk leads to a decrease of d_{99} of 20–30% on account of variation of the physical properties of the liquid and reduction of its quantity, subject to atomization. The densities of spray found experimentally and the radii of the nonevaporating jets of the atomization also have considerably smaller values for the disk atomizer – evaporator than for the case of atomization by a nonheated disk.

The differences indicated above enable the disk atomizer – evaporator to be modified for intensifying the process of atomizing drying in small drying installations. The relationships obtained can be used for calculations of drying plant and other equipment which uses the principle of evaporation of a film on rotating surfaces.

NOTATION

R	is the radius of the disk;
ω	is the angular velocity;
r, c, ν, γ	are the latent heat of evaporation, specific heat kinematic viscosity, specific weight and surface tension of the liquid;
Δt	is the extent of liquid heating;
G	is the flow rate;
q	is the specific heat flux;
P	is the water vapor pressures;
d_{99}	is the diameter of drops, maximum for 99% of the whole quantity of drops in the atomizing jet;
F	is the heated surface area of the disk.

Subscripts

0	is the supply to the disk;
R	on the radius R;
d	is the disk.

LITERATURE CITED

1. Author's Communication No. 251870, Byull, Izobretenii, No. 28 (1969).
2. A. V. Lykov and B. I. Leonchik, Atomizing Drying Plant [in Russian], Mashinostroenie (1966).
3. Author's Communication No. 193358, Byull. Izobretenii, No. 6 (1967).