CFD in Supercritical Water-cooled Nuclear Reactor (SCWR) with Horizontal Tube Bundles

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The commercial CFD code STAR-CD 4.02 is used as a numerical simulation tool for flows in the supercritical water-cooled nuclear reactor (SCWR). The basic heat transfer element in the reactor core can be considered as round tubes and tube bundles. Reactors with vertical or horizontal flow in the core can be found. In vertically oriented core, symmetric characters of flow and heat transfer can be found and two-dimensional analyses are often performed. However, in horizontally oriented core the flow and heat transfer are fully three-dimensional due to the buoyancy effect. In this paper, horizontal tubes and tube bundles at SCWR conditions are studied. Special STAR-CD subroutines were developed by the authors to correctly represent the dramatic change in physical properties of the supercritical water with temperature. From the study of single round tubes, the Speziale quadratic non-linear high-Re k-? turbulence model with the two-layer model for near wall treatment is found to produce the best results in comparison with experimental data. In tube bundle simulations, it is found that the temperature is higher in the top half of the bundle and the highest tube wall temperature is located at the outside tubes where the flow rate is the lowest. The secondary flows across the bundle are highly complex. Their main effect is to even out the temperature over the area within each individual recirculating region. Similar analysis could be useful in design and safety studies to obtain optimum fuel rod arrangement in a SCWR.

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