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COUPLING OF FUEL PERFOMANCE AND NEUTRONIC CODES FOR PWR

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We are concerned by accidental situations and associated stiff transients in Pressurized Water Reactors (PWR). In this context, accurate representations of nuclear fuel element evolution, neutron interactions with matter, heat exchanges - from the neutronic power deposition to the fuel element, up to the coolant power evacuation, are needed. Indeed, fast power transients, such as Reactivity Initiated Accidents (RIA) subsequent to control rod ejection, can lead to important deformations of fuel elements, clad failure and fuel dispersion into the coolant; accurate numerical models and coupling of physical phenomena are then key points to assess safety in reactors.
The evolution of the fuel temperature induces a change of neutronic balance due to the Doppler feedback effect (modification of absorption cross sections), which determines the fuel energy deposition by fission process. Our strategy is to couple two codes, each dedicated to a particular physics, which are: (i) the well-validated multi-dimensional fuel performance code for PWR, ALCYONE and (ii) the 3D reactor core neutronic code, APOLLO3®.

The fuel performance code for PWR, ALCYONE, is developed within the PLEIADES fuel performance software environment [1]. It implements physical models to take into account thermo-mecanical and chemico-physical behaviors of the fuel element under irradiation, and a simplified model for the fluid (coolant) flow. The thermo-mechanical pellet-gap-cladding problem is solved using the CAST3M (http://www-cast3m.cea.fr/) finite element solver, for axisymetric $1D^{1/2}$ or $2D(r, z)$, $2D(r, \theta)$ or $3D$ modelings.

APOLLO3® is a common project of CEA, AREVA and EdF for the development of a new generation code system for the core physics analysis, providing improved accuracy, flexible software architecture and high computation performances, and taking into account both

R&D and industrial application requirements [2]. The experience on earlier generations of codes and their applications provides an initial and complete set of calculation routes for the neutronic evaluation; this experience draws the ways of improving the models (flux solvers and self-shielding methods with new acceleration or effective parallelization methods). An important objective of APOLLO3® is to perform multi-systems reference calculation as well as project and industrial routine calculations with code architecture that would allow an easy implementation of new methods and models for both lattice and core calculations.

Coupled within the platform CORPUS, ALCYONE for fuel modeling and APOLLO3® for neutronics, we can obtain most of the physics needed to simulate accidental situations in PWR. CORPUS is an application of SALOME open-source integration platform developed by CEA (http://www.salome-platform.org) and is dedicated to best-estimate PWR calculations. This coupling environment allows more flexibility in the coupling strategy that can manage: different levels of modeling (e.g. $1D^{1/2}$ to 3D for ALCYONE) and spatial discretizations, meshes interpolation, parallelization, ...
Physical application consider a mini-core pattern, made up of nine fuel rod assemblies, during a cycle of base irradiation. This has been designed as starting point of a transient RIA configuration. Preliminar investigation assumes a $1D^{1/2}$ fuel rod (ALCYONE) and a 3D neutronic (APOLLO3®) modelings. The coupling scheme uses an implicit formulation solved by a fixed point method.

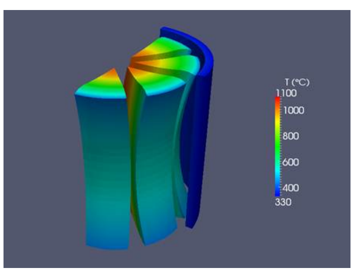

Figure 1: Pellet and clad temperature distribution obtained with ALCYONE 3D.

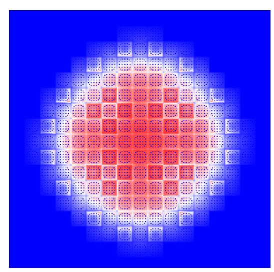

Figure 2: Heterogeneous core power map obtained with APOLLO3®.

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