Multiphase and Boiling Flow Modeling at the Paul Scherrer Institute

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Bojan Niceno works at the Paul Scherrer Institute (PSI) as the leader of the Modeling and Simulation group at Laboratory of Thermal-Hydraulics (LTH) in the Nuclear Energy and Safety (NES) department, and at the Swiss Federal Institute of Technology (ETH) Zurich, as a lecturer on Computational Multiphase Thermal Fluid Dynamics. He received his Diploma in Mechanical Engineering (Dipl. Ing.) from University of Rijeka, Croatia in 1994, and his Doctorate in Physics (Ph.D.) from Delft University of Technology in 2001. In 2002, he joined AVL in Graz, Austria, to work as a scientific software developer for AVL's Computational Fluid Dynamic (CFD) code FIRE. Since 2005 he was working as a CFD specialist in LTH at PSI. In 2007, he became the leader of the Modeling and Simulation group. In addition to the managerial tasks he performs as the group leader, he is still actively pursuing research. His personal research interests cover modeling of thermal-hydraulic phenomena pertinent to safety of nuclear installations, with particular emphasis on mathematical modeling of multiphase flows. He is also involved in the development of CFD modules/codes and numerical methods and optimization of CFD codes for high performance computational platforms. Due to his scientific output, he is a member of PSI's Research Committee, a board of experts defining research directions for PSI. Since 2012, he is one of the lecturers at highly acclaimed Short Courses on Multiphase Flow, which are held annually at ETH Zurich.

Development of **multiphase and boiling flow modeling at Paul Scherrer Institute (PSI)** is divided in two pillars: highly resolved simulations of boiling at microscales, and innovative Lagrangian particle tracking modeling techniques at milliscales. The simulations of boiling at microscales are performed by resolving the conservation equations on a grid which is fine enough for all scales of fluid motions. Even such a grid is not enough to resolve all relevant flow details of nucleate boiling and a number of novel models had to be defined on top of a standard interface tracking approach to tackle boiling. Models developed at PSI include sharp interface model, new contact angle treatment, improvements in interface tracking accuracy, and microlayer model for the liquid film present under each bubble at nucleate boiling. In addition, the phase-field approach for modeling of boiling and wetting phenomena will be presented. The phase field approach is based on minimization of free Gibbs energy, and offers the elegance of mathematical description of complex physical systems. At the milliscale, we define a new class of methods which fall in between interface tracking methods, and Lagrangian particle methods. The new methods inherit characteristics of both - resolution requirements are not as strict as in interface tracking, yet the reliance on empirical correlations diminishes with increased mesh resolution. Individual particles are described with the same (smoothed step function), making the coupling with interface tracking methods seamless. The performance of all models presented in this talk is accompanied by validation and verification examples. The direction for future research in this field is also envisaged.