Développement de techniques de sollicitations, de mesures et d'analyses vibratoires pour caractériser les interactions entre composants d'une structure complexe en milieu extrême.

Development of vibrational technique for solicitation, measurement and interpretation to characterize the interactions between components of a complex structure in an extreme environment.

Pellet-Cladding Interaction (PCI) in a Light Water Reactor is one of the major concerns to guarantee fuel rod clad integrity of PWR nuclear reactor during operations needed to follow power grid demand. In order to forbid operations leading to clad failure, modeling capability to simulate the mechanism has improved through the years. And, Codes need more and more detailed and precise experimental data. Until now, those data result from dedicated irradiation programs, named "power ramp tests", carried out in experimental devices in Material Testing Reactors, ISABELLE in OSIRIS in the past and the future ADELINE in the Jules Horowitz Reactor JHR.

Even if those irradiation devices are highly instrumented to collect the most relevant information with the highest possible accuracy and are completed with post-irradiation examination programs, there is no instrumentation for on-line PCI detection needed for a complete validation of the modelling scheme.

Since 2017, a research has been started through a PhD to state the feasibility and to identify innovative methodologies to detect and characterize PCI kinetics during irradiation tests. One of the main results issued from this work is the demonstration of the feasibility to measure, in specific conditions, the effects of PCI on the vibrations of a nuclear fuel rod externally submitted to the turbulent axial flow rate excitation [1]. Fuel rods have also shown some unexpected vibrational behaviors depending of the surrounding experimental conditions which could not have been clearly explained due to the possible limited effort put into the vibrational modelling.

These elements lead to the conclusion that the PCI detection is feasible by vibrational methods but, in order to propose a reliable and predictive method usable under irradiation several issues should be solved.

The objective of this work will then be to develop a general process, including the three aspects, modelling, measurement and data processing in order to improve existing methods able to provide accurate information on components mechanical interactions of a complex structure within a very constrained context (limited space for instrumentation, high temperatures, irradiation, etc.).

First, vibrational nonlinear properties of the global structure – the fuel rod for this application – should be fully understood and modelled in order to explore responses of the system for all the vibrational modes, and to give reliable tools for measurement analysis.

Second, specific analytic experiments have to be set up to validate these models.

Third, principles for soliciting and measurement devices and methods, which will be studied during this thesis for in-core applications, should be established : localization of solicitation of measurement devices, type (amplitude, frequency, shape) of the solicitation, technology of the device (electromagnetic, magnetic or optical)… At the end, at least one prototype for solicitation and for measurement device will be developed and tested in representatives conditions (without temperature and irradiation)

Last, measurement analysis techniques will be developed for extracting relevant information from experimental acquisitions (time and frequency analysis, noise treatment, …).

This work should give enough information for starting the technologic development of these devices in order to be integrated in the ADELINE irradiation loop.

[1] Veronica D'Ambrosi*, Modeling and Measurement Methods to characterize Pellet-Clad Interaction during dedicated normal and off-normal irradiation in nuclear research reactor*, PhD Thesis, AMU, coll. CEA/LMA, Dir. J.M. Gatt & F. Lebon, 2017-2020.