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Guest Editorial

Special issue on "Boiling in Microchannels"

In this special issue of the journal, an attempt has been made to collate some scattered knowledge in the advances in boiling in microchannels. Leading international experts in the field have contributed in this special issue. It should be useful to the readers of the journal. This special issue is a compendium of following eight papers.

- The first paper is on "Onset of Nucleate Boiling in Mini and Microchannels: A Brief Review" by Tomio Okawa

This paper summarizes the studies on the thermal hydraulic condition under which the onset of nucleate boiling (ONB) is triggered in subcooled flow boiling. Available correlations and experimental data show that the ONB is tended to be delayed in mini and microchannels. It is known that the ONB condition is significantly dependent on the surface condition even in conventional-sized channels. Accumulation of ONB data accompanied by the information on the surface condition is therefore considered of importance to elucidate the mechanisms of boiling incipience in microchannels. Discussion is also made for the bubble dynamics observed in mini and microchannels. It is indicated that the bubble behavior at ONB in mini and microchannels may significantly be different from that in conventional-sized channels and have greater impact on the system performance. Further studies on the bubble dynamics following nucleation at ONB are required to improve the design of heat transfer devices using mini and microchannels.

- The second paper is on "Heat transfer characteristics in a copper micro-evaporator and flow pattern-based prediction method for flow boiling in microchannels" by Etienne Costa-Patry, Jonathan Olivier and John R. Thome

This article presents new experimental results for two-phase flow boiling of R-134a, R-1234ze(E) and R-245fa in a micro-evaporator. The wall heat transfer coefficients were function of the heat flux, vapor quality and mass flux. A new flow pattern-based prediction method for flow boiling heat transfer coefficients in microchannels was developed based on the experimental results. The new method also predicted published data for four other test sections accurately, capturing the trends versus vapor quality well.

- The third paper is on "Characteristics of Microlayer Formation and Heat Transfer in Mini/Microchannel Boiling Systems: A review" by Yaohua Zhang and Yoshio Utaka

This paper reviews recent research on microlayer formed by confined vapor bubbles during boiling in mini/microchannels. Experimental measurements, simulations and theoretical studies are described and compared. As a reference to clarify the mechanism for the formation of a microlayer, Taylor flow (i.e. elongated bubble flow in mini/micro circular tubes under adiabatic conditions and at $Re \ll 1$) and elongated bubble flow at high velocity, with consideration of the influence of inertia, are also reviewed. Compared to the steady adiabatic conditions, one of the distinct points for the boiling condition is that the bubble grows exponentially due to rapid evaporation of the microlayer. A pattern of two regions (i.e., surface tension-viscosity controlled and boundary layer controlled regions) seems to be presently acceptable to describe microlayer formation for a wide range of bubble growth velocity. In addition, the effect of

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microlayer evaporation on the boiling heat transfer in mini/microchannel is reviewed.

- The fourth paper is on "Heat Transfer Measurements for Flow of Nanofluids in Microchannels Using Temperature Nano-Sensors" by Jiwon Yua, Seok-Won Kanga, Saeil Jeonb, and Debjyoti Banerjee.

Experiments were performed to study the forced convective heat transfer of de-ionized water (DI water) and aqueous nanofluids in a microchannel and temperature measurements were obtained using an array of nanosensors (i.e., thin film thermocouples or "TFT"). Heat flux values were calculated from the experimental measurements for temperature recorded by the TFT array. The experiments were performed for the different test fluids where the flow rate, mass concentration (of silica nanoparticles ~10-30 nm diameter) in the colloidal suspension and the wall temperature profile (as well as applied heat flux values) were varied parametrically.
Anomalous enhancement of the convective heat flux values were observed for the different experimental conditions. Precipitation of nanoparticles on heat exchanging surfaces was confirmed using materials characterization techniques such as Scanning Electron Microscopy (SEM) and Energy Dispersive X-Ray spectroscopy (EDX). It is suggested that moderate precipitation of nanoparticles lead to formation of isolated nanofins which cause the observed enhancements in forced convective heat transfer (due to increase in the effective surface area), while excessive precipitation results in scaling (fouling) of the surface which causes degradation of the heat flux values (compared to that of the pure solvent). This study shows that the surface conditions play a dominant role in determining the efficacy for heat transfer in multi-phase flows – particularly those involving nanoparticle coatings and nanoparticle suspensions (compared to the bulk properties of the test fluid itself).

- The fifth paper is on "Pressure Drop Measurements with Boiling in Diverging Microchannel" by Amit Agrawal, V.S. Duryodhan and S. G. Singh.

An experimental study of flow boiling through diverging microchannels has been carried out in this work, with the aim of exploring reduction in flow instabilities during boiling in diverging microchannels. Effect of mass flux, heat flux and divergence angle on two phase pressure drop has been studied using deionized water as the working fluid. The experiments are carried out on three test sections with divergence angle of 4, 8 and 12 degree with nearly constant hydraulic diameter (146, 154 and 157 μm respectively), for inlet mass flux and heat flux range of 117 - 1197 kg/m^2-s and 2.5 to 19.7 W/cm^2 respectively. Pressure drop with respect to mass flux is linear and non-linear in single and two phase regimes, respectively. There are up to three points in single/two-phase regime having the same pressure drop, which is similar to uniform cross section microchannel. However, unlike uniform cross section microchannel, the slope of demand curve at the point of onset of flow boiling is less steep in diverging microchannel; further, the slope is an inverse function of the divergence angle. Preliminary study suggests that diverging microchannel can reduce the flow instabilities.

- The sixth paper is on "A Critical Review of Recent Investigations on Flow Pattern and Heat Transfer during Flow Boiling in Microchannels" by Sira Saisorn and Somchai Wongwises.

A summary of recent research on flow boiling in micro-channels is provided in this article. This review aims to survey and identify new findings arising in this important area, which may contribute to optimum design and process control of high performance miniature devices comprising extremely small channels. Several criteria for defining a micro-channel are presented at first and the recent works on micro-scale flow boiling are subsequently described into two parts including flow visualization and two-phase heat transfer. The results obtained from a number of previous studies show that the flow behaviours and heat transfer mechanisms in micro-channels deviate significantly from those in ordinarily sized channels. Future research with numerous aspects of flow boiling phenomena necessary to answer the fundamental questions is still required.

- The seventh paper is “A Critical Review of Recent Investigations on Two-Phase Pressure Drop in a Flow Boiling Microchannels” by Sira Saisorn and Somchai Wongwises.

Two-phase pressure drop during flow boiling has been studied for several decades. Obviously, the publications available on micro-channels are relatively small compared with those for ordinarily sized channels. Although the use of micro-channels yields several advantages, the pressure drop taking place in these extremely small channels is higher than that in the ordinarily sized channels because of the increased wall friction. The knowledge of the two-phase pressure drop characteristics in addition to heat transfer phenomena is essential to the design and evaluation of the micro-systems. In this paper, recent research on the flow boiling pressure drop in micro-scale channels is reviewed. The experimental results as well as the relevant prediction methods based on different researchers are presented.

- The eighth paper is on “Critical Heat Flux during Flow Boiling in Mini and Microchannel-A State of the Art Review” by P. K. Das, S. Chakraborty and S. Bhaduri.

A state of the art review of critical heat flux during flow boiling through mini and microchannels has been provided. This review mainly examines three aspects, namely the experimental investigations, the available correlations and the state of prediction using those correlations and finally the proposed physical mechanisms as well as the theoretical models. Before discussing the specific literature on microchannels, a brief overview of critical heat flux for pool and flow boiling is provided. The review has been concluded with a summary of the available information on this topic and the need for future research.

Wish you happy reading.

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