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Direct Numerical Simulation of a Simplified Pressurized Thermal Shock

Streszczenie:

Pressurized Thermal Shock (PTS) is considered as an important issue that challenges the integrity of the Reactor Pressure Vessel (RPV). PTS is defined as a rapid cooling of the Reactor Pressure Vessel (RPV) wall along with repressurization of the primary cooling system. The worst-case scenario is represented by Emergency Core Cooling (ECC) injection of cold water into the cold leg during a Loss Of Coolant Accident (LOCA). The injected water mixes with hot water present in the cold leg and subsequently flows into the down-comer where further thermal mixing takes place. The time-dependent temperature gradients inside the RPV wall may induce high thermal stresses in this RPV wall; this may lead to the propagation of already existing flaws. Thermal-hydraulic analyses for the aforementioned scenario are aimed at evaluating temperature distributions in the down-comer and RPV walls. Currently, the investigation of Nuclear Reactor Safety (NRS) related issues are mainly performed with thermal-hydraulic system codes. Such codes are based on one-dimensional representations, and therefore cannot reliably predict the considered complex three-dimensional thermal mixing phenomena. On the other hand, Computational Fluid Dynamics (CFD) can play an important role in predicting such complex three-dimensional flow features. However, predicting a PTS scenario is a challenge for the available turbulence models; therefore, these models need to be properly validated. In particular, currently available turbulence models are capable of qualitatively predicting the global flow and thermal mixing phenomena; but the prediction capabilities of these models to quantitatively predict the RPV wall cooling need to be further validated.

In this regard, a number of international research projects have been focused on the assessment of turbulence models against experiments. One example is the experiments performed in the Rossendorf Coolant Mixing Model (ROCOM) test facility. ROCOM represents the RPV and primary circuit of a German KONVOI type reactor on a 1:5 linear scale; due to experimental complexities and limitations, the available databases are not always sufficient enough for an extensive and thorough validation of the turbulence models. For example, the RPV wall cooling cannot be studied, since we are mostly dealing with plexi-glas facilities for optical access. High fidelity CFD could be helpful to fill this gap. A high quality DNS database could serve as a reference to validate the low order turbulence modelling approaches, such as Large Eddy Simulation (LES), Unsteady-Reynolds-averaged Navier-Stokes (U-RANS) and hybrid (LES/U-RANS) simulations. Despite the advancement in the supercomputing, the DNS studies are mostly restricted to simplistic geometries and a limited range of Reynolds numbers.

The aim of this research work is to perform a high quality DNS of a simplified single-phase PTS scenario without buoyancy effects, and will be the main focus of this seminar. The obtained DNS results will serve as a reference to validate low order CFD approaches, such as (U-) RANS and Hybrid (RANS/LES) methods. This DNS computation has been carried-out, using 5000 processors at Centrum Informatyczne Świerk (CIS), within the framework of a bilateral collaboration between NCBJ and NRG. Due to the complex nature of the flow field, the simulation has run for approximately 30-million core hrs (i.e. 240 days on 5000 processors) to obtain a statistically converged solution.

Serdecznie zapraszamy,
M. Dąbrowski, T. Kwiatkowski