

Abstract

An accurate prediction of the flow distribution inside fuel rod bundles is required for both design and safe operation of innovative as well as conventional nuclear systems. The unsteady axial characteristic flow pulsations which appear in the bare rod bundle configuration have been investigated (experimentally and numerically) over the last 70 years and remain a research topic up to the present time.

In the past, the majority of studies of flow and heat transfer inside the fuel rod bundles have been performed experimentally. However, most of them were conducted on the simplified geometries and under conditions that are not the same as in normally operating reactors.

A good prediction of the flow and heat transfer inside the rod bundle is a challenge for the available and commonly used RANS (Reynolds-Averaged Navier-Stokes) turbulence models and these models need to be validated and improved accordingly. Although the measurement techniques are constantly getting improved, the CFD-grade (Computational Fluid Dynamics) experiments of flow mixing and heat transfer in the sub-channel scale are often impossible or quite costly to be performed. In addition, lack of experimental databases makes it impossible to validate properly and/or calibrate the available RANS turbulence models for certain flow situations. In that context, Direct Numerical Simulation (DNS) can be served as a reference for model development and verification.

In this thesis, a numerical experiment for a tight lattice bare rod bundle case using different Prandtl fluids (air, water, liquid metal) is designed. In the next step, the high fidelity database by means of DNS is generated. The obtained DNS results serve as a reference database to validate and calibrate/improve the available and commonly used low order turbulence models. The RANS turbulent models are thoroughly investigated in order to understand their capabilities and limitations. Finally, the comprehensive CFD methodology toward the accurate prediction of turbulent flow and heat transfer phenomena at sub-channel level with the set of the best practices guidelines is developed.