Numerical Investigation of Critical Heat Flux in Water Cooled Reactors

There are approximately 440 nuclear power reactors in operation worldwide with capacity to produce 375 GWe, 28 reactors are under construction and a large number are in different stages of planning and designing. The latest generation of pressurised water reactors (PWR) – the most common type of nuclear reactor, is designed to minimize the risk of damage to fuel and control rods during potential accidents. Fuel rods may overheat during a loss-of-coolant accident (LOCA) due to either the coupled thermohydraulics and neutronics instabilities or critical heat flux (CHF) events (i.e., sharp reduction of the local heat flux due to nucleate boiling). In the latter, the flow of water/steam and heat can produce local hydrodynamics instabilities that can lead to damages to the cladding, control and fuel rods.

During a LOCA event, the resulting boiling leads to the formation and transport of bubbles of vapour by the high velocity coolant fluid. Bubbles can form clusters or coalesce, resulting in vapour clots or slug flows in the narrow reactor core channels, which in turn affect the designed coolant heat flux. The resulting large temperature system can potentially damage the solid structures (cladding and fuel rods) leading to core melting and fragmentation. This project aims to improve our understanding of the initial LOCA stages that may lead to a reactor core melting. The project will exploit existing state-of-the-art computational methods to investigate CHF in tube bundles during a LOCA event. This will involve the development of CFD models for:

(a) multi-scale heat and fluid flows using high-order accurate schemes coupled with adaptive LES turbulent methods;
(b) heterogeneous and homogeneous nucleation mechanisms;
(c) prediction of heat transfer and bubble size distribution;
(d) non-linear dynamic analysis for flow regime characterisation.

Applicants must hold, or expect to receive, a first or upper second class honours degree (or equivalent) in a relevant engineering, mathematical, computing or physical sciences discipline. Expertise in fluid mechanics and strong programming (Fortran or C) skills are essential. Background in computational fluid dynamics is desirable.

References


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