Coupling CFD and 1D two-phase flow codes for the thermal-hydraulic analysis of nuclear steam generators

A coupling methodology using porous CFD and two-phase flow modelling has been developed at the EDF Energy R&D UK Centre to perform high-fidelity thermal-hydraulic studies on nuclear steam generators. The computational tool, developed within the plant life extension programme of the Advanced Gas-cooled Reactors (AGR) fleet in the UK, is currently being used to support structural integrity assessments of boilers, identified as a potential risk to extended operation.

The coupled model is based on Code_Saturne, a generic-purpose Computational Fluid Dynamics (CFD) code developed and maintained by EDF R&D. A porous media approach is used considering that an explicit representation of all geometrical details of the boiler would require prohibitive computational resources. At the same time, with the purpose of having a good representation of three-dimensional effects and therefore an accurate prediction of temperature fields, the CFD model is coupled to the code NUMEL, a suite of 1D models for computing the steady state, static/dynamic stability and transient responses of once-through nuclear boilers. The coupling is implemented on a single-tube level, allowing obtaining a tube-by-tube representation of the heat transfer and accounting for variations of operating conditions including unplugging of tubes.

Furthermore, to account for thermal diffusion across the metal structures, the model includes coupling between the CFD code and the solid solver SYRTHES, a finite element code developed by EDF R&D.