Kairos Power
partnered with
Argone National Laboratory

NE-20-23946, Pebble Bed Large Eddy Simulations for Lower Order Methods Benchmarking and Uncertainty Quantification Development

YEAR AWARDED: 2020

TOTAL PROJECT VALUE: $538k (DOE: $430k, Kairos: $100k)

STATUS: Completed

PRINCIPAL LAB INVESTIGATORS: Tanju Sofu (ANL), Brian Jackson (Kairos Power)

DESCRIPTION: Kairos Power is a nuclear energy technology, engineering, and manufacturing company singularly focused on the commercialization of the fluoride salt-cooled, high-temperature reactor (FHR). To simulate the core thermal hydraulic behavior, researchers employ simplified empirical correlation-based porous media and heat transfer models. For different operation and accident scenario conditions, Large Eddy Simulations (LES) can produce numerical benchmark data that capture local velocity and temperature effects. This can be used to further understand the different modes of heat transfer in an FHR core. Under this GAIN voucher, Argonne National Laboratory provided Kairos Power its expertise in LES and turbulence modeling and made available its advanced computational resources.

BENEFIT: This work generated new high-fidelity data regarding flow and heat transfer behavior in pebble bed geometries. Through heat transfer simulations of a random-packed bed of 1,741 pebbles and a larger bed of about 34,000 pebbles in full- and low-flow conditions, a significant amount of data was generated that will provide high-quality reference data for Kairos Power to use to support design of its Hermes test reactor, recipient of a DOE Advanced Reactor Demonstration Project risk reduction award.

IMPACT: The several terabytes of numerical data generated based on high fidelity large eddy simulations using Nek5000/NekRS code will support development of reduced order models needed for design and license application of the Hermes test reactor. The simulations provided numerical LES results quantifying pebble bed heat transfer behavior of convection and radiation as a function of location in the pebble bed in both operating and accident conditions. In addition, flow communication between the pebble bed and bypass flow channels was simulated to provide input for reduced order model development to account for these phenomena.

SIGNIFICANT CONCLUSIONS: In addition to producing numerical data to be used as a reference benchmark, this work assessed modeling methodology and uncertainties in porous media and distributed resistance models used in system analyses. Insights gained from this work informed recommendations for fuel pebble conjugate heat transfer modeling methodology, effects of radiation heat transfer under low and mixed convection conditions, and effects of convective heat transfer from local conditions.

NEXT STEPS: As a result of this work, Kairos Power and the Nuclear Energy Advanced Modeling and Simulation (NEAMS) program have a better understanding of the behavior of pebble bed geometries. Kairos Power will leverage the data generated and conclusions reached as part of this investigation to help accelerate the deployment of their reactor design.