IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Postdoctoral position

Experimental study of two-phase air-water cross-flows in a tube bundle and of the associated fluid-structure interactions.

Subject: thermal-hydraulics
Keywords: two-phase flows, fluid-structure interactions, experimental measurements, steam generators
Place: Cadarache - France (13)
Length: 18 months
Availability date: 01 February 2023 (different starting date – sooner or later - possible, depending on the candidate availability)
Supervisors: Daniele VIVALDI and Guillaume BRILLANT

Context:

Fluid-structure interactions (FSI) are a concern in nuclear power plants. One main example is the fluid-induced vibrations (FIV) of the steam generator (SG) tube bundle. The external steam-water two-phase flow crossing the tubes induces FSI mechanisms that, if not mastered, can lead to high amplitudes of vibration, which can result in a SG tube rupture accident.

The *Gathering expertise On Vibration ImpaKt In Nuclear power Generation* (GO-VIKING) European project, starting in 2022, aims at increasing the expertise and at improving the tools and skills of the European nuclear stakeholders for the analysis of complex FIV phenomena, in order to maintain and enhance nuclear plant safety. The scope of work package (WP) 4 of GO-VIKING is the generation of high-quality experimental data for FIV in multiphase flows in fuel assemblies and SGs, with the aim of providing deeper understanding of these complex phenomena and use this data to improve medium-resolution models for two-phase FIV.

In the frame of WP4 of GO-VIKING, IRSN – Institut de Radioprotection et de Sûreté Nucléaire – proposes the generation of two-phase experimental data inside a SG relevant tube bundle configuration. To achieve this, IRSN developed the experimental device TREFLE [1], located at IRSN in Cadarache. TREFLE allows to realize air-water cross-flows inside a square-pitch 5x5 straight tube bundle. The device is highly instrumented for two-phase flow measurements: optical probes to measure local void fractions and velocities, Wire Mesh Sensor to measure 2D void fraction distributions and high speed camera to study the flow dynamics. Besides, TREFLE allows to measure the vibration response of the central tube of the tube bundle thanks to accelerometers. A sketch of TREFLE is presented in Fig. 1. Fig. 2 shows some pictures of the two-phase flow generated and observed inside TREFLE.

The experimental data generated with TREFLE will be shared with all GO-VIKING participants, and will be used as reference data for numerical simulation result validation: the experimental tests will be simulated through different multiphase CFD tools by some participants of WP4 (*Nuclear Research and*

consultancy Group (NRG), *Teknologian tutkimuskeskus VTT Oy* (VTT), *Commissariat à l'énergie atomique et aux énergies alternatives* (CEA), *EDF Energy R&D UK Centre Limited* (EDF-E)).

Work:

Previously to the beginning of the Postdoctoral position, a first experimental campaign with TREFLE is planned for the second semester of 2022, for different air and water superficial velocities. For this campaign, TREFLE can operate in two configurations: with all rigid (fixed) tubes and with one flexible (vibrating) tube (the one in the centre of the cluster).

The study can be divided into three main tasks:

1/ TREFLE update:

During the first months, the Postdoctoral student will work on some upgrades of TREFLE, such as adding a second flexible tube, in order to study the effects of multi-tube displacement coupling in the tube bundle.

2/ Data generation:

Two main experimental campaigns will be realized: the first one is dedicated to the study of the two-phase flow characteristics, using rigid tubes; the second one is dedicated to the study of the fluid-structure interactions, therefore using two flexible tubes the vibrations of which will be monitored. For both campaigns, water and air flow rates will be varied, in order to modify the void fraction and to study the different possible two-phase regimes.

3/ Data analyse:

The experimental results will be analysed in terms of bubble/slug sizes, gas velocities, gas-liquid interface rising frequency, tube vibration response as a function of the specific two-phase flow, etc. The student will write a report presenting the work realized and the results obtained. This report may be published in a peer-reviewed journal. Deliverables are planned to be submitted describing these experimental results in the frame of GO-VIKING.

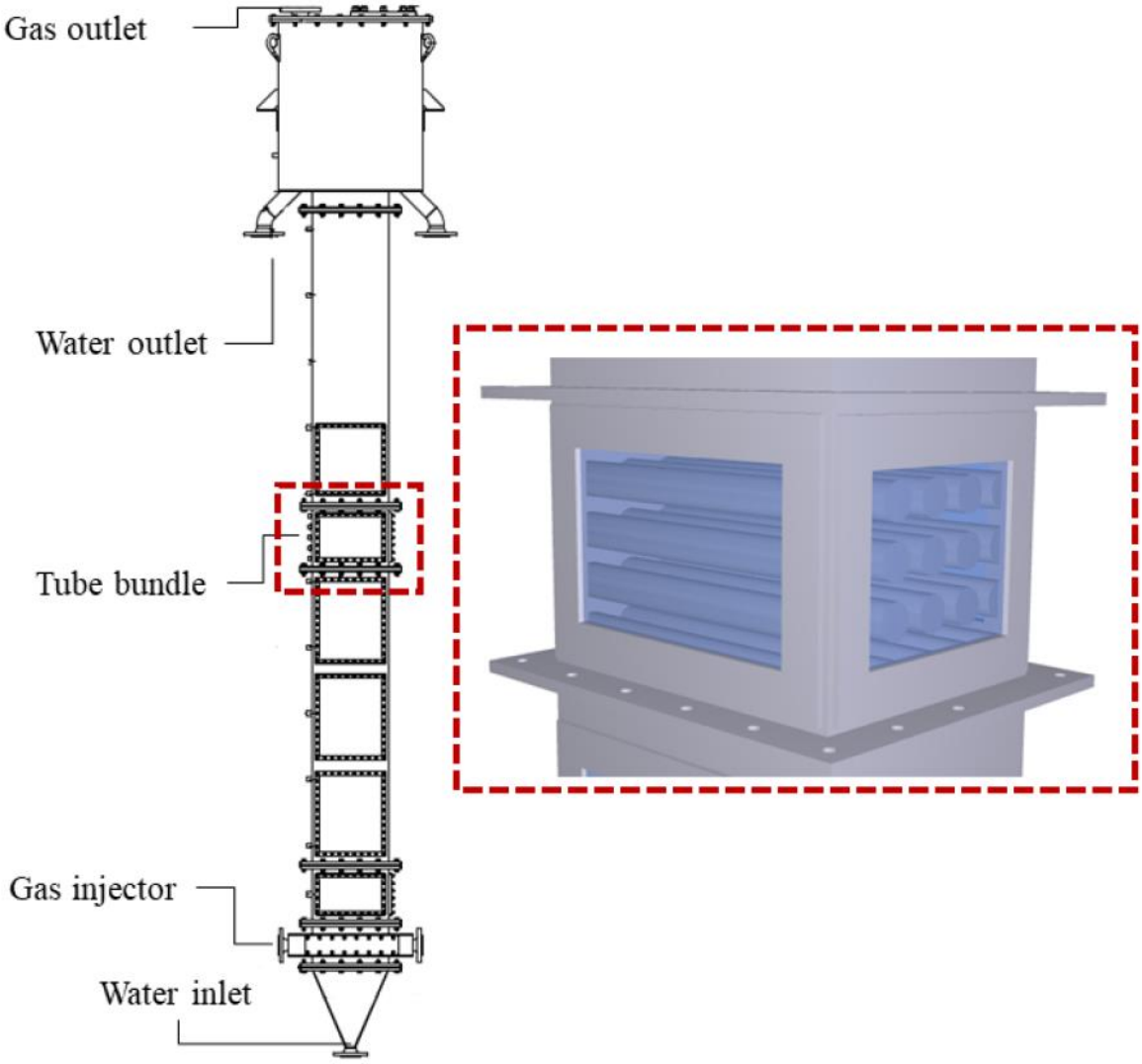

Figure 1: Schematic of TREFLE and detail of the tube bundle test section [2].

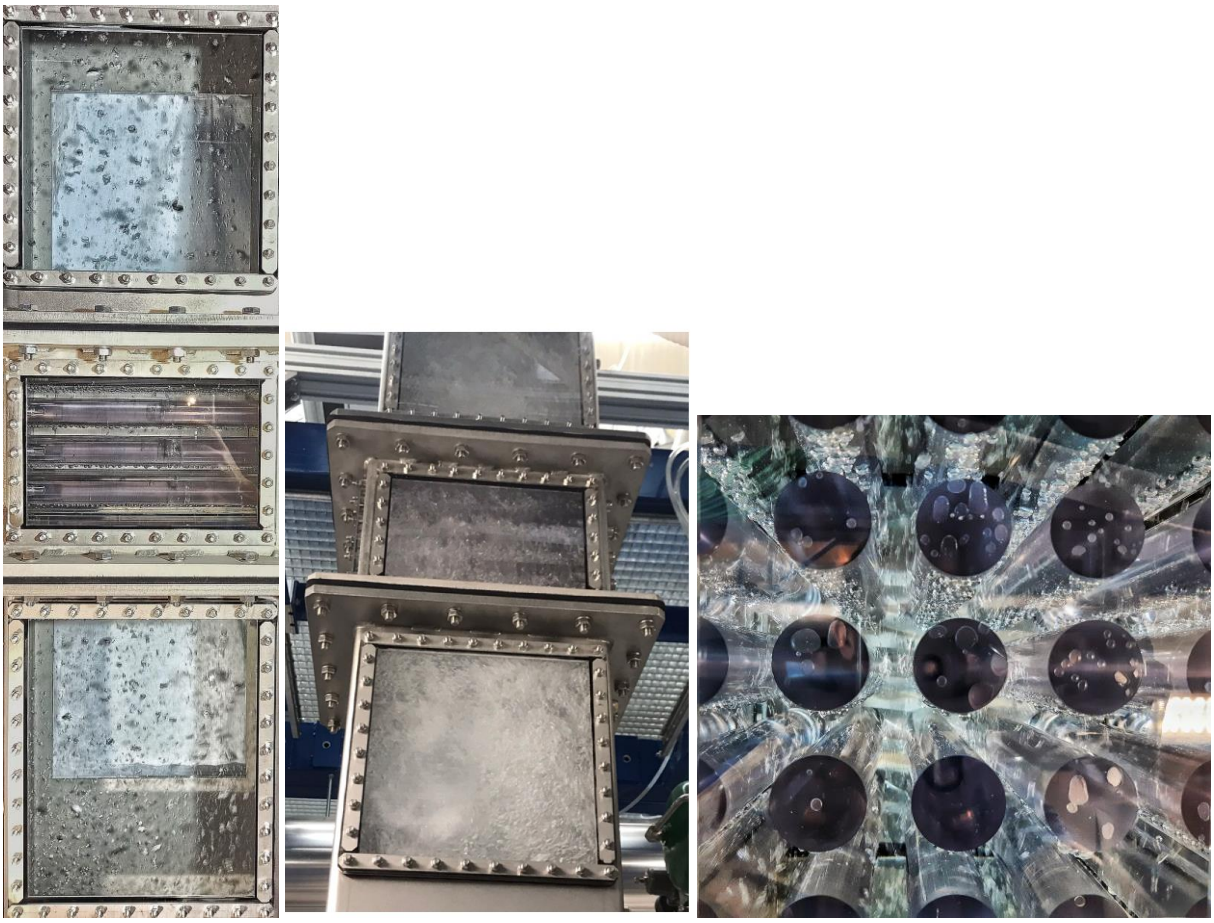

Figure 2: Two-phase flow observations in TREFLE: bubbly flow regime (left), intermittent flow regime (middle) and bubbly flow regime within the tube bundle (right) [2].

[1] Giuseppe Spina et al. TUBE BUNDLES SUBJECTED TO TWO-PHASE FLOW: A NEW EXPERIMENTAL APPARATUS DESIGN FOR FLOW REGIMES AND VIBRATION STUDY. Proceedings of NURETH-19 (2022).

[2] Giuseppe Spina et al. A NEW EXPERIMENTAL FACILITY FOR TWO PHASE FLOW CHARACTERIZATION IN A TUBE BUNDLE AND VIBRATION STUDY. Proceedings of Flow-Induced Vibration conference (FIV) 2022.

Qualifications:
PhD in the field of thermal-hydraulics, with personal interest towards experimental work.

Contacts:
Candidates should send their CV, a motivation letter, the PhD thesis (and the review of the referees), a recommendation letter by the PhD supervisors/professors, to the following persons:

Daniele VIVALDI, Guillaume BRILLANT
daniele.vivaldi@irsn.fr, guillaume.brillant@irsn.fr
IRSN PSN-RES/SEMIA/LSMA, BP3, 13115 Saint-Paul-lez-Durance CEDEX