NUCLEAR ENERGY UNIVERSITY PROGRAMS

Multi-Scale Multi-physics Methods Development for the Calculation of Hot-Spots in the NGNP

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Abstract

Radioactive gaseous fission products are released out of the fuel element at a significantly higher rate when the fuel temperature exceeds 1600°C in high-temperature gas-cooled reactors (HTGRs). Therefore, it is of paramount importance to accurately predict the peak fuel temperature during all operational and design-basis accident conditions. The current methods used to predict the peak fuel temperature in HTGRs, such as the Next-Generation Nuclear Plant (NGNP), estimate the average fuel temperature in a computational mesh modeling hundreds of fuel pebbles or a fuel assembly in a pebble-bed reactor (PBR) or prismatic block type reactor (PMR), respectively. Experiments conducted in operating HTGRs indicate considerable uncertainty in the current methods and correlations used to predict actual temperatures. The objective of this project is to improve the accuracy in the prediction of local "hot" spots by developing multi-scale, multi-physics methods and implementing them within the framework of established codes used for NGNP analysis.

The multi-scale approach which this project will implement begins with defining suitable scales for a physical and mathematical model and then deriving and applying the appropriate boundary conditions between scales. The macro scale is the greatest length that describes the entire reactor, whereas the meso scale models only a fuel block in a prismatic reactor and ten to hundreds of pebbles in a pebble bed reactor. The smallest scale is the micro scale—the level of a fuel kernel of the pebble in a PBR and fuel compact in a PMR—which needs to be resolved in order to calculate the peak temperature in a fuel kernel.