Development of a multiphysics Best-Estimate approach for LWR reference calculation

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Abstract

For almost 20 years, a special effort in the field of reactor physics is carried out to develop a best-estimate approach based on a fine multi physics description including neutronic, thermal-hydraulic and fuel thermomecanics. In this context, CEA develops the multiphysics tool CORPUS [1] based on the SALOME platform [2]. The main CORPUS ambition is to develop and maintain in operational conditions a set of best-estimate calculation schemes for different operating/accidental situations in the framework of complete scenarios analysis.

The following analysis has the objective to answer some of the fundamental questions that arise when trying to build a best-estimate multiphysics calculation scheme. This work includes three main parts.

The first one deals with the comparison among some calculation schemes offered by the deterministic neutronic code APOLLO3® [3] to perform a stand-alone static calculation. All these alternative solutions follow the rather standard two steps approach. The first step (lattice calculation) deals with a very accurate resolution of a subdomain of the problem (fuel assembly with simplified boundary conditions under a set of core conditions). The results are synthetized in homogenized and collapsed cross-sections stored in a multi-parametrized library. Between lattice and core calculations, these cross-sections are corrected through the super-homogenization equivalence procedure (SPH) [4] and finally they are used to solve the entire problem (coarser solver or SN transport calculation) on the 3D configuration. The reflector's cross-sections are processed with the 1D traverses technique [5]. For the core calculation, two spatial meshes are used, the cross-sections are homogenized either on the fourth of the assembly or at the fuel pin cell scale. APOLLO3® offers transport solvers able to perform well even at this finer scale, so that local parameters can be accurately predicted. Four energy meshes, from two to thirty groups, are adopted following the solver precision. An analysis is performed to rank the available neutronic calculation schemes in terms of precision and computational time. Some partial conclusions are also drawn on the impact of the radial reflector's isotopic composition (standard LWR reflector or steel baffle) on the power distribution.

The second section focuses on the impact of various assumptions in the feedback model that will be used for the coupling calculations. The major one concerns the multi-1D assumption that consist in neglecting the coolant mass exchanges between the fuel assemblies. The analysis will be performed using FLICA4 [6] 3D thermal-hydraulic code (four equations model). The impact of various assumptions

in the fuel assembly thermal calculation (spatial fuel temperature distribution) will be also evaluated using a multi-1D thermal hydraulic model (4 equations) in APOLLO3® code.

In the third part, we focus on the coupling iteration scheme. The study of adequate numerical methods is crucial to have a time efficient iteration scheme. Finally, the so built neutronic - thermal hydraulic scheme is tested. The analysis focuses on several core design parameters including power distribution. The configuration selected for the analysis is a mini-core 5x5 with radial, bottom and top reflectors, two material isotopic compositions are considered for the radial reflector. The size of the mini-core is the result of the trade-off between representativeness as compared to a real reactor and a reasonable computational time for this initial test phase.

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