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Pronghorn: A Porous Media Thermal-Hydraulics Core Simulator and its Validation with the SANA Experiments

Pebble bed High Temperature Reactors (HTRs) are characterized by many advantageous design features, such as excellent passive heat removal in accidents, large margins to fuel failure, and online refueling potential. However, a significant challenge in the core modeling of pebble bed reactors is the complex fuel-coolant structure. This paper presents a new porous media simulation code, Pronghorn, that aims to alleviate modeling challenges for pebble bed reactors by providing a fast-running, mediumfidelity core simulator. Pronghorn is intended to accelerate the design and analysis cycle for pebble bed and prismatic HTRs by permitting fast scoping studies and providing boundary conditions for systems-level analysis. Pronghorn is built on the Multiphysics Object- Oriented Simulation Environment (MOOSE) using modern software practices and a thorough testing framework. This paper describes the physical models used in Pronghorn and demonstrates Pronghorn's capability for modeling gas-cooled pebble bed HTRs by presenting simulation results obtained for the German SANA pebble bed decay heat experiments. Within the limitations of the porous media approximation and existing available closure relationships, Pronghorn predicts the SANA experimental pebble temperatures well, expanding the code's validation base. A brief code-to-code comparison shows a level of accuracy comparable to other porous media simulation tools. Pronghorn's advantages over these related tools include: an arbitrary equation of state, unstructured mesh capabilities, compressible flow models, the ability to couple to MOOSE fuels performance and systems-level thermal-hydraulics codes, and modern software design.