ENHANCEMENT OF NUCLEAR HEAT TRANSFER IN A TYPICAL PRESSURIZED WATER REACTOR BY NEW SPACER GRIDS

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ABSTRACT

The fuel element geometry typically used in nuclear reactor is rod bundle whose rod-to-rod clearance is maintained by grid spacer. The heat generated in the rod by nuclear reaction is removed by coolant, usually in turbulent flow. The coolant moves axially through the sub-channels. Fuel spacer grid affects the coolant flow distribution in a fuel rod bundle, and so spacer geometry has a strong influence on a bundle's thermal-hydraulic characteristics such as critical heat flux and pressure drop. An understanding of the detailed structure of the turbulent flow and heat transfer in the rod bundle, used especially as nuclear fuel elements, is of major interest to the nuclear power industry for their safe and reliable operation. The flow mixing devices on grid spacer would enhance the mixing rate between sub-channels and promote the turbulence in sub-channel. The present study evaluates the effects of mixing vane shape on flow structure and heat transfer downstream of mixing vane in a sub-channel of fuel assembly, by obtaining velocity and pressure fields, turbulent intensity, flow mixing factors, heat transfer coefficient and friction factor using three-dimensional RANS analysis. Six new shapes mixing vane designed by the authors, are simulated numerically to evaluate the performance in enhancing the heat transfer, in comparison with commercialized split vane. Standard K-epsilon model are used as a turbulence closure model and periodic and symmetry condition are set as boundary conditions. The capability of the model to predict the coolant flow distribution inside rod bundles is shown and discussed on the base of comparison with experimental data for a variety of geometrical and Reynolds number conditions. It is conformed that the turbulence in the sub-channel was significantly promoted by spacer and mixing devices but rapidly decreased to a fully developed level approximately 10 time of hydraulic diameter downstream of the top of spacer. Ring type mixer showed a high enhancement in nuclear heat transfer among the other mixing devices. Also the results show very clearly that the mixing vanes have a significant effect on both the DNB azimuthal location and the CHF value.

Keywords: Pressurized water reactor, mixing vane, spacer grid, turbulent heat transfer, computational fluid dynamic, standard k-epsilon model.