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On Disturbance Waves and Their Importance for Dryout

Abstract:

An efficient and reliable heat transfer is important in many systems with a high power density, such as, e.g., modern electronic devices or nuclear reactors. Thanks to the high heat transfer efficiency, the temperature of such systems can be kept below prescribed limits. In addition, if the systems are cooled with a boiling fluid, their temperature is rather uniformly distributed and close to the saturation temperature at the prevailing fluid pressure. These features are employed in Boiling Water Reactors (BWRs), where the coolant total temperature increase in the core is about 10 K. This is much less than in reactor cores that are cooled with non-boiling fluids. Likewise, a quite high heat transfer coefficient can be achieved with a rather moderated mass flow rate of the coolant through the core.

One immediate consequence of using a boiling fluid for reactor core cooling is the increase of the vapour phase fraction in the two-phase mixture. Due to this an annular two-phase flow pattern is formed in the exit section of the boiling channel. Such a two-phase flow pattern manifests itself with droplets swarms flowing at the central part of the channel, whereas a thin liquid film flows along the heated walls. This fact has a tremendous impact on the heat transfer reliability, since, with a decreasing liquid phase fraction, the risk of liquid film disappearance increases. Once this occurs, the local heat transfer dramatically deteriorates and the heated wall temperature significantly increases. Such phenomenon is called the dryout and it must be avoided in BWRs under normal operation.

Already early observations of annular two-phase flows indicated that the liquid film surface was not smooth and two types of waves travelling on the film

surface could be discerned: small ripple waves and large, coherent disturbance waves. Actually the latter were observed to have a tremendous influence on the liquid film thickness and, consequently, on the dryout occurrence. Disturbance waves are known to influence the phase distribution in annular two-phase flows. In particular, their amplitudes, frequencies and wave lengths have significant influence on drop entrainment from the liquid film. In that way, the liquid film flow rate, and thus the onset of a dry patch on a heated wall, depends on the characteristic of the disturbance waves. There exist experimental evidences that the disturbance wave behavior plays a significant role in establishing of a stable dry patch leading to dryout.

In this seminar, disturbance wave characteristics obtained from available experimental data and retrieved from numerical calculations are discussed. In particular, a numerical approach based on the Volume of Fluid (VOF) method with the k-ω SST turbulence model and employing continuum surface force model to account for surface tension effects is shown. A new advanced post-processing approach to retrieve the characteristics of disturbance waves is demonstrated. All these new results might, hopefully, contribute to better understanding of the dryout phenomenon and allow for more accurate prediction of thermal margins in BWRs in the future.

Serdecznie zapraszamy,
M. Dąbrowski, T. Kwiatkowski