Post-Doc proposal

Development and application of Inverse Uncertainty Quantification methods in thermal-hydraulics within the new OECD/NEA activity ATRIUM

Duration: 2 years
Desired start date: February-April 2022
Institution: CEA-Saclay
Unit: DES/ISAS/DM2S/STMF/LATF
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Context:

In the framework of the Best Estimate Plus Uncertainty methodologies (BEPU) for the safety analysis of the Nuclear Power Plants (NPPs), one of the crucial issue is to quantify the input uncertainties associated to the physical models in the code. Such a quantification consists of assessing the probability distribution of the input parameters needed for the uncertainty propagation through a comparison between simulations and experimental data. It is usually referred to as Inverse Uncertainty Quantification (IUQ). Previous research activities within the OECD/NEA (Nuclear Energy Agency) have highlighted the need to dispose of accurate, reliable and applicable IUQ methodologies. In particular, the recently completed SAPIUM project led to define a guideline containing several recommendations and best practices to perform IUQ.

Scope:

The Service of Thermal-hydraulics and Fluid dynamics (STMF) at CEA-Saclay has proposed a new international project within the OECD/NEA WGAMA working group. It is called ATRIUM (Application Tests for Realization of Inverse Uncertainty quantification and validation Methodologies in thermal-hydraulics). Its main objectives are to perform a benchmark on relevant Inverse Uncertainty Quantification (IUQ) exercises, to prove the applicability of the SAPIUM guideline and to promote best practices for IUQ in thermal-hydraulics.

It is proposed to quantify the uncertainties associated to some physical phenomena relevant during a Loss Of Coolant Accident (LOCA) in a nuclear reactor. Two main IUQ exercises with increasing complexity are planned. The first one is about the critical flow at the break and the second one is related to the post-CHF heat transfer phenomena. A particular attention will be dedicated to the evaluation of the adequacy of the experimental databases for extrapolation to the study of a LOCA in a full-scale reactor. Finally, the obtained input model uncertainties will be propagated on a suitable Integral Effect Test (IET) to validate their application in experiments at a larger scale and possibly justify the extrapolation to reactor scale.

Mission:

The Post-Doc candidate will participate in the ATRIUM project in support and in coordination with the CEA team. In details, the candidate will:

- Analyze the available experimental data and evaluate their adequacy for IUQ via the decision making process.

- Carry out the proposed IUQ exercises. The thermal-hydraulic simulations will be performed with the system code CATHARE, which is the reference code for the safety analysis of French nuclear reactors. The model uncertainties will be quantified with the statistical methodology CIRCE. Both CATHARE and CIRCE are developed by CEA.
- Bring new insights on the applicability of the SAPIUM best-practices and on the possible improvements necessary when quantifying model uncertainties with CIRCE.
- Perform the uncertainty propagation on the IET and analyze the results.
- Collect, analyze and summarize the results obtained by the different participants of the benchmark (more than 20 participants worldwide).
- Write scientific articles in peer-reviewed journals and technical reports.
- Present the work at OECD/NEA meetings and at international conferences.
- The work will lead the candidate to develop his/her skills in the modelling of complex thermal-hydraulic systems, in two-phase fluid dynamics and in statistical analysis. These skills are of great interest in the current industrial sector (e.g. nuclear, automotive, and aerospace). The candidate will work in a multidisciplinary, dynamic and stimulating environment in direct contact with experts in the domain.

Applicant skills:

We are seeking an innovative self-motivated person that will be able work independently as well as in a team. The candidate should have a PhD degree with a strong interest in fluid dynamics/thermal-hydraulic applications, experimental data and statistical modelling and analysis. Experience in nuclear reactor thermal-hydraulic modeling is highly appreciated. Knowledge of a programming language (e.g. C++, Fortran, Python or Matlab) is required. A good knowledge of English is a requirement. Knowledge of French is appreciated, but not mandatory.

References:

G. Geffraye et al., “CATHARE 2 V2.5_2: A single version for various applications”, Nuclear Engineering and Design 241, pp. 4456-4463, 2011

R. Préa et al., “CATHARE-3 V2.1: the new industrial version of the CATHARE code”, ATH’2020 conference, 2020.

A. De Crécy, “Determination of the uncertainties of the constitutive relationships of the CATHARE 2 code”, Proceedings of the M&C conference, Salt Lake City, USA, 2001

E. Nouy, A. De Crécy, “Quantification of the uncertainty of physical models integrated into system thermohydraulic codes”, Nuclear Engineering and Design 321, pp. 278-287, 2017

G. Damblin, P. Gaillard, “Bayesian inference and non-linear extensions of the CIRCE method or quantifying the uncertainty of closure relationships integrated into thermal-hydraulic system codes”, Nuclear Engineering and Design, 359, 2020.

J. Baccou et al., “Development of good practice guidance for quantification of thermal-hydraulic code model input uncertainty”, Nuclear Engineering and Design 354, 110173, 2019