NEAR-WALL TURBULENCE-BUBBLES INTERACTIONS IN A CHANNEL FLOW AT Re_τ=400: A DNS/LES INVESTIGATION

D. Métrailler, S. Reboux and D. Lakehal
ASCOMP GmbH, Zurich, Technoparkstr. 1, Switzerland
Metrailler@ascomp.ch; Reboux@ascomp.ch; Lakehal@ascomp.ch

ABSTRACT

This paper presents results of a Large-Eddy Simulation (LES) of a two-phase air—water mixture in a convective channel flow at Re_τ =400 using the CFD code TransAT. The aim of this work is to understand the effects of inertial turbulence in convective boiling flow. Thermal effects, nucleation and phase-change are taken into account in companion papers. The interactions between the bubbles and the liquid were studied through an in-depth analysis of the turbulence statistics. The near-wall flow is affected by the bubbles, which act like roughness elements. The coherent structures are different in shape than in single-phase flow, featuring less elongated, broken structures. The decay in the energy spectra near the wall was found to be significantly slower (slope of -3) for the bubbly flow than for a single-phase flow (slope of -6). The database generated is of sufficient quality to extract time-, space- and phase-averaged quantities, thus paving the way for model upscaling and accurate closure models for near-wall bubbly flow simulations using the mixture formulation.

KEYWORDS
Interface Tracking, turbulence, LES, DNS, bubbly flow

1. INTRODUCTION

The prediction of critical heat flux (CHF) conditions is vital in many industrial systems. In pressurized nuclear power reactors, CHF is a kind of limit parameter of operation; therefore its accurate prediction is important both from safety and economic point of views. In the last decade, considerable efforts have been made to use computational fluid dynamics (CFD) methods for the prediction of CHF. The limited success of these attempts motivates more work on the side of modeling. To support the modeling efforts we need reliable and accurate measurements, which are dedicated for development and validation of CFD methods. Beside complex CHF measurements, separate effect tests can be used to develop particulate models relevant in complex CHF modeling. In the development of CHF all transport mechanisms such as mass, momentum and energy transfer play important role.
In the PWR hot channel, beyond the onset of nucleate boiling but before the point of net vapor generation, small vapor bubbles are attached to the fuel rods. Heat and mass are transferred by evaporation from the base to the tip of the bubbles where condensation occurs; therefore, the heat transfer coefficient increases with respect to single-phase flow conditions. Also, the bubbles, effectively, act as surface roughness and thus, depending on their size, may affect the friction coefficient and ultimately the flow distribution across the sub-channels within the fuel assembly. Here the focus is on the effect of the departing bubbles on turbulence characteristics, time-average profiles of the fluid flow, and other global parameters including friction coefficient, pressure drop, etc. Heat transfer and phase change are not part of this benchmark; we only seed bubbles in the channel, as described below.

The aim of these simulations is to demonstrate that the methods applied here are able to predict the major characteristics of bubbly channel flow (bubble clustering, steepening of the rms of the mean velocity etc.). Furthermore, these simulations provide information for higher-level modeling. In particular, a method for

7. REFERENCES

[1] B. Phillips, J. Buongiorno and T. McKrell. 'Nucleation site density, bubble departure diameter, wait time and local temperature distribution in subcooled flow boiling of water at atmospheric pressure, as measured by synchronized high-speed video and infrared thermography', Proc. NURETH 15, Pisa, May 12-15 (2013)

[2] A. Ashrafian , H.I. Andersson, M. Manhart. 'DNS of turbulent flow in a rodroughened channel'. Int. J. Heat Fluid Flow 25 (3), 373–383. (2004)

[3] P.-Å. Krogstad et al. 'An experimental and numerical study of channel flow with rough walls'. J. Fluid Mech. 530, 327–352 (2005)

[4] D. Chatzikyriakou, J. Buongiorno, D. Caviezel, D. Lakehal. 'DNS and LES of turbulent flow in a closed channel featuring a pattern of hemispherical roughness elements', International Journal of Heat and Fluid Flow 53, 29–43 (2015)

[5] P. Sagaut. 'Large Eddy Simulation for Incompressible Flows', Springer Verlag (2006)

[6] R. D. Moser, J. Kim, & N. N. Mansour. 'Direct numerical simulation of turbulent channel flow up to Re= 590'. *Phys. Fluids*, *11*(4), 943-945 (1999).

[7] G. Tryggvason, J. Lu. 'DNS for multiphase flow model generation and validation', Proc. NURETH14, Toronto, Sept. 25-30 (2011).