The Spatial Kinetic Analysis of Accelerator-Driven Subcritical Reactor

H. Takahashi, Y. An, and X. Chen

Brookhaven National Laboratory
Upton, New York, USA 11973

The operation of the accelerator-driven reactor with subcritical condition provides a more flexible choice of the reactor materials and of design parameters [1-3]. A deep subcriticality [4-5] is chosen sometime from the analysis of point kinetics. When a large reactor is operated in deep subcritical condition by using a localized spallation source, the power distribution has strong spatial dependence, and point kinetics does not provide proper analysis for reactor safety.

In order to analyze the spatial and energy dependent kinetic behavior in the subcritical reactor, we developed a computation code which is composed of two parts, the first one is for creating the group cross section and the second part solves the multi-group kinetic diffusion equations. The reactor parameters such as the cross-section of fission, scattering, and energy transfer among the several energy groups and regions are calculated by using a code modified from the Monte Carlo codes MCNP-4[6] and LAHET [7] instead of the usual analytical method of ANISN, TWOTRAN codes. Thus the complicated geometry of the accelerator-driven reactor core can be precisely taken into account.

We analyzed the subcritical minor actinide transmutor studied by Japan Atomic Energy Research Institute (JAERI) using the code. The spallation neutrons are created in the central target.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MASTER
DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.
the target material should have a small neutron-capture cross-section to reduce stress due to a high temperature gradient.

This analysis indicated that a small reactor like JAERI's fast neutron transmutor of minor actinides can operate safely even though it has rather deep subcriticality because of its small peaking factor; nevertheless, it requires the use of a high-powered proton accelerator, and consequently, radiation damage to the beam's windows might be high.

Although we studied the effects of subcriticality on the spatial distribution of heat generation by simply varying the k values, an accident scenario, such as Na boiling which introduces positive reactivity into the reactor, can be calculated by slight modification of the diffusion code. To make a more accurate analysis, a kinetic code based on the three-dimensional diffusion code or the integral transport theory using first-flight collision probability should be developed. However, this study has clearly demonstrated the usability of Monte Carlo calculations to get cross-section data for kinetic problems.

Acknowledgments

The authors would like to express their thanks to Drs. G.A.D. Woodhead for her editorial work. This work was performed under the auspices of the U.S. Department of Energy under Contract No. DE-AC02-76CH00016, and supported by Japan Atomic Energy Research Institute.

References

Figure 1 (a - c)
The Neutron Flux Distribution Change After Proton Beam Shut Off At t = 0

The graphs show the neutron flux distribution in different radial regions for a target with a moderator ($k = 0.9$) over time after the proton beam is shut off. The graphs are labeled as follows:

- **(a)** Neutron Flux in the 1st Energy Group
- **(b)** Neutron Flux in the 2nd Energy Group
- **(c)** Neutron Flux in the 3rd Energy Group

The graphs are labeled with time intervals of 0, 20 nsec, 40 nsec, 60 nsec, 80 nsec, and 100 nsec. The neutron flux distribution is indicated in the core and S.S. reflector regions for each energy group.