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CFD Simulation of Spacer Effect on Turbulent Mixing Phenomena in Sub Channels of Boiling Nuclear Assemblies

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Abstract : Numerical simulations of selected subchannel tracer (Potassium Nitrate) based experiments have been performed to study the capabilities of state-of-the-art of Computational Fluid Dynamics (CFD) codes. The Computational Fluid Dynamics (CFD) methodology can be useful for investigating the spacer effect on turbulent mixing to predict turbulent flow behavior such as Dimensionless mixing scalar distributions, radial velocity and vortices in the nuclear fuel assembly. A Gibson and Launder (GL) Reynolds stress model (RSM) has been selected as the primary turbulence model to be applied for the simulation case as it has been previously found reasonably accurate to predict flows inside rod bundles. As a comparison, the case is also simulated using a standard k-ε turbulence model that is widely used in industry. Despite being an isotropic turbulence model, it has also been used in the modeling of flow in rod bundles and to produce lateral velocities after thorough mixing of coolant fairly. Both these models have been solved numerically to find out fully developed isothermal turbulent flow in a 30º segment of a 54-rod bundle. Numerical simulation has been carried out for the study of natural mixing of a Tracer (Passive scalar) to characterize the growth of turbulent diffusion in an injected sub-channel and, afterwards on, cross-mixing between adjacent sub-channels. The mixing with water has been numerically studied by means of steady state CFD simulations with the commercial code STAR-CCM+. Flow enters into the computational domain through the mass inflow at the three subchannel faces. Turbulence intensity and hydraulic diameter of 1% and 5.9 mm respectively were used for the inlet. A passive scalar (Potassium nitrate) is injected through the mass fraction of 5.536 PPM at subchannel 2 (Upstream of the mixing section). Flow exited the domain through the pressure outlet boundary (0 Pa), and the reference pressure was 1 atm. Simulation results have been extracted at different locations of the mixing zone and downstream zone. The local mass fraction shows uniform mixing. The effect of the applied turbulence model is nearly negligible just before the outlet plane because the distributions look like almost identical and the flow is fully developed. On the other hand, quantitatively the dimensionless mixing scalar distributions change noticeably, which is visible in the different scale of the colour bars.

Keywords : single-phase flow, turbulent mixing, tracer, sub channel analysis
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