Supercritical transient analysis in light water moderated coupled small fuel debris regions using integral kinetic model and point kinetic model

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Supercritical transient analyses were performed in symmetric and asymmetric systems of light water moderated coupled small fuel debris regions using the integral kinetic model (IKM) and the point kinetic model (PKM). The obtained quantities included fission rate, released energy, and temperature in whole system by the PKM. The same quantities were obtained for each region by the IKM. The result showed the PKM gives more conservative results than the IKM in asymmetric systems.

Keywords: criticality accident, Fukushima Daiichi, coupled fuel debris, integral kinetic model, point kinetic model

1. Introduction

Evaluation of possible re-criticality accident in the damaged cores of the Fukushima Daiichi nuclear power station necessitates a transient kinetic analysis. As the current condition of damaged core is unknown, we performed the supercritical transient analysis in coupled small fuel debris region of simple symmetric and asymmetric geometry using the IKM and PKM.

2. Methodology

2-1. Description of coupled fuel debris system

Symmetric and asymmetric systems were considered. Symmetric system consisted of two spheres of the same size located at certain distances inside the light water while asymmetric system consisted of two different sized spheres. Each sphere further consisted of 6-mm-radius spherical UO_2 particles inside a light water. The packing fraction of each sphere was 0.25. Enrichment of ^{235}U was 5 wt%. The size of the sphere was decided such that each sphere (i.e., Unit-1 and Unit-2) is critical on its own in case of symmetric systems, while in asymmetric systems the size of larger sphere (i.e., Unit-1) corresponded to a critical size. Thus, in both symmetric and asymmetric systems the excess reactivity was provided by the coupling between two spheres. Furthermore, in both systems a various distances between the two spheres were considered to obtain various coupling and excess reactivity.

2-1. Analysis method

The IKM describes time- and region-dependent quantities (e.g., fission rate) in coupled system of arbitrary geometry [1]. On the other hand, the PKM describes time-dependent quantities in a whole region. When compared against the PKM, the IKM is advantageous because of treatment of region-dependency, while it is disadvantageous due to its more complexity. In both models, we considered Doppler feedback. The kinetic parameters used in the IKM were obtained with continuous energy Monte Carlo code MVP2.0 [2] while the neutron lifetime used in the PKM was obtained by the SRAC code [3].

3. Results and conclusion

In each system, as the distance between two spheres increased, the coupling and excess reactivity decreased leading to smaller energy release. In case of asymmetric system, as the coupling decreased, the power ratio between two spheres increased. In general, it was found that the PKM gives more conservative results than the IKM in asymmetric systems while it gives closer results to the IKM in symmetric systems. As for the fission rate (e.g., power profile), an example of first power spike obtained by the IKM and PKM in asymmetric system of 5 cm distance is shown in Fig.1. As shown, the fission rate in Unit-2 by the IKM is much lower than that in Unit-1 due to smaller size and weak coupling.

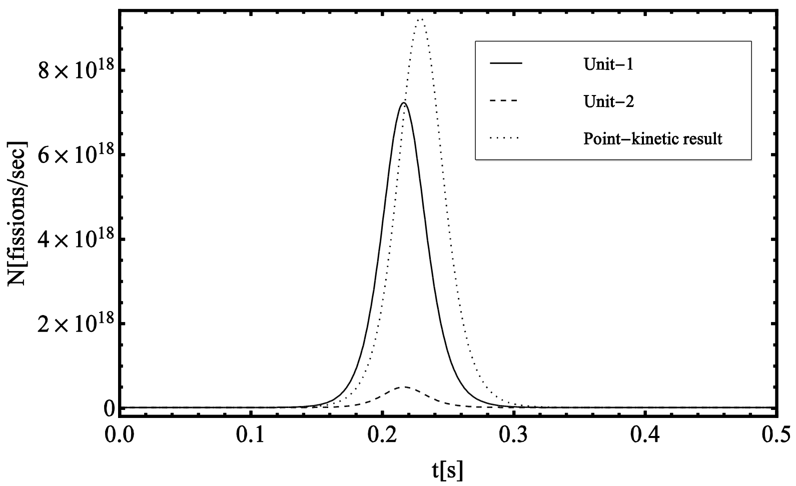

Figure 1. First power spike in asymmetric system of 5 cm distance

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