POST-DOCTORAL POSITION AVAILABLE AT IRSN

CONTEXT

The « Institut de radioprotection et de Sûreté Nucléaire » (IRSN) is the institution in charge of research and evaluation activities on safety of nuclear facilities in support to the French Nuclear Safety Authority. To that purpose IRSN was and is still involved in various European research projects linked to the safety of different kinds of reactors (PWRs, BWRs…). Nowadays, IRSN is coordinating the R2CA European project dealing with Design Basis Accidents and Design Extension Conditions Accidents and dedicated to the Reduction of Radiological Consequences of Accidents.

Expectations from these programs are significant gains not only on the predictive capabilities of accident evolution but on the valorisation of these capabilities to improve severe accident management guidelines and mitigation devices.

In normal operation, nuclear reactor fuel rods can be damaged (by fretting, migrating bodies, etc.) and lose their tightness; this is known as a "leaking rod". In this situation, fission products are released into the primary circuit of the reactor. If the radiological limits set for the primary circuit are not exceeded, the reactor operation can be continued until the end of the current cycle at the end of which the leaking rods will be located and removed from the reactor. Although the radioactivity generated is largely recovered by the purification systems, the residue poses safety problems in the event of a steam generator tube rupture accident, potentially leading to the release of contaminated primary circuit water into the environment. It is therefore important to detect the occurrence of these defects and to be able to characterise them.

The aim of this post-doc is to participate in the development of a diagnostic and characterisation tool for cladding faults in normal operation based on the monitoring of the radioactivity of the primary circuit.

SUBJECT

The cladding fault diagnostic tool will consist of two components: the first is based on a physical model to simulate the effect of the opening of the cladding fault, i.e. the release and the radioactivity evolution in the primary circuit; the second is an artificial intelligence tool fed by a knowledge base built from simulations of various contamination situations and evaluated by the physical model. This knowledge base will include several million calculations.

The subject of the post-doc will consist of the development, validation and use of the physical model. The physical model, in order to satisfy the need for a fast tool linked to the production of several million calculations, will be a meta-model resulting from simulations using the MFPR-F code, under development at IRSN.

The MFPR-F code is a mechanistic code that simulates the behaviour of fission products in nuclear fuel under irradiation, at the grain scale of the fuel matrix (UO2). It includes in particular a modelling of the evolution of defects in the UO2 crystal structure, which can influence the transport of fission gases out of the fuel grains and pellets. These defects can be point defects (vacancies, uranium interstitials) or extensive defects (bubbles, pores and dislocations). Concerning the chemically active fission products, MFPR-F takes into account in its models a combination of diffusion-vaporisation mechanisms of these fission products involving a multi-phase and multi-component thermochemical equilibrium at the grain boundary with an accurate calculation of the fuel oxidation.

In a first step, the adaptation of the MFPR-F code to the problem to be addressed will require the development of a model for the recoil and ejection of fission products in the free volume of the fuel.

In a second phase, new models will be developed to deal with the following phenomena:

- the behaviour of iodine, in terms of release from the fuel and possible retention in the free volume ;
- the release of fission products from the gap into the primary circuit; Veschunov's model [1] might be used for this purpose ;
- radioactive decay in the free volume. The ISODOP module available in the ASTEC code might be used as a basis.

These models will be "chained" with the MFPR-F code in order to have a tool covering all the phenomena. The MFPR-F code itself could eventually be called in Python, by developing an interface, a draft of which currently exists.

The model thus developed will then be used to produce a meta-model, which will consist of:

- specifications for the calculations allowing the elaboration of the meta-model ;
- carrying out these calculations ;
- finding a machine-learning algorithm that will faithfully represent the knowledge base (neural networks can be an interesting basis for this kind of tool) ;
- the learning performance.

The last part of the work will consist in the development of a model for the activity evolution in the primary circuit: the various parts of the primary circuit (water, filters and resins of the purification circuits, pressurizer...) will have to be represented and the mass balance in each part of the primary circuit will have to be implemented taking into account the radioactive decays.

The MFPR-F based meta-model will allow to calculate the source term in the primary circuit.

Références

[1] M. S. Veshchunov, “Mechanisms of fission gas release from defective fuel rods to water coolant during steady-state operation of nuclear power reactors,” *Nucl. Eng. Des.*, vol. 343, no. November 2018, pp. 57–62, 2019, doi: 10.1016/j.nucengdes.2018.12.021.

Required skills

The person in charge of this work should have a PhD in materials/solid physics or equivalent, knowledge on fuel irradiation behaviour, and should enjoy development (knowledge in fortran is required whereas experience in python will be an important additional value).

The demonstration of your skills on the specific above scientific issues through either publications, presentations in major conferences or contribution to international research programs would be greatly appreciated.

Position

The position is opened as of 01 September 2021 to PhD that can demonstrate most of the above mentioned skills and knowledge. It is a 18-month position. The work will take place in the Major Accident Department in the Cadarache research center (near Aix en Provence, in the south of France). The salary will be evaluated by the human resources department from criteria that include the experience of the candidate and the mid salary of an IRSN permanent employee having a similar experience.

Contact

Application data including a resume have to be sent to Karine CHEVALIER-JABET (karine.chevalier-jabet@irsn.fr) and Jean DENIS (jean.denis@irsn.fr).