frontiers | Frontiers in Energy Research

TYPE Editorial
PUBLISHED 21 March 2024
DOI 10.3389/fenrg.2024.1394770

OPEN ACCESS

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RECEIVED 02 March 2024
ACCEPTED 12 March 2024
PUBLISHED 21 March 2024

CITATION
Ma Y, Huang S, Yu J, Liu S and Zhang P (2024), Editorial: Numerical and experimental studies on small/micro nuclear reactors.
Front. Energy Res. 12:1394770.
doi: 10.3389/fenrg.2024.1394770

Editorial: Numerical and experimental studies on small/ micro nuclear reactors

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KEYWORDS

numerical, experimental, small nuclear reactor, micro nuclear reactor, editorial

Editorial on the Research Topic
Numerical and experimental studies on small/micro nuclear reactors

Future space missions and deep-sea explorations are expected to rely on small/micro nuclear reactors, ranging from kilowatt-electric (kWe) to megawatt-electric (MWe) power output, for their power generation needs. These reactors offer numerous advantages over conventional energy systems, such as storage batteries and fossil fuels. They provide higher energy density, increased reliability, and longer operational lifetimes. Small/micro nuclear reactors can be classified into various categories based on the coolant they use, including heat pipe cooled reactors, liquid metal cooled reactors, and gas-cooled reactors. Currently, most of these reactors are still in the conceptual design stage, undergoing numerical studies and experimental research.

The unique core structure and operating principles of these emerging reactors differ significantly from existing light water reactors. Consequently, there is a need for the development of updated simulation methods and experimental studies to accurately understand their behavior. Researchers are actively working on improving simulation capabilities and validating them through experiments. They are also making efforts to develop multi-physics coupled analysis programs that consider various physical processes. These advancements provide researchers with a powerful tool to gain in-depth insights into the behavior and performance of small/micro nuclear reactors.

This Research Topic serves as a crucial platform for researchers to share and publish their latest findings and advancements in the field of small/micro nuclear reactors. The Research Topic covers various topics, including thermal-hydraulic and safety analysis, multiphysics coupling, computational code development, and validation, which is divided into three parts: reviews, experiments and simulation.

To comprehensively and systematically summarize and synthesize the field of small/ micro nuclear reactors, reviews are provided. In this part, Wang et al. (Wang et al.) provide a comprehensive review of heat pipe cooled reactor (HPCR) conceptual designed by various countries in recent years. The research progress of high temperature heat pipes on flow and heat transfer performance is reviewed, with an emphasis on both transient and steady-state characteristics.

The current research on small/micro nuclear reactors primarily revolves around specific numerical simulations, which are instrumental in analyzing their behavior and performance. These simulations enable researchers to explore different operational scenarios and optimize various parameters for efficient and reliable reactor designs. In this part, Liu et al. (Liu et al.) focus on the impact of rapid power fluctuations in the core during the start-up and power-up processes of HPCR on the safe operation of the reactor. The peak power dataset of HPCR start-up and power-up processes is established and analyzed, using Monte Carlo sampling method. A fast prediction model of peak power was developed based on the artificial neural network. Ma and Hu focused on heat pipe cooled traveling wave reactor (HPTWR) and utilized the Monte Carlo program RMC (Reactor Monte Carlo) to obtain the reactivity swing, propagation of axial power peak, burnup, and productions of bred fissile nuclides for the HPTWR with Thu and U fuels. Liu et al. analyzed the design scheme of coupling a small fluoride-salt-cooled high-temperature reactor (FHR) with the Brayton cycle. A comparison was made among four different configurations of S-CO2 Brayton cycles coupled with FHR in terms of efficiency, exergy energy efficiency, and exergy loss. Meanwhile, the effects of the cooling conditions on the thermal efficiency and exergy efficiency of different cycle configurations are discussed. Jeong et al. developed a multi-physics coupled analysis program based on Open FOAM and the heat pipe thermal analysis code ANLHTP for accurate analysis of heat-pipe-cooled microreactors (HPRs) core. They validated the multi-physics analysis capabilities of this coupled program through analysis and verification of MegaPower. Chen et al. proposed a non-inclusive Proper Orthogonal Decomposition (POD) method based on a neural network. They validated the accuracy of this method using a transient heat conduction model for a two-dimensional plate and applied it to a rapid thermal analysis of the gas-cooled micro-reactor core. Wang et al. analyzed the errors of the stiffness confinement method and proposed a more achievable adaptive time-stepping (ATS) algorithm based on the error analysis by controlling the neutron flux amplitude error. The ATS algorithm yields a higher accuracy at a commensurate computational cost than calculations with fixed time-steps.

Luo et al. presents an inherent safety analysis of an ADS using the ARTAP code, investigating various accident scenarios, including proton beam interruption, transient overpower, reactivity insertion, loss of flow, and loss of heat sink. The results highlight the remarkable advantage of the ADS in mitigating severe accidents and underscore its inherent safety characteristics, demonstrating the ability to ensure reactor shutdown by cutting off the proton beam following accidents.

While numerical simulations dominate the research, complementary experimental studies and validation efforts are also underway to ensure the accuracy and reliability of the findings. In this part, Liu et al. addressed the phenomena of heat transfer deterioration or enhancement in supercritical fluid heat transfer. They proposed a new understanding for pseudo-boiling theory, emphasizing the essential difference between subcritical boiling and supercritical pseudo-boiling, and discussed the physical mechanisms of pseudo-boiling.

In conclusion, ongoing research and development in small/micro nuclear reactors for future space missions and deep-sea explorations are of great significance. Advanced simulation methods and rigorous experimental studies are essential for optimizing the design, operation, and application of these reactors, given their unique core structures and operational principles. Through these efforts, researchers aim to advance the integration of small/micro nuclear reactors into future missions, enabling their utilization in challenging environments for long-duration and high-energy applications. This Research Topic provides a valuable platform for researchers to share their latest findings, contributing to the broader understanding and continued progress in the field of small/micro nuclear reactors.

Author contributions

YM: Supervision, Writing–original draft, Writing–review and editing. SH: Conceptualization, Supervision, Writing–review and editing. JY: Conceptualization, Supervision, Writing–review and editing. SL: Conceptualization, Supervision, Writing–review and editing. PZ: Conceptualization, Supervision, Writing–review and editing.

Conflict of interest

Author PZ was employed by China Nuclear Power Engineering Co Ltd.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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