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On Microlayer Growth in Liquid Metal Boiling Flows

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Introduction

The use of liquid metal heat transfer fluid integrated with a phase change heat storage system in concentrated solar thermal power (CSP) plants is a viable option to supply high-temperature, isothermal heat source under variable solar conditions. The success of this method partly depends on gaining a clear understanding of the boiling process of liquid metals in the tubes of a receiver. An integral part of the boiling process is the growth of the microlayer below a bubble. A microlayer is a thin liquid film which forms below a growing bubble on a heated surface, and is primarily responsible for bubble growth owing to the occurrence of extremely high heat fluxes (Stephan et. al, 1994) (Fig. 1). Significant research has been reported on the microlayer growth in high Prandtl number fluids like water and refrigerants (Stephan et. al, 1994, Jiang et al 2013, Yabuki et al, 2014). However, a significant gap exists in understanding the growth of this thin layer in low Prandtl number fluids like liquid metals. Liquid metals are fundamentally different from ordinary fluids like water and refrigerants due to the presence of free electrons which produces an … to
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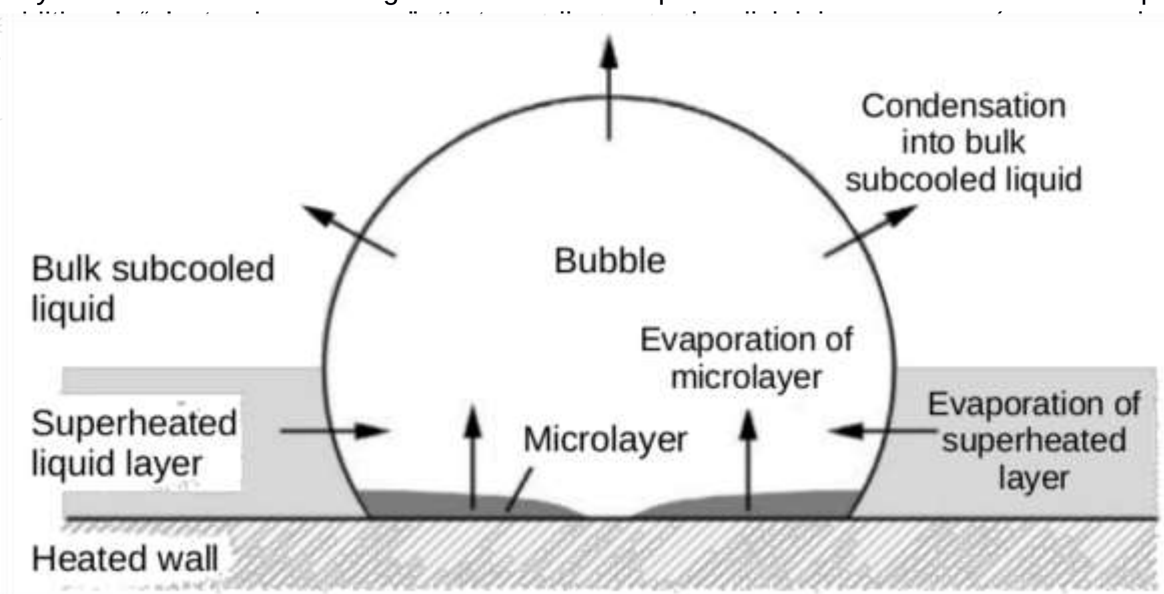

Figure 1: Heat transfer during bubble growth in boiling flows.

Scope

A microlayer model based on first principles is developed to predict the microlayer thickness below a bubble. Heat transfer and fluid flow in the microlayer are studied taking into account the influence of thermal resistance, meniscus curvature, adhesion forces and capillary forces on the liquid-vapour interface. A numerical investigation is performed using the developed model to study the influence of each parameter on microlayer growth in high and low Prandtl number flows. Major differences in the microlayer growth characteristics in low Prandtl number flows are highlighted and presented. Additionally, this research also explores the significance of the electronic component of the disjoining pressure on the heat flux and microlayer growth in liquid metals.

Results

The developed model predicts the microlayer thickness, heat flux and the pressure in the microlayer. Figure 2 shows the growth of the microlayer, disjoining pressure and the heat flux below a 0.125 mm bubble in a pool of refrigerant R114. The disjoining pressure acts close to the triple point where the microlayer thickness is extremely small (of the order of nanometres) and decreases with increasing length. As the microlayer grows, the disjoining pressure which inhibits heat transfer decreases, thus causing a peak in the heat flux as shown in Figure 2. Further downstream, the heat flux reduces due to a decrease in the interfacial thermal resistance.

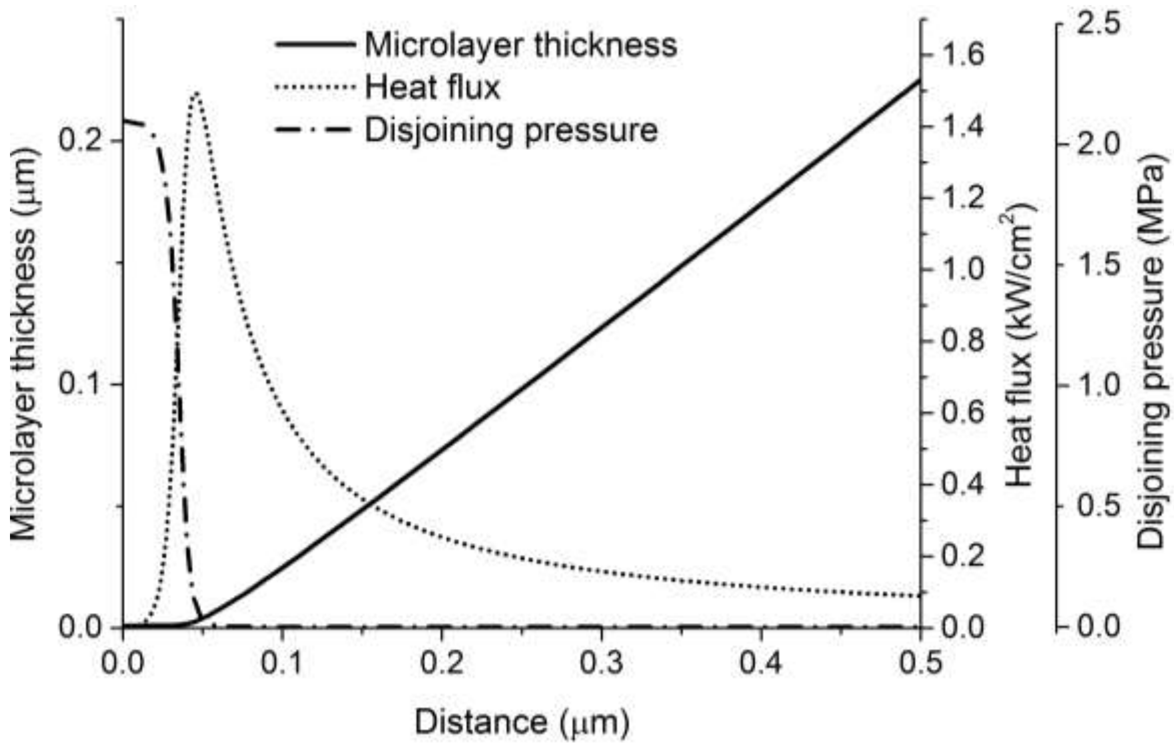

Figure 2: Microlayer thickness, heat flux and disjoining pressure in the microlayer below a bubble in a pool of R114.

References

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