Validation of CFD models for jets and plums in fission reactors

Introduction

The design of fission and fusion power plants depends on availability of computational models, whose validity needs to be assessed by means of a careful verification and validation (V&V) process. In particular, the comparison with experimental data, carried out in the validation phase, is fundamental for the qualification of the models used to design and verify the plant subsystems, both in case of normal operation and accidental scenarios. For this reason, international benchmark exercises are frequently proposed and carried out. One of these benchmarks has been recently proposed by the ASME V&V Committee in collaboration with the Texas A&M University [1]. The proposed benchmark consists in modelling the Texas A&M University's Upper Plenum Experimental Facility, which is a scaled-down version of a High Temperature Gas Reactor.

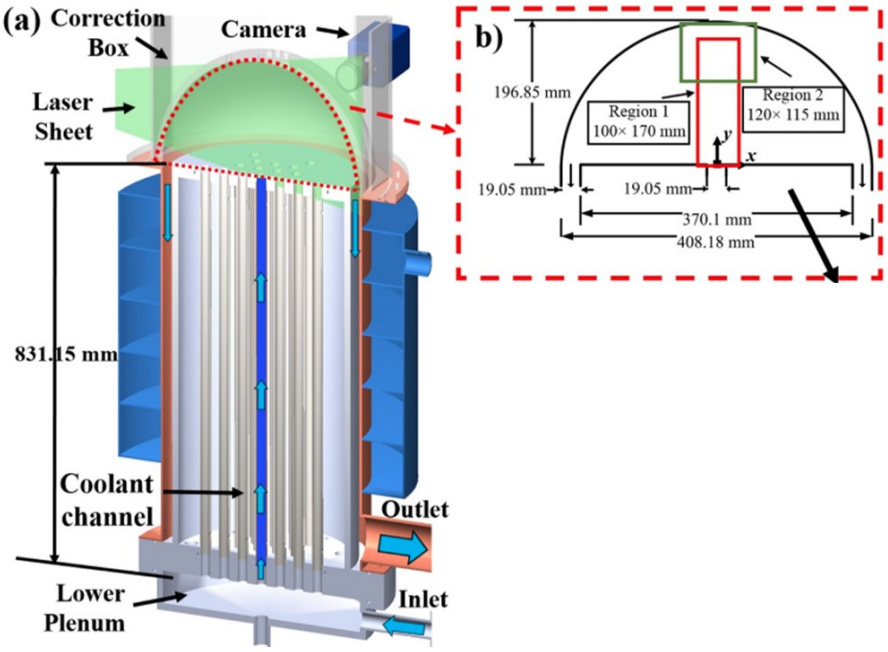

Figure 1: Scheme of the experimental facility [1].

Aim of the work

Several data are made available from the different experiments carried out in the facility, including a twin-jet experiment (i.e. with coolant flowing in two coolant channels) and a single-jet experiment, both in isothermal (forced convection) and non-isothermal (natural convection) conditions. The facility is equipped with Particle Image Velocimetry (PIV) and Laser Image Fluorescence (LIF) measurements, which allow retrieving a refined 2D map of several interesting quantities such as mean velocity (vector), turbulent quantities (i.e. velocity fluctuations), and temperature, thus providing an excellent set of experimental data for the validation of turbulent CFD models. The aim of the present proposal is to develop and apply a CFD model of the facility with the commercial Star-CCM+ code, investigating in detail the validity of the different RANS turbulence models (e.g. k-ε, k-ω, RSM, …) and of the different available model solver options (e.g. discretization order, wall treatment, …). Given the availability of turbulent quantities and the relative simplicity of the model, a Large Eddy Simulation (LES) model might also be considered.

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References

[1] A. Alwafi, T. Nguyen, Y. Hassan, and N. K. Anand, “Time-resolved particle image velocimetry measurements of a single impinging jet in the upper plenum of a scaled facility of high temperature gas-cooled reactors,” International Journal of Heat and Fluid Flow 76:113-129, 2019.