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Preface

Integrated physics design of conventional H-mode scenario for China Fusion Engineering Demo Reactor

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As ITER is under construction, various designs of next-generation devices have been initiated in different countries and regions, including Europe (EU-DEMO [1]), Japan (JA-DEMO [2]), the USA (FNSF [3], ARIES-ACT1 [4]) and Korea (K-DEMO [5]). In the previous roadmap of Chinese magnetic fusion energy development, the China Fusion Engineering Test Reactor (CFETR) was proposed to bridge the gap between ITER and the commercial fusion power plant [6, 7]. The engineering design of CFETR was completed in 2020 with the contribution of multiple fusion institutions and universities in China. Meanwhile, the Comprehensive Research Facility for Fusion Technology (CRAFT) has been making steady progress in research and development, and will provide key technologies for the construction of future fusion reactors. Moreover, a new compact fusion device, the Burning plasma Experimental Superconducting Tokamak (BEST) has been launched, which overlaps with some of CFETR's objectives and acts to shorten the gap to a commercial power plant. Therefore, it is appropriate to have a new DEMO-level device with more achievable goals. The new device is aptly named China Fusion Engineering Demo Reactor (CFEDR).

With valuable experiences from the design of CFETR, CFEDR uses the physics design of a larger plasma volume with a major radius of 7.8 m, a minor radius of 2.5 m and similar on-axis magnetic field of 6.3 T. The mission of CFEDR is to demonstrate high fusion power at fusion power plant level (1.5–3 GW) with high fusion gain (Q = 15–30) and net electrical power generation, steady-state burning plasma operation with a high duty factor > 0.5, tritium self-sufficiency and cycling technologies with a tritium breeding ratio > 1. Before tackling the advanced scenarios for achieving its ultimate goals, it is proposed to first focus on a conventional H-mode scenario grounded in solid and reliable physics to learn and mitigate the potential risks with DEMO parameters. The main objective of the conventional H-mode scenario is to demonstrate close to steady-state operation with a fusion power of around 1.5 GW.

The integrated scenario development has been carried out by 13 task forces focusing on different topics utilizing state-of-the-art analyses and physics design models, including core-to-edge integration, shape optimization and wave form design, disruption prediction, control and mitigation, divertor design and pedestal optimization, evaluation of heat and particle flux on the first wall, particle fueling and impurity control, MHD stability analysis, burning plasma physics, tritium circulation, auxiliary heating systems, shielding and blanket design, diagnostics, and artificial intelligence applications for control and operation. A standard CFEDR H-mode scenario evolves from the 1.5D self-consistent core–pedestal integrated modeling, and then different key aspects are evaluated. Dimensionally similar experimental validations on EAST with a full metal wall environment are also carried out to provide a high-fidelity physics design for the CFEDR conventional H-mode scenario. Different task groups have worked collaboratively to

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pursue the same goal and ensure that all key components are self-consistently connected. In light of the significant progress made by the CFEDR physics design team, it is now appropriate to share the interim achievements with the broader fusion community. This will facilitate the gathering of diverse suggestions and collaborations.

This special issue releases the latest research advances on the CFEDR physics design. The 15 manuscripts compiled in this issue have undergone rigorous peer-reviews, offering comprehensive discussions about different aspects of the CFEDR conventional H-mode operation scenario, as well as the corresponding auxiliary heating and diagnostic designs.

In the next step, we are going to explore candidate advanced operation scenarios with high confinement, which will help to achieve a higher fusion power (2–3 GW) and high fusion gain ($Q > 30$). A critical aspect of this endeavor is to establish strong coupling between the design physics and the experimental database. We are poised to integrate innovative concepts, such as machine learning and artificial intelligence, into the realms of plasma control and operation, enhancing our capabilities in managing complex fusion processes. The engineering design of CFEDR will be initiated soon, ensuring enough iterations between physics and engineering designs. Such an iterative process is vital for the successful realization of a credible CFEDR design that is based on a strong technical foundation for first-generation fusion power plants.

References

[1] Federici G *et al* 2018 *Fusion Eng. Des.* **136** 729
[2] Tobita K *et al* 2017 *Fusion Sci. Technol.* **72** 537
[3] Kessel C E *et al* 2018 *Fusion Eng. Des.* **135** 356
[4] Kessel C E *et al* 2015 *Fusion Sci. Technol.* **67** 1
[5] Kim K *et al* 2015 *Nucl. Fusion* **55** 053027
[6] Wan Y X *et al* 2017 *Nucl. Fusion* **57** 102009
[7] Zhuang G *et al* 2019 *Nucl. Fusion* **59** 112010