HEAT TRANSFER TO SUPERCRITICAL WATER

V. Tulkki, D. Danielyan, R. Salomaa

TKK, Department of Applied Physics, Advanced Energy Systems
email: ville.tulkki@tkk.fi

Nuclear power currently produces 16% of world's electricity and is one of the largest sources of non-fossil energy. Currently operating power plants are mostly built during the 70s and early 80s and have proved to be able to provide electricity reliably and safely. New plants now under construction rely on the same light water technology, but enhance their efficiency and safety with improved plant design.

However, plant design goes only so far in increasing the thermal efficiency in light water cooled nuclear reactors. As the heat sink temperature depends on the outside temperature the only viable way to increase efficiency is to increase the highest temperature, i.e. temperature inside the reactor. With conventional nuclear power plants boiling limits the temperature, as steam has poor heat transfer capability compared to water. To circumvent this limit modern fossil fuel fired plants utilize pressures above the critical point of water (22.064 MPa, 374 °C).

Supercritical water (SCW) does not undergo phase transition, and thus its heat transfer properties do not degrade violently. While SCW properties are known well enough to be used in coal-fired power plants, the strong coupling between coolant and power level in nuclear reactors require better understanding of SCW phenomena.

In plant-level modeling codes the water flow in pipes and channels is usually modeled as 1-D model due to the requirements in computing power. 3-D computational fluid dynamics codes might be more precise, but are not fast enough for large systems. The averaging of properties requires the use of several experimentally derived correlations for constants such as Nusselt number used for turbulent heat transfer.

In our work we compare the performance of correlations calculated for supercritical flow. As the experiments with supercritical pressures are expensive and difficult, most of the correlations are calculated for very specific experimental geometries, and their validity for general use is at doubt. The baseline used is Dittus-Boelter correlation that holds well for single-phase subcritical flows in smooth tubes, but does not describe well supercritical phenomena.