Foreword

Special issue on Large-Scale Systems Analysis

Guest Editor

Katherine Royston

Oak Ridge National Laboratory

This special issue of *Fusion Science and Technology* brings together the latest research in large-scale systems analysis in support of fusion. This is a broad topic that includes simulating integrated systems, multiphysics coupling, and modeling large components. The papers in this issue share a theme of helping design, build, and maintain future fusion facilities by facilitating rapid design studies, verification and validation of codes, and multiphysics and component coupling for higher-fidelity solutions. The need for iterative design solutions and experimental data is noted in several papers. The facilities modeled include existing facilities, such as the Joint European Torus (JET); facilities under construction, such as ITER; and future facilities, such as the Fusion Nuclear Science Facility (FNSF). What follows is a brief introduction of each paper.

Hassan et al. provide a concrete demonstration of the advantages of a coupled simulation for plasma physics with the IPS-FASTRAN framework by comparing the study against a previous work in which information was manually shared between independently run codes. The study also included a parameter sweep to identify optimal configurations for the FNSF, an important capability for facilitating device design.

The difficult multiphysics problem of modeling impurity transport is addressed by Navarro et al. using the ERO2.0 code. In this work, an interface was developed to iteratively examine plasma–surface interactions and impurity transport from plasma-facing components in the FNSF, enabling the primary contributor to tungsten erosion to be identified.

The dual-coolant lead lithium (DCLL) blanket concept has been pursued in recent FNSF studies and is featured in papers by Youchison et al. and Smolentsev. Youchison et al. demonstrate how advancements in scientific computing continue to enable larger and more complex simulations than have ever been attempted before, while noting that even larger simulations will be needed in the future. These multiphysics simulations of an integrated DCLL model revealed features that are not apparent in smaller decomposed models. Smolentsev's paper is unique in this special issue in that it reviews the immense progress that has been made and is ongoing in the multiphysics problem of modeling liquid metal breeding blankets. The paper discusses several promising codes and needed capabilities and presents two simulations of a DCLL blanket as examples.

In the area of fusion neutronics, Wu et al. discuss radiation field analyses that were performed on a 360-deg model of the China Fusion Engineering Test Reactor that was derived from a CAD geometry. Generating neutronics models from CAD geometries is a particularly challenging aspect of fusion neutronics, and this work used the cosVMPT geometry conversion platform to overcome that difficulty. The results demonstrate the importance of modeling the full geometry to properly assess asymmetric features and identify situations in which a sector model is appropriate.

Kos et al. and Harb et al. both present extensive sets of neutronics analyses, focusing on radiation conditions during operation and shutdown at different facilities. Kos et al. apply the workflows developed at Oak Ridge National Laboratory for fusion analyses to the streaming and shutdown dose rate experiments at JET. The importance of validating codes against experimental results, as is done in this paper, cannot be overstated. In neutronics

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simulations that encompass multiple sources, two operational modes, and different shielding configurations, Harb et al. analyze the latest design of the ITER test blanket systems. The results will affect shielding design and inform maintenance operations throughout the facility's lifetime.

Weisberg et al. present a design study for a new experimental U.S. facility with the vital objective of addressing key physics gaps to enable a fusion pilot plant in the future. The workflow in this paper seeks to balance finite computational resources with the need for high-fidelity and integrated solutions with a two-step approach that uses the General Atomics systems code to optimize parameters before performing several independent high-fidelity simulations and then iterating between these steps.

The concept of integrated systems modeling is exemplified in the final paper of this special issue. Badalassi et al. introduce the FERMI simulation environment, which is under development to perform coupled, multiphysics simulations of the plasma, first wall, and blanket. The paper presents first-of-a-kind coupled 3D simulations of the DCLL blanket and the liquid immersion blanket.

I hope you will enjoy this collection of papers describing advancements in large-scale fusion systems analysis.

ORCID

Katherine Royston http://orcid.org/0000-0002-7443-3242