Modeling of EAST scenarios with the upgraded H/CD systems using METIS code

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1. Introduction

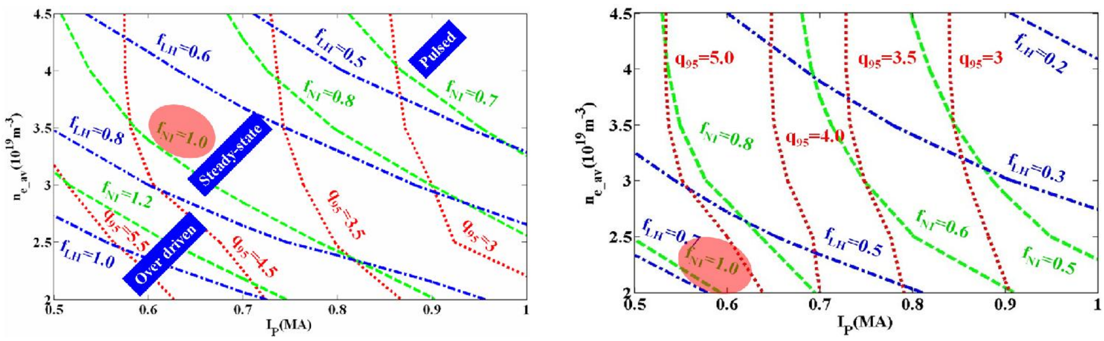
EAST is a fully superconducting tokamak with a major radius of 1.86m and a minor radius of 0.45m. Significant progress has been achieved in long-pulse L- and H-mode discharges in the recent campaign in 2012 [1, 2]. Now, the heating and current drive (H/CD) capabilities of EAST have been upgraded to a new level over the last two years, which provide a potential to extend operational space and to improve plasma performance. More specifically, EAST in 2014 is equipped with two lower hybrid current drive (LHCD) systems (one with source power of 4MW at 2.45 GHz and the other with 6MW at 4.6GHz), and 12MW ion cyclotron resonant heating (ICRH) system in continuous wave (CW). A new neutral beam injection (NBI) system with source power of 4MW is available. In addition, a new 4MW electron cyclotron resonant heating (ECRH) system with frequency of 140GHz is under construction. Based on the new H/CD systems, integrated modeling of various scenarios, including steady-state, advanced and high power are performed in this work using the 0.5-D code METIS [3], to assess the current drive capability and to define the operational space.

2. Descriptions of the modeling

METIS is an integrated transport code but with simplified assumptions of source profiles. It is usually used for preliminary scenario designs and also for designing and testing feed-back controllers. In METIS, a 1.5D current diffusion equation is solved with an approximate moment equilibrium evolution. The fast calculation (CPU time in the order of one minute) is an important feature of METIS. The global energy content W is calculated by $W = \tau \times P$, where the energy confinement time τ depends on various scaling laws and P is the loss power. For our simulations, the standard ITER scaling law is used, namely, ITER-96P(th) for L-mode and ITER-98P(y, 2) for H-mode [4]. The parameters related to H/CD systems are specified as: the parallel refraction index of LHCD $N_{//}$ = 2.1, (H)-D minority heating scheme for ICRH and NBI adjusted for heating (no current drive).

3. Modeling results

The capability of current drive with B_t = 2.3T, P_{LH} = 3MW, P_{IC} = 5MW and P_{NBI} = 2MW is assessed at first as shown in Fig. 1a. It is seen that the LH current, which is



(a) (b)

Fig.1 Assessment of current drive capability with LH current drive efficiency calculated by a Fisch-like law (a) and fixed (b).

calculated by a Fisch-like law, decreases significantly with the line-averaged density n_{e_av}, but the bootstrap current increases with n_{e_av}. A large fraction of non-inductive current is composed by LH current. Since LHCD mechanism at high density is quite

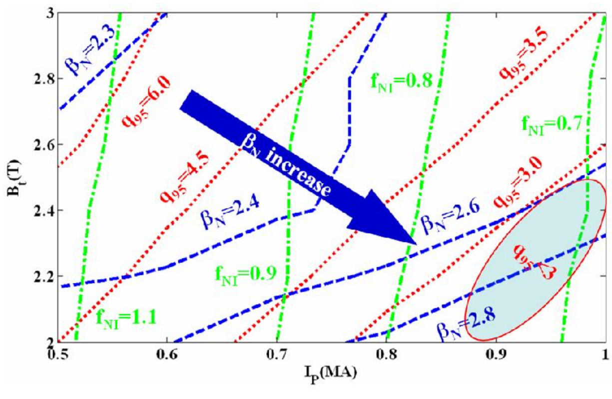


Fig. 2 Operational space with H98(y, 2) = 0.8.

complicated and many experiments have observed a decrease in current drive efficiency even steeper than the quasilinear theory value above a critical density [5-7], an experimental current drive efficiency is used for another assessment. The simulation results are shown in Fig. 1b with current drive efficiency $\eta_{LH} = 0.5 \times 10^{19}$ (A/W.m^2) according to previous LHCD experiments [8]

During the simulations, it is found that the plasma performance depends on the H factor significantly. An empirical value of 0.8 is used to explore the operational space with the global parameters as: $n_{e\_av} = 3.5 \times 10^{19}/m^3$, $P_{LH} = 3MW$, $P_{IC} = 5MW$ and $P_{NBI} = 2MW$. It can be seen from Fig. 2 that the normalized β increases with plasma current, but decreases with magnetic field. However, in the space of $\beta_N > 2.6$, the safety factor of q_{95} is less than 3.

The METIS results of steady-state, advanced and high power scenarios are illustrated in Fig. 3, Fig. 4 and Fig. 5 respectively. It is found that steady-state H-mode

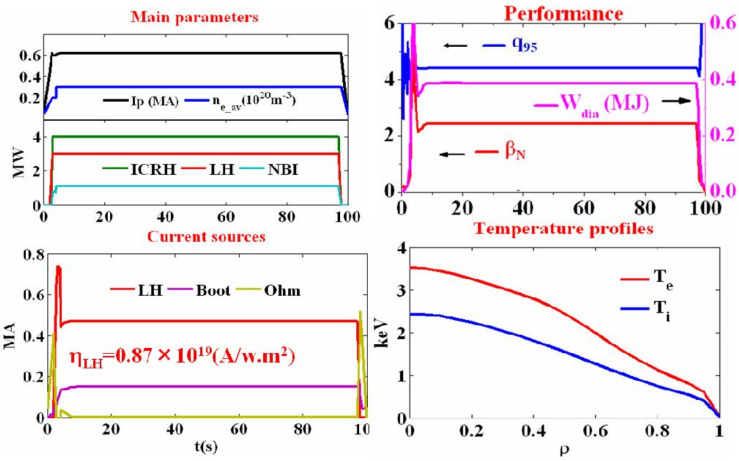


Fig. 3 Steady-state H-mode scenario.

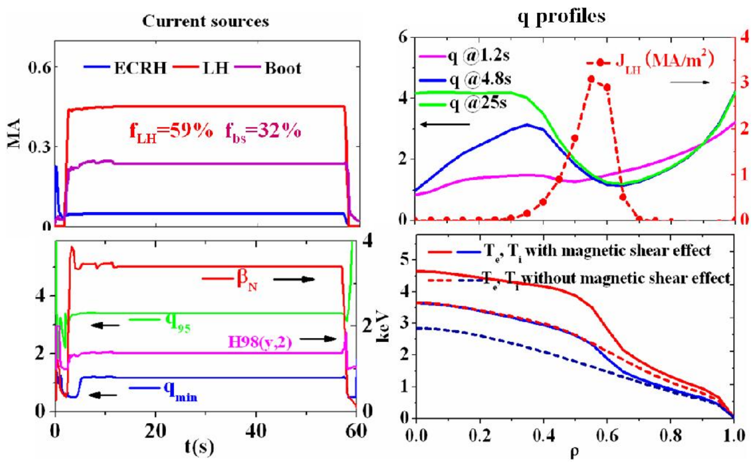


Fig. 4 Advanced scenario.

discharges with $I_p = 0.6MA$ and $n_{e\_av} = 3.0 \times 10^{19}/m^3$ can be achieved with $P_{LH} = 3MW$,

P_{IC} = 4MW and P_{NBI} = 2MW. For this scenario, LH current drive efficiency is calculated to be 0.87 × 10^{19} (A/W.m^2). The main input parameters for advanced scenario are as follows: I_p = 0.7MA, n_{e_av} = 3.5 × 10^{19}/m^3, B_t = 2.0T, P_{LH} = 3MW, P_{IC} = 4MW, P_{NBI} = 2MW and P_{EC} = 0.9MW. The magnetic shear is optimized and maintained by the off-axis LH current and an internal transport barrier (ITB) for T_e and T_i is formed. As shown in Fig. 5, T_{e0} and T_{i0} are predicted to be about 7.0keV and 4.0keV in the high power simulation.

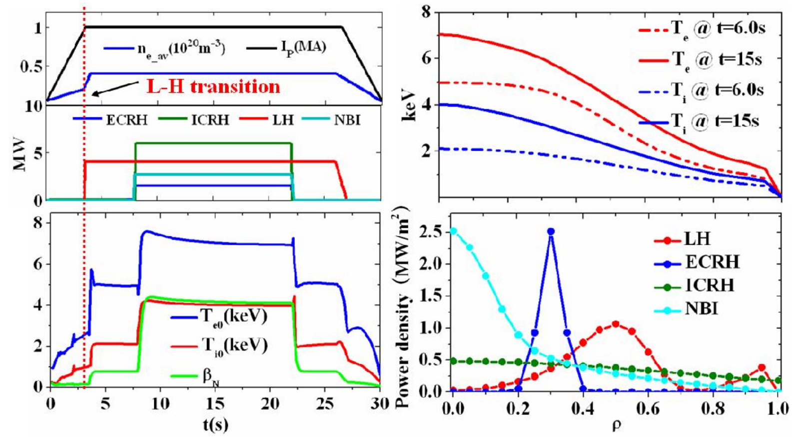


Fig.5 High power scenario.

Acknowledgments

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