

KOURA

Three dimensional reactor analyses

Ville Hovi • Anitta Hämäläinen • Mikko Ilvonen • Hanna Rätty • Ville Sahlberg • Veikko Taivassalo • Elina Syrjälähti
VTT Technical Research Centre of Finland Ltd

Introduction

KOURA was a four-year project focused on reactor dynamics and thermal hydraulics. Focus of the project has been on modelling of the boiling water reactors and coupling of 3D thermal hydraulics with reactor dynamic codes.

BWR modelling

Enhancement of BWR modelling capabilities has been one focus area of the project. OECD/NEA launched in a 2011 new BWR benchmark, which is based on the stability event at the Oskarshamn-2 NPP. VTT decided to participate in the benchmark with the aim of challenging and enhancing its BWR modelling capabilities, with special emphasis on deepening the expertise on BWR phenomena. In 2012 the TRAB3D model for Oskarshamn-2 power plant was created from scratch. During 2013-2014 the stability event was modelled (Figure 1).

TRAB3D and the system code SMABRE have earlier been connected with parallel coupling and recently with internal coupling. For BWRs the internal coupling of TRAB3D and SMABRE has been validated against measurements in an overpressurization transient and a load rejection test at the Oikiluoto NPP. Results of the internally coupled TRAB3D-SMABRE were in good agreement with the TRAB3D standalone calculation and measurements (Figure 2).

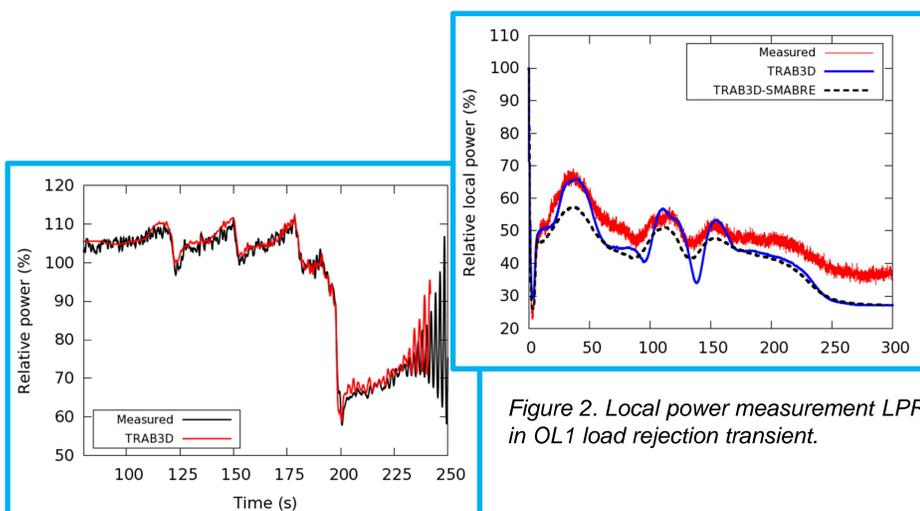


Figure 1. Local power measurement APRM during Oskarshamn-2 stability event.

Figure 2. Local power measurement LPRM in OL1 load rejection transient.

Development of improved submodels

A TRAB3D – Serpent 2 code sequence was developed in cooperation with KÄÄRME project, allowing the use of group constants generated by Serpent 2 for TRAB3D calculations. The TRAB3D code has also been supplemented with a pin power reconstruction model, Figure 4. Pinwise power distributions are needed for more accurate safety analyses and modern thermal hydraulic solvers.

VTT's fuel behavior code FINIX has been coupled to the reactor dynamics codes TRAB-1D, TRAB3D, and HEXTRAN. FINIX has been used in the simulation of fast power transients and a main steam line break in different types of reactors, Figure 5.

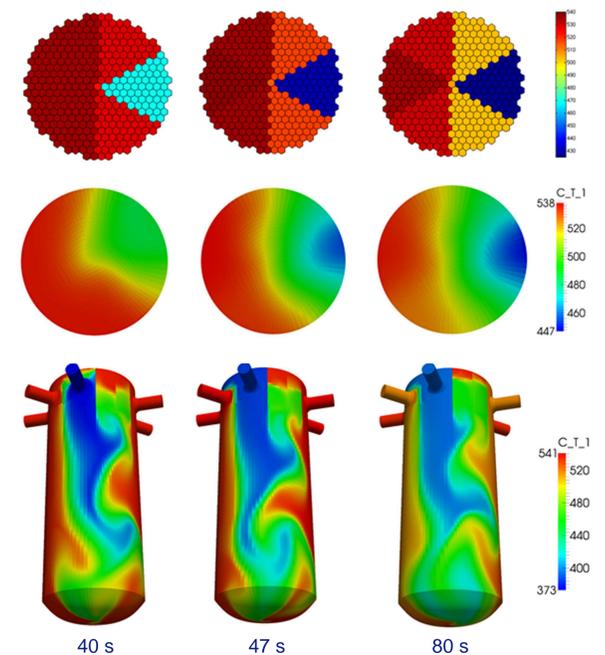


Figure 3. Results of temperature mixing in AER-7 benchmark by SMABRE (top row) and PORFLO (two lower rows).

3D Thermal hydraulics

The PORFLO code is a two-phase 3D flow simulation tool that is mainly targeted at coupled reactor dynamics modelling. Its main applications are such that 3D phenomena may be significant but geometrical complexity does not allow for a CFD-style structure fitted grid all around the computational domain. PORFLO utilizes the concept of porous medium to model structural features not represented explicitly in a computational mesh. The PORFLO code was rewritten in 2011 and after that it has been applied e.g. to modelling of the EPR pressure vessel and fuel assembly.

The capability of PORFLO to function as the 3D thermal-hydraulic part of a reactor dynamic transient calculation system is tested by simulations of the AER 7th benchmark with the coupled code system PORFLO-HEXTRAN/SMABRE, Figure 3. The benchmark considers start-up of a cold loop of a VVER-440. The objective is to predict core power when it receives coolant that was first mixed in the downcomer and then in the lower plenum.

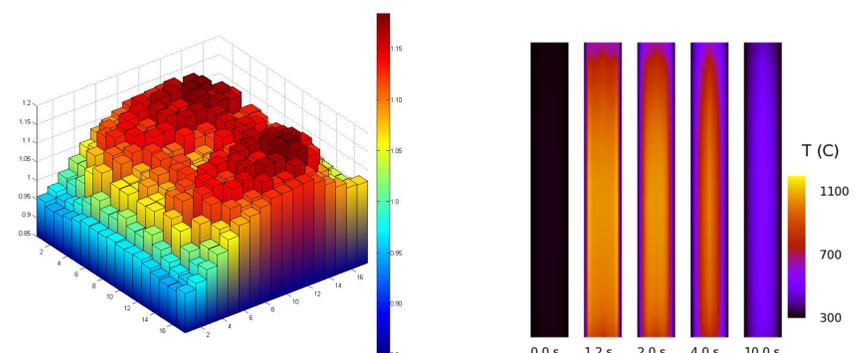


Figure 4. Relative power distribution of a top of a fuel assembly at the second outermost radial layer of an EPR core, reconstructed by TRAB3D.

Figure 5. Propagation of heat in a fuel rod during power peak transient with TRAB-1D –FINIX.

Contacts

Elina Syrjälähti
Tel. +358 20 722 5017
Elina.Syrjalahti@vtt.fi