Statistical Uncertainty in Kinetic Analysis using Integral Kinetic Model for Re-criticality Accident in Weakly-Coupled Fuel Debris

*Delgersaikhan Tuya[1], Toru Obara[2] and Hiroki Takezawa[2]
[1]Department of Nuclear Engineering, Tokyo Institute of Technology, [2]Research Laboratory for Nuclear Reactors, Tokyo Institute of Technology

When using the Integral Kinetic Model (IKM), which describes time- and space-dependent fission rate during criticality excursion in nuclear fissile system of arbitrary geometry, the key kinetic parameters are obtained using the Monte Carlo method and therefore have statistical uncertainty. Estimation of such statistical uncertainty propagation through the IKM is considered in this study.

Keywords: integral kinetic model, criticality accident, statistical uncertainty propagation, weakly-coupled fuel debris

1. Introduction

The Integral Kinetic Model (IKM) can describe time- and space-dependent fission rate in criticality excursion in fissile system of arbitrary geometry. The kinetic parameters used in the IKM are obtained by the Monte Carlo method. There is often a concern about a propagation of statistical uncertainty that stemmed from Monte Carlo method through the IKM. Previously, statistical uncertainty was treated in supercritical kinetic analysis in fuel debris system containing two similar spherical regions [1]. The purpose of the current study was to clarify the treatment of such statistical uncertainty propagation and then apply it to a supercritical kinetic analysis in a neutronically weakly-coupled system of fragmented and consolidated fuel debris regions.

2. Method

The statistical uncertainty in the kinetic parameters are presented in usual way of standard deviation using sets of data obtained by each batch calculation of the modified version [2] of continues energy Monte Carlo code MVP2.0 [3]. For the statistical uncertainty propagation through the IKM, we treat a fission rate at each time step as independent variable [4]. Then, the IKM with such statistical uncertainty treatment was applied to a supercritical kinetic analysis in weakly-coupled fuel debris system. The fuel debris system was consisted of a spherical fragmented debris region, which contains 1-mm-radius spherical fuel debris particles submerged in light water making a packing fraction of 0.2, located in contact with a rectangular consolidated debris region inside a rectangular prism of light water of thickness of 50 cm. The radius of the spherical region was 30.3 cm and the size of rectangular consolidated region was 8.75x80x70 cm at the critical condition. The outmost region was vacuum. The material composition for both regions was homogenous mixture of 76% UO_2, 19% Zr, and other reactor structural materials. The enrichment of U-235 was 5wt%. The reactivity of 197 pcm was inserted in step-wise manner by increasing the radius of spherical fragmented debris region.

3. Results and discussion

The obtained fission rate in each region is shown in the figure below together with standard deviation at every 5 ms interval. Maximum statistical uncertainty in the form of standard deviation of the obtained kinetic parameters was around 0.2%. Then maximum statistical uncertainties in the form of standard deviation in the obtained fission rate by the IKM and released energy were around 1.1% and 3×10^{-3}%, respectively. The maximum statistical uncertainty was observed in the consolidated debris region, where fission rate is much less than that in the fragmented debris region. If we, however, consider the total fission and energy release over the whole range of excursion duration, the corresponding statistical uncertainties were around 8×10^{-4}%.

4. Conclusion

The treatment of the propagation of statistical uncertainty of the kinetic parameters obtained by Monte Carlo method through the Integral Kinetic Model was presented. It then was applied to the weakly-coupled fuel debris system and the results showed that statistical uncertainty of the kinetic parameters could hardly give an impact on the outcome of the IKM.

References

[1] D. Tuya and T. Obara, 2016. Supercritical Kinetic Analysis in Simplified System of Fuel Debris using Integral Kinetic Model, *Ann. Nucl. Energy*, 91, 59-64.
[2] H. Takezawa and T. Obara, 2010. Calculation of the Integral Kinetic Model Transient Parameters by the Monte Carlo Method for Space-Dependent Kinetic Analysis, *Nucl. Sci. Eng*, 164, 80-86.
[3] Y. Nagaya et al, 2005. MVP/GMVP II: General Purpose Monte Carlo Codes for Neutron and Photon Transport Calculation Based on Continuous Energy and Multigroup Method, *JAERI-1348*.
[4] H. Takezawa and T. Obara, 2012. New Approach to Space-Dependent Kinetic Analysis by the Integral Kinetic Model, *Nucl. Sci. Eng*, 171, 1-12.