Experimental and Numerical Investigations on the Direct Contact Condensation Phenomenon in Horizontal Flow Channels and its Implications in Nuclear Safety

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Abstract

Within this work the complex phenomenon of Direct Contact Condensation (DCC) in horizontal flow channels will be analyzed both experimental and numerical, while its implications in nuclear safety will be addressed. Such a crucial implication is that under certain conditions DCC can act with devastating results as the driving force for the Water Hammer phenomenon posing a threat to the integrity of NPP components.

DCC depends on many factors such as the two-phase flow morphology the temperature of each phase, but also on secondary parameters, such as thermo-physical properties of the liquid phase, the turbulence, the surface renewal rate, the resulting condensation flux and the steam momentum. The steam momentum in particular has a strong impact on the energy and momentum transfer to the interface. Moreover the accumulation of non-condensable gases at the two-phase interface impacts the heat and mass transfer.

Experiments focusing on the in depth analysis of the DCC phenomena haven been investigated at the Lithuanian Energy Institute based on a stratified co-current two-phase flow within a narrow rectangular channel (cross-section 20x100 mm) by measuring the water temperature profiles with a high resolution infrared camera.

A new strategy for the modelling of the Heat Transfer Coefficient (HTC) based on the mechanistic Surface Renewal Theory (SRT), accounting for two eddy length scales, combined with the Interfacial Area Transport Equation will be presented. The hybrid HTC model was implemented into the German system analysis code ATHLET and assessed against experimental data of Condensation Induced Water Hammers. The applicability range of the system analysis code ATHLET was thereby enhanced offering qualitative predictive capabilities of the condensation induced water hammer phenomenon during complex dynamic transients. The integral thermal-hydraulic experimental facility PMK-2 used in the validation process of the newly developed HTC model has a similar design to the main steam line of a WWER nuclear power plant.