Foreword

Special issue on the Transformational Challenge Reactor

Guest Editor

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The U.S. Department of Energy, Office of Nuclear Energy (DOE-NE) Transformational Challenge Reactor (TCR) program was launched in 2019 to offset the economic and deployment challenges of commercial nuclear plants, to break the 40-year hiatus in building a non-water advanced reactor in the United States, to support near-term advanced nuclear reactor deployments, and to build and maintain technical leadership in advanced nuclear technologies. The program targeted additive manufacturing (AM), artificial intelligence (AI), and advanced computation as key enabling technologies for accelerating reactor deployment. Demonstrations were pursued to enforce technical rigor, efficacy, and regulatory acceptance of newly developed technologies and processes. The major demonstration effort was the 4-year design, analysis, and deployment of the TCR: a small gas-cooled microreactor consisting of additively manufactured components and novel fuel and moderator materials.

Out of this directed TCR deployment effort emerged an agile design process with four key integrated technical areas, integrating AM with AI and digital frameworks: (1) AI-informed design of AM components, (2) advanced materials, (3) integrated sensing and control, and (4) digital-informed certification of AM components. Bridging basic and applied science and technology and harnessing the breadth of the national laboratory complex, the TCR program delivered first-of-a-kind technologies in these four technical areas:

1. Pioneered an agile nuclear reactor design process uniquely enabled by rapid prototyping with AM.
2. Manufactured, tested, and irradiated additively manufactured/advanced materials, including crack-free yttrium hydride, a volumetrically efficient neutron moderator.
3. Codified the production of additively manufactured metal and ceramic nuclear components under an NQA-1–based quality assurance program.
4. Integrated design, manufacturing, and control strategies to demonstrate functional reactor components and systems.
5. Collected hundreds of digital threads on additively manufactured components, including safety-related fuel assembly brackets inserted in the Tennessee Valley Authority's Browns Ferry nuclear reactor.

The delivery of these technologies was a direct product of the focus on a near-term reactor demonstration.

In late 2020, the TCR program was directed by DOE-NE to no longer pursue a reactor demonstration. At this point, the core and system had reached a preliminary design (i.e., up to 70% design completion). This special issue of *Nuclear Science and Engineering* is dedicated to capturing and disseminating the TCR conceptual design, including supporting design and optimization studies.

The TCR design discussed herein is influenced by programmatic objectives, a manufacturing-driven agile design approach, and a targeted design and deployment timeline of 4 years. With the targeted deployment date, design decisions based on high technological readiness, procurement availability, and manufacturability were favored over complex optimization and cost-benefit analyses traditionally focused around long-term business sustainability and profitability goals. The TCR design was not intended as a commercial demonstration or a test reactor. It was a novel system that was envisioned to provide the confidence and experience to enable future advanced reactor deployments on a similar short timeline for meeting emerging national interests.

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