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Spheroid droplets evaporation of water solutions

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Abstract. Droplet film boiling on a horizontal heating surface was studied experimentally. The heat transfer coefficient of droplet water solution in the spheroidal state decreases with a rise of wall overheating and spheroid diameter. Evaporation of small spheroid (diameter $d < 5$ mm) is markedly different from the large one ($d > 20$ mm). At the evaporation of large spheroids a spheroid shape changes in time that significantly affect coefficients of generalizing curves that use dimensionless numbers.

Introduction

The high temperature boiling is widely used in engineering apparatus. There is boiling crisis at high heat fluxes. During nucleate boiling the formed vapor layer reduces the heat transfer by several orders, resulting the wall overheating. The lowest temperature boundary of this regime with stable vapor layer is referred to as the Leidenfrost point (LFP). Evaporation of pure liquids differs significantly from solutions [1-9]. Acceleration of the flow affects the transport mechanisms in the gas mixture [10]. Influence of the wettability and physicochemical wall properties on the droplet evaporation is considered in the works [11]. The boiling crisis in mini channels lead to flow locking [12]. Phase transitions rates strongly depend on both the external and internal local heat fluxs [13-19] and on impurities [20, 21]. Thermal imager measurement procedure is presented in [22].

Experimental data

Heat transfer between a spheroidal droplet and a heated wall is generalized by the dependence of Nusselt number ($Nu = \alpha l/\lambda$) on Prandtl (Pr), Reynolds (Re), Grashof (Gr) numbers in the form of $Nu = cGr^{n_1}\,\mathrm{Pr}^{n_2}\,\mathrm{Re}^{n_3}$ (α-heat transfer coefficient, λ-liquid thermal conductivity).Neglecting liquid circulation in a spheroid, we can simplify the expression for $Nu = f\left(\dfrac{c_{pv}\Delta T_W}{r}\right)$. If we take the capillary constant as characteristic size l, then we can

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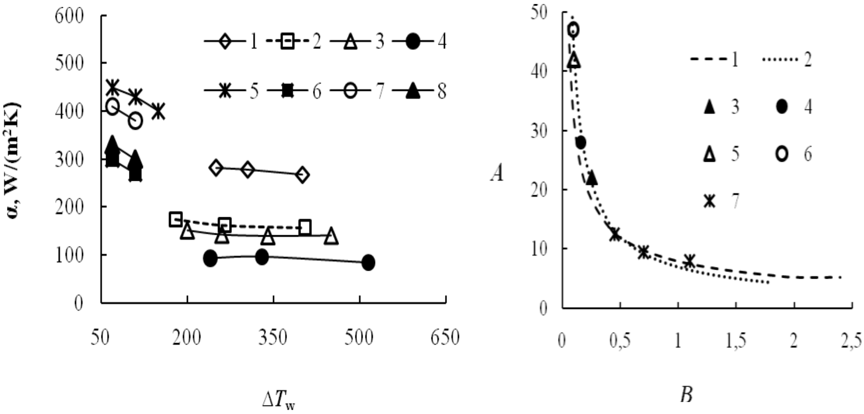
obtain $A = c_1(B)^n$, where parameters B and A will be $A = \frac{\alpha}{\lambda_v}\sqrt{\frac{\sigma}{g(\rho_l - \rho_v)}}, B = \frac{c_{pv}\Delta T_w}{r}$.

In Fig. 1(a) experimental data on heat transfer for different liquids and mixtures are shown in dependence on wall overheating ΔT_w (the difference between the wall temperature and the saturation temperature). Significant changes in the thermal-physical properties of liquids and ΔT_w lead to variation of α by the factor of 4.



(a) (b)

Fig. 1. a) A change in α for the droplet spheroidal state vs. ΔT_w of different liquids: 1–water; 2–ethanol; 3–CCl_4; 4–C_6H_6; 5–water; 6-8: water solution of ethanol 6-(C_0=92%); 7–(C_0 = 27%); 8–(C_0=64%),
b) A change in α for the droplet spheroidal state in generalizing coordinates A and B: Curve 1 for large spheroids – $A=7.85(B)^{-0.58}$; Curve 2 for small spheroids – $A = 6,9(B)^{-0.81}$; 3–water solution of ethanol C_0=92%, ΔT_w=110°C; 4–water solution of ethanol (70%, 110°C); 5–water, 110°C; 6–water, 70 ºC; 7–CCl_4, C_6H_6.

In Fig. 1(b) experimental data are generalized by the empirical criteria dependence in the form of

$$A = c_1(B)^n \quad (1)$$

For curve1 in Fig. 1(b) data correspond to large spheroids (diameter d is greater than 20 mm). For curve2 all spheroids were small (diameter d is less than 5 mm). Moreover, α was determined as the average value for the whole period of evaporation, when the diameter decreased from the maximal to zero values. It is characteristic, points 7 were obtained for high values of ΔT_w=200-500°C. Points 3-6 for low values of ΔT_w=60-70 ºC, i.e., the data were carried out near the transitional crisis area. Generalizing curve kind varies when approaching the transitional crisis area.

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