

DROPLETS EVAPORATION ON HEATED WALL

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Abstract. Various modes of evaporation in a wide range of droplet sizes and wall temperatures have been investigated in the present work. For any initial drop size there are three typical boiling regime: 1) the nucleate boiling; 2) the transitional regime; 3) the film boiling. The width of the transition region of boiling crisis increases with increasing the initial volume V_0 . Evaporation of large droplets at high superheat depends on the initial droplet shape.

1 Introduction

Boiling and evaporation processes widely used in practice. Efficiency of technological processes depends on the correct description of boiling and evaporation. The simplest form of evaporation - a drop of small size (initial diameter of 3 mm) and at low wall superheat (ΔT less than 80 °C). In this case the shape of the drop is described by the well-known empirical dependence and convection inside the drop can be neglected. There are various modes of liquid boiling (nucleate boiling and film boiling [1]) when placing a drop on a heated horizontal surface of a solid wall. Various modes of evaporation in a wide range of droplet sizes and wall temperatures have been investigated in the present work. The process of evaporation and boiling crisis were studied in [2-15]. The fine droplets evaporation of liquid nitrogen during explosive of nitrogen-water mixture is presented in [16-17].

2 Experimental data

Experiments were carried out under the conditions: 1 atm., copper working section, ambient temperature was 23 °C. Description of the experimental setup is given in [1]. The wall temperature was maintained constant automatically to within 1 °C. The droplets were obtained via microdispensers providing maximum limit of relative error of less than 2.5 % volume. Dosed droplet sizes vary over a wide range of volumes from 0.01 to 1 cm³. This interval corresponds to the initial diameter of the spot wetting of 1-30 mm. The drop shape takes the form: (hemisphere for $d < 2h$, h - the height of the drop; ellipsoid for $d > 2h$; almost flat shape for $d \gg h$) depending on the initial volume of the sample. Fig. 1 shows a generalized curves of evaporation - the dependence of the Fourier number Fo on the dimensionless wall temperature T_1 ($Fo = at_1/d_1^2$, where d_1 - the equivalent diameter of the sphere for relations $V_0 = 4/3 \cdot \pi r^3$, a - liquid thermal diffusivity, t_1 - time for a complete evaporation of the droplet, $T_1 = T_w/T_s$, where T_s - the saturation temperature at the given external environment pressure).

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The evaporation curves divided into three characteristic curves: 1) the lower curves correspond to the hemispherical droplet shape (the initial sample volume is $V_0 = 0-0.05 \text{ cm}^3$), 2) the middle curves generalize the transition shape and 3) the upper curves correspond to the flat form (the initial sample volume greater than 0.5 cm^3). Thus, it is necessary to take into account the shape of the droplet surface in determining generalizing formula. Dependence of the total evaporation time t_1 of distilled water on the dimensionless wall temperature $T_j = T_w/T_s$ in a wide range of initial volume V_0 is shown in Fig. 2. Measurements were carried out on the copper area. Minimum time correspond to wall overheating $\Delta T_w = T_w - T_s = 20-35 \text{ }^\circ\text{C}$, T_{L1} , T_{L2} – Leidenfrost temperature. With the further increase of an overheating the liquid periodically separates from the wall and there is the transition boiling regime (the regime of periodic droplet separation). The growth of the evaporation time is caused by presence of a vapor layer that separates the liquid from the wall. The thermal conductivity of steam is much lower than that of the liquid. In case of overheating above $80 \text{ }^\circ\text{C}$ the liquid ceases to touch the wall. This steady detachment is called the film boiling under Leidenfrost temperature. As can be seen from the graphs for any initial drop size there are three typical boiling regime: 1) the nucleate boiling; 2) the transitional regime; 3) the film boiling.

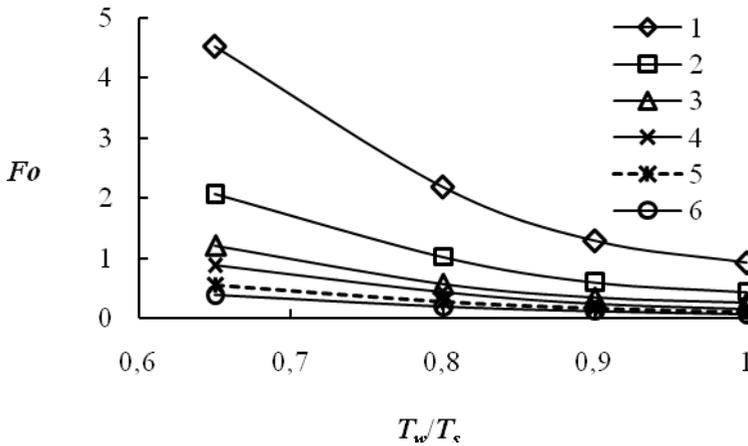


Fig. 1. Dependence of Fo on the dimensionless wall temperature T_w/T_s (1 – $V_0 = 0.02 \text{ cm}^3$, 2 – 0.046 cm^3 , 3 – 0.1 cm^3 , 4 – 0.2 cm^3 , 5 – 0.5 cm^3 , 6 – 1 cm^3).

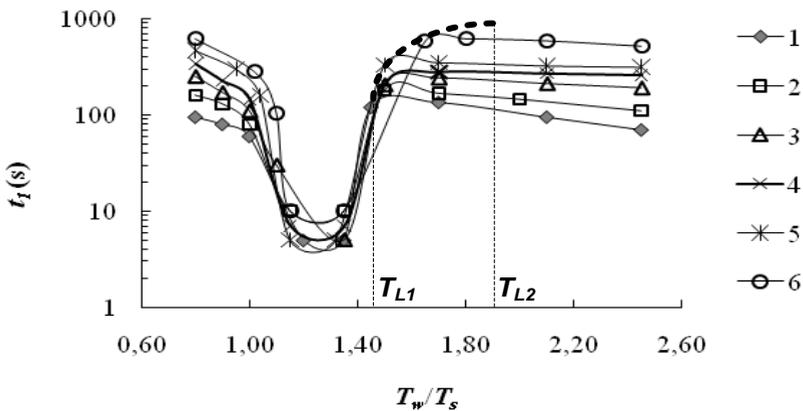


Fig. 2. The dependence of the total droplet evaporation time t_1 of distilled water on the dimensionless wall temperature T_w/T_s (1 – $V_0 = 0.02 \text{ cm}^3$, 2 – 0.046 cm^3 , 3 – 0.1 cm^3 , 4 – 0.2 cm^3 , 5 – 0.5 cm^3 , 6 – 1 cm^3).

3 Conclusion

Thus, there are 3 drops boiling regimes for all investigated droplet sizes: 1) the nucleate boiling; 2) the transitional regime; 3) the film boiling. The width of the transition region of boiling crisis increases with increasing the initial volume V_0 . The number of Fo decreases with increasing temperature of the wall. The effect of droplet diameter and the temperature on the number of Fo is reduced with increasing overheating wall and droplet diameter. Evaporation of large droplets at high superheat depends on the initial droplet shape.

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