2010 International Congress on Advances in Nuclear Power Plants (ICAPP '10)
San Diego, California, USA, June 13-17, 2010

CFD Analysis on the Influence of Wire Wrap Spacers on the Heat Transfer to Supercritical CO_2

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Abstract

In a Supercritical Water Reactor (SCWR) the reactor core is cooled with supercritical water (SCW). For the design and operation of a SCWR, the characteristics of the heat transfer from the fuel rods to the SCW coolant needs to be well understood. These heat transfer characteristics are complex and cannot be captured by the correlations that are currently available in literature. First of all, the physical properties of SCW undergo strong changes near the pseudo-critical point which complicate the flow and heat transfer. Secondly, there is the complicated flow structure in the channels between the fuel rods separated by spacers and influenced by buoyancy forces. This is in particular true for the European design of the SCWR, which makes use of wire wrap spacers that are coiled around the full length of each fuel rod. Therefore, Computational Fluid Dynamics (CFD) models have been developed and applied within NRG to predict the heat transfer to supercritical fluids. With CFD it is possible to model flow dynamics in complex geometries. Furthermore, strong variations of the physical properties with temperature can be included in the CFD model as well as buoyancy forces.

The present paper describes the influence of a wire wrap spacer on the heat transfer to supercritical carbon-dioxide (SC-CO2). SC-CO2 has similar heat transfer characteristics as SCW at a lower pressure and temperature and is, therefore, an attractive substitute for SCW in experimental studies. The heat transfer to SC-CO2 in a heated tube without and with wire wrap inside is analyzed with CFD and compared to experiments from KAERI. Both, the experiments and the CFD analysis show an increased heat transfer rate due to the influence of the wire wrap spacer.

In order to investigate the influence of conduction, the solid material of the wire wrap and the solid material of the tube wall are included in the CFD model. Without conduction high wall temperatures are found near the wire where the flow is stagnant. The CFD analysis reveal that these local regions of high wall temperature are effectively mitigated by conductive heat transport through the solid tube wall and solid wire wrap spacer for the studied tube and wire geometry.

Keywords: Supercritical fluids, SCWR, heat transfer, wire wrap, CFD, FLUENT.