World Academy of Science, Engineering and Technology
International Journal of Energy and Power Engineering
Vol:11, No:10, 2017

Numerical Investigation of Flow Boiling within Micro-Channels in the Slug-Plug Flow Regime

Authors : Anastasios Georgoulas, Manolia Andredaki, Marco Marengo

Abstract : The present paper investigates the hydrodynamics and heat transfer characteristics of slug-plug flows under saturated flow boiling conditions within circular micro-channels. Numerical simulations are carried out, using an enhanced version of the open-source CFD-based solver 'interFoam' of OpenFOAM CFD Toolbox. The proposed user-defined solver is based in the Volume Of Fluid (VOF) method for interface advection, and the mentioned enhancements include the implementation of a smoothing process for spurious current reduction, the coupling with heat transfer and phase change as well as the incorporation of conjugate heat transfer to account for transient solid conduction. In all of the considered cases in the present paper, a single phase simulation is initially conducted until a quasi-steady state is reached with respect to the hydrodynamic and thermal boundary layer development. Then, a predefined and constant frequency of successive vapour bubbles is patched upstream at a certain distance from the channel inlet. The proposed numerical simulation set-up can capture the main hydrodynamic and heat transfer characteristics of slug-plug flow regimes within circular micro-channels. In more detail, the present investigation is focused on exploring the interaction between subsequent vapour slugs with respect to their generation frequency, the hydrodynamic characteristics of the liquid film between the generated vapour slugs and the channel wall as well as of the liquid plug between two subsequent vapour slugs. The proposed investigation is carried out for the 3 different working fluids and three different values of applied heat flux in the heated part of the considered microchannel. The post-processing and analysis of the results indicate that the dynamics of the evolving bubbles in each case are influenced by both the upstream and downstream bubbles in the generated sequence. In each case a slip velocity between the vapour bubbles and the liquid slugs is evident. In most cases interfacial waves appear close to the bubble tail that significantly reduce the liquid film thickness. Finally, in accordance with previous investigations vortices that are identified in the liquid slugs between two subsequent vapour bubbles can significantly enhance the convection heat transfer between the liquid regions and the heated channel walls. The overall results of the present investigation can be used to enhance the present understanding by providing better insight of the complex, underpinned heat transfer mechanisms in saturated boiling within micro-channels in the slug-plug flow regime.

Keywords : slug-plug flow regime, micro-channels, VOF method, OpenFOAM
Conference Title : ICETS 2017 : International Conference on Energy and Thermal Sciences
Conference Location : Barcelona, Spain
Conference Dates : October 30-31, 2017