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ABSTRACT

Development of Advanced Suite of Deterministic Codes for VHTR Physics Analysis

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Physics analysis of very high temperature reactor (VHTR), which is a leading candidate for the Next Generation Nuclear Plant (NGNP), requires different modeling capabilities from those of current light water reactors (LWRs), including the double heterogeneity of coated fuel particles, neutron streaming in coolant channels, and core/reflector coupling. Monte Carlo techniques have these capabilities, but they are not sufficiently efficient for use in routine design calculations, in particular in calculating fuel pin level power distributions and small reactivity effects. Furthermore, several important phenomena such as reactivity feedbacks, flux uncertainty propagation into depletion calculations and fission product buildup are not properly addressed yet. Therefore, in addition to Monte Carlo tools, it is essential to employ deterministic analysis tools for the scoping and design evaluation of VHTR, similarly to the current approaches used for analyzing operating reactors.

However, current deterministic codes for high-temperature gas cooled reactor analysis are generally based on old technology in pedigree and platform. These old approaches are both cumbersome and provide only approximate treatments. For example, multi-group constants are generated based on pin cell calculations, and whole core calculations and depletion analyses are performed based on two-dimensional diffusion theory. This directs to the need for adapting modern deterministic tools for VHTR analysis and for verifying and validating them for current and future applications. Improved computational methods and models will enhance the safety and economics of VHTR by reducing the computational uncertainties of performance parameters. Efforts are being made both at ANL (under Work Package A0802J01 of Gen IV Design and Evaluation Methods) and at KAERI (Pilot Study for Establishing VHTGR Design Concepts) to evaluate the currently available physics analysis tools and to identify and implement required enhancements. The proposed project is aimed at leveraging these U.S. and Korean efforts through international collaborations.

The objective of the proposed project is to develop an advanced suite of deterministic codes for use in VHTR design and licensing. The capabilities of currently available physics analysis tools will be investigated focusing on the modeling requirements for VHTR. Based on the assessment, required enhancements to the lattice physics, whole-core, and fuel cycle modeling capabilities will be identified. Focusing on applying to block-type VHTR, an advanced suite of codes based on the conventional two-step lattice and whole-core calculation approach will be developed by implementing these identified enhancements. In parallel, adaptation for VHTR analyses of the 3D whole-core transport code DeCART, which is being developed for LWR applications at KAERI under an on-going U.S./ROK I-NERI project of ANL and KAERI, will be pursued. This code eliminates the approximations and laborious multi-group constant generation need of the two-step approach by representing local heterogeneity explicitly without homogenization, using a multi-group cross section library directly without group condensation, and incorporating pin-wise thermal-hydraulic feedback. Verification and validation tests of the new suite of codes will be performed using appropriately defined benchmark problems and available experimental data.