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CFD validation of forced and natural convection for the open phase of IAEA benchmark CRP - I31038

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The goal of the IAEA Coordinated Research Project "Benchmark of Transition from Forced to Natural Circulation Experiment with Heavy Liquid Metal Loop" (CRP - I31038) is to develop Member State advanced fast reactor analytical capabilities for simulation and design using system, CFD, and subchannel analysis codes. Here we present CFD validation employing the commercial CFD code Star CCM+ applied to the fuel pin simulator for forced and natural convection cases in the open phase where experimental data is provided in the benchmark specification provided by ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development) for the NACIE-Up facility (NAtural CIrculation Experiment-UPgrade). Considered is the fuel pin simulator with 19 pins, each consisting of a preheated lower section and heated upper sections, respectively. Three configurations (i) all pins heated, (ii) inner 7 pins heated and (iii) asymmetric heating are studied. For each heating configuration data for forced and natural convection are provided. Here case (i) is studied. Temperatures at three planes are measured near the inlet, in the middle and near the end of the heated section, respectively. In addition, the axial temperature along the wall of one fuel pin simulator (in second row) is measured so that in total 67 thermocouples measure fluid and wall temperatures for validation purposes.

Our validation confirms that the thermos hydraulics inside the fuel pin simulator can be simulated with a good accuracy. Applied is a polyhedral mesh with 2 prism layers, the k-omega SST model with all all-wall treatment and order unity y+ values. Moreover, we performed a grid-sensitivity study and analysed the importance of conjugate heat transfer inside the fuel-pin simulators and the wrapper. Our studies indicate that it is possible to implement further simplifications without corrupting the accuracy of the simulation to reduce computational effort.

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