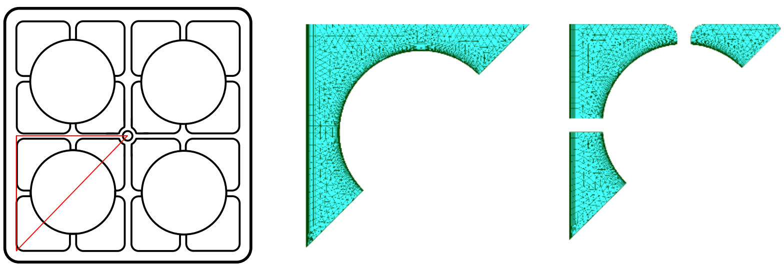
Project FORTE - Nuclear Thermal Hydraulics R&D for BEIS

A Benchmarking Study for SCWR

THE CHALLENGE

The Supercritical Water-Cooled Reactor (SCWR) is the only light water reactor in the six advanced nuclear reactor designs currently under development in the framework of the Generation IV International Forum (GIF). A major challenge of SCWR is the complex behaviour of the flow and heat transfer at supercritical conditions due to drastic changes in the coolant thermal-physical properties. Severe heat transfer deterioration, potentially leading to fuel pin failures, may occur in the fuel channels under certain conditions, due to strong buoyancy forces resulting from sharp variations of density. Such complexity of the physical processes demands high levels of optimisation in the design using reliable and robust modelling and prediction methodologies and tools. To increase our modelling confidence, the IAEA Coordinated Research Project (CRP) in SCWR Thermal Hydraulics has organised a benchmarking exercise to evaluate the performance of the major numerical tools currently in use or in development for conditions including strongly buoyancy-influenced flows. In addition, to enhance our understanding of the complex flow physics of supercritical water in SCWRs, the exercise also aims to generally improve our prediction capabilities for buoyancy-driven passive cooling systems and expand UK engagement in international initiatives.

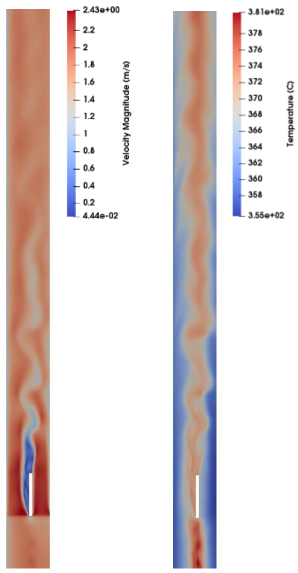
OUR SOLUTION



Geometry and mesh

Our CFD model has been created for the heated 2x2 rod bundle operated at supercritical conditions in the University of Wisconsin High-pressure Heat Transfer Test Facility. To resolve the complex physics of the boundary layer, the low Reynolds number k-ω SST model was used to account for turbulence. Simulations have been carried out using two different CFD packages, Code_Saturne and ANSYS Fluent; the former is a general purpose open-source code developed by EDF R&D and the latter is a commercial code that is widely used in academia and industry. In this benchmarking campaign, notable deviations have been found in the numerical predictions of the two CFD codes under nominally the same modelling setup. Such deviations become greater for conditions with high buoyancy effects. Detailed investigation into the effects of the key modelling factors such as turbulence model, mesh strategy and numerical scheme are among the plans for future work.

Some interesting flow behaviours have also been found through the numerical simulations. An example is that the flow is very sensitive to the thermal environment at supercritical conditions and becomes unstable as it passes through the spacer grid, even when the geometry has been simplified to minimize any potential disturbances to the flow. As a result, the suppressed turbulence re-develops and dominates the flow in the wake region downstream of the spacer grid, leading to a significant reduction in wall temperature. Such phenomena are of crucial importance to the design and optimization of nuclear reactors and need to be predicted accurately.



Flow instability due to spacers

THE BENEFITS

This work has been carried out in close collaboration with a number of international research institutes and national labs, which facilitates knowledge transfer and sharing among international research communities. As the only participant from the UK, our work showcases the UK's research in nuclear thermal hydraulics and demonstrates the UK's participation in the early stages of research and development of Gen IV nuclear reactors. The benchmarking exercise provides an excellent opportunity for developing international collaborations as well as educating the UK thermal hydraulics community in the modelling of buoyancy influenced flow.

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