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MULTI-PHYSICS SIMULATION OF CRITICAL DEBRIS BED

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Abstract

Corium, formed during PWR severe accidents, can present criticality risks in water moderated debris bed configurations. This risk is eliminated by using borated water aspersion. However, the accident of Fukushima Daiichi nuclear power plant showed that the supply of borated water could not be ensured. The corium may be quenched and fragmented into debris when it flows out of the vessel. The debris bed flooded with non-borated or low borated water could be super-critical depending on moderator ratio driven by porosity and debris mean size. In order to expand the knowledge about a hypothetical re-criticality transient, multi-physics calculations must be performed.

A simulation code using point kinetics model, neutronic's feedbacks and thermal-hydraulic calculation has been developed to investigate such a transient. Thanks to the CEA Monte-Carlo code TRIPOLI-4®, the feedback coefficients (Doppler's effect, void's fraction effect), reactivity insertion law (function of debris bed thickness) and fission rate profile over the debris bed were calculated. During a transient, the feedback effect are calculated on each node of a mesh covering the debris bed and then integrated to get the system reactivity using adjoint weighting reconstruction. The kinetics calculation is done to obtain the nuclear power transmitted to the debris bed and water. Debris temperatures are calculated thanks to finite-volume scheme and the void fraction inside the bed is obtained from a Lipinski based correlation or the IRSN code MC3D. Comparison with reference calculation have been done to check the feedback coefficient estimation. Lipinski simplified model is compared over MC3D simulation.

The purpose of this paper is to address the methodology to extend knowledge about an hypothetical critical debris bed transient. A multi-physics code, coupling neutronics and thermal-hydraulics have been developed. Test case scenarios, including the assessment of the associated uncertainties, will be assessed in the future.

Keywords: Debris bed coolability, criticality, kinetics point model, multi-physics