OECD/NEA Sponsored CFD Benchmark Exercise: Thermal Fatigue in a T-Junction

Invitation to Kick-Off Meeting: Deadline April 30, 2009

NEA Headquarters, 12 boulevard des Iles
Issy-les-Moulineaux, Paris, FRANCE

20 May, 2009

Background

Failures of structures due to high-cycle thermal fatigue have occurred in several nuclear plants around the world, for different reactor types. Many of these have been associated with mixing zones where hot and cold streams meet, and particularly near T-junctions. An example is the failure event at the Civaux-1 PWR in France in May 1998.

As the hot and cold streams from the main and branch pipes meet, shear instabilities produce turbulent eddies, causing temperature fluctuations on the pipe walls downstream of the junction. The fluctuations induce cyclic strain variations in the pipe material, and may result in fatigue damage and cracking. A typical value for the temperature difference between the hot/cold streams is 160°C.

Critical parameters for thermal fatigue analyses are frequencies ($\omega$), temperature differences ($\Delta T$), number of cycles ($N$), and material properties. Most damaging thermal loads appear to be due to large-scale turbulent fluctuations of low frequency (3-10 Hz). From a thermal hydraulic standpoint, the accurate prediction of such large coherent eddies is a challenging task, requiring CFD and advanced turbulence modelling.

A Blind CFD Benchmark Exercise

In November 2008, a T-junction thermal mixing test was carried out at the Älvkarleby Laboratory of Vattenfall Research and Development (VRD) in Sweden. Data from this test have been reserved specifically for this CFD benchmark exercise, and will be kept secret for its duration.

**CFD simulations are invited.**

Participants in the exercise will be given details of the test geometry, operating conditions and upstream parameters. Following numerical simulation, participants will supply to the organizers results in the form of temperature, velocity and turbulence profiles at specified locations downstream.

A synthesis of the results, including comparisons against measured data, will be carried out, and reported in the form of a Keynote Lecture at the forthcoming OECD/NEA–IAEA Workshop CFD4NRS-3, which will take place in Washington DC in the fall of 2010. Participants will have the opportunity to present their work in the form of a dedicated Poster Session at this workshop.

The Kick-Off Meeting is to be held at the NEA Headquarters in Paris on Wednesday, May 20, 2009. There are 5 places only left available. These will be allocated on a first-come-first-served basis to late registrations. Please register with the NEA Secretariat: JongChullJO@oecd.org, with copies to Abdallah.AMRI@oecd.org and Brian.Smith@psi.ch.
The Vattenfall T-Junction Experiment

The test section is constructed from Plexiglas, and the junction itself from one solid block into which the main and branch pipes fit. The temperatures of the water in the main and branch pipes were maintained at 15°C and 30°C, respectively, with minimal heat loss.

Special care was taken to provide simple and well-defined inlet boundary conditions to remove ambiguities in defining the CFD input data. Temperature fluctuations near pipe walls were measured using thermocouples. These were placed around the inner wall perimeter of the main pipe at seven stations downstream of the junction and at one station upstream. All thermocouples were positioned 1 mm from the wall. Velocity profiles upstream and downstream of the junction were measured using a two-component LDV system. These were positioned at each inlet, and at the outlet. Data are in the form of mean values, rms values and turbulence statistics.

Preliminary Agenda of Kick-Off Meeting

A detailed agenda is being compiled, but items to be included are:

- Plan of the Benchmark Activity  Brian Smith, PSI, Switzerland
- Test Facility and Instrumentation  Kristian Angele, VRD, Sweden
- Keynote Speaker  Stéphane Chapuliot, AREVA, France
- Benchmark Specifications  Brian Smith/Kristian Angele
- Synthesis and Reporting Procedure  John Mahaffy, NRC, USA
- Open Forum Discussion

Organising Committee

Brian L. Smith, Paul Scherrer Institute, Switzerland
Kristian Angele, Vattenfall R&D, Sweden
John H. Mahaffy, US Nuclear Regulatory Commission, USA
Dominique Bestion, Commissariat à l’Energie Atomique, France
Ghani Zigh, US Nuclear Regulatory Commission, USA
Jong-Chull Jo, OECD Nuclear Energy Agency, France (Secretariat)

Dates & Deadlines

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