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FC72 and FC87 nucleate boiling inside a narrow horizontal space

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ABSTRACT

This paper presents new experimental results for saturated nucleate boiling of FC72 and FC87 on a horizontal copper disc, at atmospheric pressure, for different degrees of confinement, *s*, in the range of 0.1–13 mm, and with two kinds of confining element, for low and moderated heat fluxes ($\leqslant$40 kW/m^2), on both a downward and an upward facing heating surface. For low heat flux a decrease of the confinement gap causes an enhancement of the boiling and a decrease in the dryout heat flux. A visualization of the boiling phenomenon shows the effect of confinement and heat flux on the liquid–vapor configuration.

1. Introduction

Boiling is of great interest in all applications involving high heat flux. Because of its high heat transfer, nucleate boiling enables the transfer of a large amount of energy without requiring a strong superheat. Boiling in a narrow space occurs in many industrial applications, such as in the cooling of electronic devices, in micro-heat exchangers and in heat spreaders. The first studies focusing on confined boiling were performed by Katto et al. [1] and Ishibashi and Nishikawa [2]. The former focused on the confined boiling on a horizontal plate, and showed that confinement enhances the boiling heat transfer at low heat flux while it causes a decrease in the critical heat flux (CHF). In the latter publication, the authors presented a detailed analysis of the effect of pressure, surface tension and confinement for pool boiling in an annular vertical channel. The authors also showed that the confinement leads to an increase in heat transfer at low heat fluxes. Furthermore, they established the existence of two regimes depending on the Bond number, *Bo*, defined as the ratio of the gap, *s*, between the heating surface and the unheated surface, and the capillary length, L_c:

$$Bo = \frac{s}{L_c} \tag{1}$$

with,

$$L_c = \left[\frac{\sigma}{g(\rho_l - \rho_v)}\right]^{1/2} \tag{2}$$

where σ, g, ρ_l and ρ_v represent the surface tension, the acceleration due to gravity, the vapor density and the liquid density, respectively. Also, Ishibashi and Nishikawa showed that the enhancement of heat transfer due to confinement becomes stronger when $Bo < 1$, meaning that the gap *s* is equal to or smaller than the bubble detachment diameter.

The effect of pressure was also studied by Bonjour et al. [3] for vertical and horizontal configurations, and the authors found, in agreement with Ishibashi and Nishikawa [2], that the enhancement of heat transfer due to pressure in unconfined boiling tends to disappear as the confinement increases. Ishibashi and Nishikawa [2] also showed that the surfactant effect disappears with the confinement, a result confirmed later by Hetsroni et al. [4]. The effect of subcooling was investigated by Passos et al. [5], who showed that while in saturated boiling the confinement has a positive effect on heat transfer, its effect is negative in subcooled boiling: the subcooling increases the heat transfer for unconfined boiling at low heat flux while its influence is much lower in the confined case and heat transfer is higher during unconfined subcooled boiling than during confined subcooled boiling. The effect of the active nucleation site density was also studied by Bonjour et al. [3] and the authors showed that while in unconfined boiling a single active nucleation site does not enhance heat transfer compared to natural convection, this enhancement of the heat transfer by a single nucleation can clearly be seen in confined boiling.

The boiling patterns and regimes in confined boiling were studied in detail by Bonjour and Lallemand [6] for a vertical heating surface. According to this study, boiling before the CHF in a confined space presents three different regimes: isolated deformed bubbles at low heat flux, coalesced bubbles at moderate heat flux,

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