P11-DPP2017

1st Asia-Pacific Conference on Plasma Physics, 18-22, 09.2017, Chengdu, China

Challenges in support of steady-state tokamak operation for fusion reactor

Baonian Wan[1] and EAST-team*

[1] Institute of Plasma Physics, Chinese Academy of Sciences, Hefei, China

It is foresee that a steady-state operation of ITER and future fusion power plant, i.e. CFETR and DEMO, requires a substantial fraction of non-inductive plasma current driven by current-drive power and the bootstrap effect, while such plasmas are often operated at high power densities and near or even beyond the pressure limit. Therefore, both a reliable plasma stability control and a tolerable plasma exhaust, including steady-state and transient heat and particle fluxes on plasma-facing components, are essential issues. In addition, the most challenging issue is the coupling (integration) of these individual issues (multiple time-scale physics processes), while their compatibilities with the core plasma performance are needed, however, it is not yet solved. To investigate this issue, it is very likely that a superconducting device, which allows a long-pulse stable operation, is required.

As of a long-term research programme, EAST aims demonstrating steady-state advanced high-performance H-mode plasmas with ITER-like configuration, plasma control and heating schemes. On the basis of the physics achievements in the past few years and the exceptional capabilities being implemented since 2013 [1], EAST has advanced capabilities to address many of the critical physics and technology issues, and to explore steady-state operation with advanced tokamak characteristics, which would be of great value to ITER but also could lead to an attractive fusion power plant.

- EAST is capable of pulse durations beyond 400 seconds with high power electron heating (as in ITER), ITER-like advanced divertor configuration and Tungsten (W) monoblock technology to challenge power and particle handling at high-normalized levels (10 MW/m^2) comparable to ITER.
- EAST is equipped with all ITER-related auxiliary heating and current driven systems, and capable of H-mode access with each of individual heating system, and investigation of plasma profile control by coupling/integration of different methods. In addition, two NBI systems, injected from Co- and Ctr- current directions, allow a flexible study of the plasma rotation effect.
- EAST successfully demonstrated ELM suppression / mitigation with most of existing methods, including RMP [2], pellet pacing, SMBI, LHW [3] and Li-pellet injections [4], and it is capable of investigating ELM control with different combinations of those methods.
- EAST is equipped with most of modern diagnostics, and capable of measuring dynamic of plasma profiles, stabilities, and plasma wall interactions.

All above exceptional capabilities advance EAST to be a valuable facility to investigate high performance steady-state operation scenario in support of physics design of future fusion reactor. A strong international collaboration between two devices, DIII-D and EAST, has been established aiming to demonstrate the steady-state high-performance plasma operation on EAST based on the advanced scenario originally developed on DIII-D.

Recently, significant progresses in development of high performance steady-state operation have been achieved on EAST [5], including:

- First demonstration of long-pulse (>50s) fully non-inductive steady-state scenario with a good plasma performance ($H_{98(y2)} \sim 1.1$) and a good control of impurity and heat exhaust with the Tungsten divertor [6];
- Demonstration of a steady-state scenario at high $\beta_P \sim 1.8$ with the tungsten divertor;
- Discovery of a stationary ELM-stable H-mode regime with 4.6 GHz LHCD [7];
- Extension of the current drive in high density domain (up to $4.5\times10^{19}m^{-3}$) with 4.6 GHz LHCD system;
- Achievement of ELM suppression for > 20 s in slowly-rotating H-mode plasma with the application of $n = 1$ RMPs;
- Regulating heat deposition distribution and reducing transit peak heat fluxes on the divertor and PFCs by applying either LHW or 3D magnetic perturbations at the plasma boundary.

In addition to these achievements, the first investigations of both the active control of neoclassical tearing modes (NTMs) and formation of the internal transport barrier (ITB) are performed on EAST for the future development of a steady-state H-mode scenario towards the high β_N regime.

In this paper, challenges in support of steady-state tokamak operation for fusion reactor will be discussed systematically, based on the lessons learned from EAST experiments.

References

[1] Wan, B.N. *et al.*, Nucl. Fusion 55 (2015) 104015
[2] Sun, Y. *et al.*, Phys. Rev. Lett. 117 (2016) 115001
[3] Liang, Y. *et al.*, Phys. Rev. Lett. 110 (2013) 235002
[4] Hu, J.S. *et al*, Phys. Rev. Lett. 114, 055001 (2015)
[5] Wan, B.N. *et al.*, OV/2-2, 26th IAEA-FEC (2016)
[6] Garofalo, A.M. *et al.*, EX/4-3, 26th IAEA-FEC (2016)
[7] Xu, G.S. *et al.*, EX/10-2, 26th IAEA-FEC (2016