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U.S. Department of Energy

Lagrangian Particle Tracking Methods for Multiscale Graphite Dust Transport in Pebble Bed Reactors

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ABSTRACT:

Pebble bed reactors (PBRs) are expected to display excellent heat removal and control properties due to the use of large quantities of graphite, the high failure temperatures of TRISO fuel, and on-line refueling. An important operations and maintenance (O&M) consideration in PBRs is the production and transport of graphite dust. Dust is formed by numerous mechanisms, including (i) wear, as the pebbles slide and rotate past one another and structural components; (ii) chemical processes, such as peeling or hydrocarbon decomposition during ingress events; (iii) erosion; and (iv) macroscopic failures. Fission products and activated materials readily adhere to the dust, producing a mobile source term which may deposit throughout the primary loop. Physical processes including turbulent diffusion, thermophoresis, gravitational settling, coagulation, and resuspension necessitate a coupling between thermal-hydraulics (T/H) methods and graphite dust transport particle solvers. However, the NEAMS coarse-mesh T/H suite currently lacks an integrated capability to account for graphite dust transport for reactor design, safety analysis, and operation-supporting predictions.

This work proposes three objectives. First, we will develop a **new modeling capability in MOOSE for discrete Lagrangian particle tracking** which accounts for the physics mechanisms driving graphite dust transport. This capability shall be added as an open-source, general-purpose MOOSE module for one-way coupling between Eulerian fluid solvers and Lagrangian particle methods, with robust verification and validation while meeting MOOSE's NQA-1 software standards. Second, we deploy this capability using a multiscale coupling of Pronghorn's 3-D porous media solver with SAM's 1-D systems-level solver for **steady-state and transient modeling of gas-cooled PBR dust transport.** A multiscale approach will effectively leverage 3-D/1-D solvers and entail methods research on coupling strategies for dust transport. Engineering insight into questions regarding dust transport, such as the spatial distribution of graphite dust, time constants for accumulation/deposition, and dominant deposition/resuspension processes shall be gained through a series of full-system PBR simulations. Models used to predict dust production, as well as the constitutive models comprising Lagrangian particle methods for graphite, are subject to high uncertainty. Uncertainty quantification (UQ) and sensitivity analysis (SA) using MOOSE's Stochastic Tools module shall be used to improve understanding of critical knowledge gaps in dust transport physics.

Finally, this R&D will be integrated with new and creative educational opportunities at UIUC in the areas of (i) new undergraduate degree programs in data science and computer science (NPRE+DS, NPRE+CS), (ii) a new computational T/H course for UIUC's Computational Science and Engineering (CSE) minor, and (iii) a summer school on advanced reactor T/H principles and methods.