Predictive simulation of H-mode performance in EAST

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1. Introduction

The high-confinement mode (H-mode), which was first discovered in ASDEX [1], is believed to be the most likely method for achieving the goals of fusion. The most important character of the H-mode is that its higher energy confinement time compared to L-mode. Accordingly, the standard and advanced ITER operation modes are designed to be based on this confinement mode [2]. EAST is a fully superconducting tokamak with a major radius of 1.86m and a minor radius of 0.45m. One of the EAST's goals is to demonstrate long pulse, steady-state H-mode plasmas. Fortunately, stationary H-mode discharges over a wide range of parameters have been achieved on EAST by either lower hybrid current drive (LHCD) alone or combination of LHCD and ion cyclotron resonance heating (ICRH) in the last campaign [3]. Now, the old 2.45GHz LHCD system has been upgraded from 2MW to 4MW, and a new 4.6GHz (6MW) LHCD system, 8MW ICRH and 4MW electron cyclotron resonance heating (ECRH) auxiliary heating systems are under development, which provide a potential to realize higher parameters, steady-state H-mode discharges.

2. **Modeling techniques**

In this work, the CRONOS suite of codes with an empirical transport model, the mixed Bohm / gyro-Bohm transport model [4], was used for the predictive simulations. It should be noted that the numerical coefficients for both of Bohm and a gyro-Bohm terms may be different in different machines. However, new values of the empirical coefficients have been set for EAST in reference [5] and are kept constant from there. The pedestal structures are calculated by the Kiauto model [6]. The LH power deposition and current density profiles are calculated by the combination of a ray tracing code C3PO [7] and a 3D linearized relativistic bounce-averaged Fokker - Planck solver LUKE [8] in a self-consistent way. The ICRH in minority heating of hydrogen in deuterium plasma is simulated by the PION code [9] and the ECRH absorption by REMA module [10].

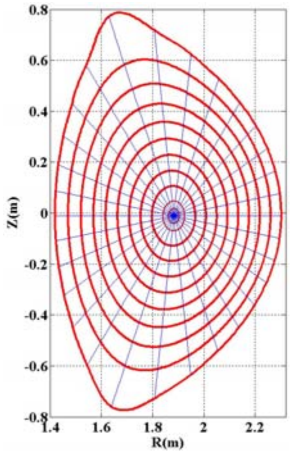


Fig. 1 Magnetic equilibrium of EAST with triangularity $\delta = 0.46$ and elongation $\kappa = 1.79$.

An up / down symmetric magnetic equilibrium configuration (triangularity δ = 0.46, elongation κ = 1.79, as shown in Fig. 1) was used, in which most of EAST H-mode discharges were reproduced. No particle transport was considered for the simulations, namely the density profiles were prescribed and fixed during the time evolution. The electron density profiles are obtained by experimental data fitting and the toroidal magnetic field B_{t0} on axis was set to 2.5T.

3. Simulation results and analysis

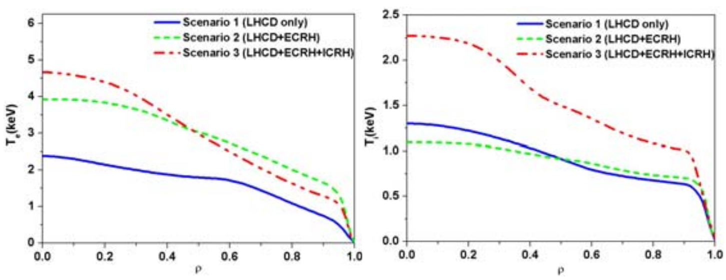
Three scenarios, namely H-mode with LHCD only, LHCD + ECRH, and LHCD + ECRH + ICRH, are considered in order to assess LH current drive capacity and to evaluate plasma performance with high power injected. In these simulations, the total LH power is equal to 5.5MW, provided by 2.5MW 2.45GHz system with $N_{//0}$ = 2.1 and 3.0MW 4.6GHz system with $N_{//0}$ = 1.8. The ECRH parameters are set as: P_{EC} = 0.9MW, f = 140 GHz, fundamental frequency X-mode from lower field side (LFS). For the 3rd scenario, the ICRH power is given by 4MW, provided by the ICRH system at 37 MHz in (H)-D minority scheme.

Synthetic results of these simulations are shown in table 1, from which we can see that the non inductive current fraction could be as high as more than 95% for all the selected scenarios. Figure 2 (a) and (b) present the electron and ion temperature profiles obtained in these simulations respectively. For LHCD only case, the central

Table 1 Parameters and synthetic results of quasi-steady-state H-mode simulations.

	I_p MA	n_{e_av} $10^{19}m^{-3}$	P_{LH} MW	P_{EC} MW	P_{IC} MW	I_{LH} kA	I_{EC} kA	I_{BS} kA	I_{NI} / I_p	T_{e0} keV	T_{i0} keV	β_p
Scenario 1 (LHCD only)	0.6	3.0	5.5	×	×	470	×	98	95%	2.4	1.3	0.72
Scenario 2 (LHCD+ ECRH)	0.8	2.0	5.5	0.9	×	530	135	115	98%	3.9	1.1	0.81
Scenario 3 (LHCD+ECRH+ ICRH)	0.7	3.0	5.5	0.9	4.0	485	85	125	99%	4.7	2.3	0.98

electron temperature (T_e) is predicted up to be 2.4keV with the pedestal temperature T_{ped} ~ 0.9keV. It should be noted that, in Fig. 2(a), the electron temperature profile for this case becomes flat with respect to other ones in the region of ρ < 0.5. This phenomenon could be explained by a large amount of non-inductive current (namely, the sum of LH current I_{LH} and bootstrap current I_{BS}) located in the plasma peripheral (see LH power deposition in Fig. 3). So, the Ohmic heating power should be very small related to the decrease in plasma current at plasma center. The second scenario is characterized by the maximum non-inductive current owning to the decrease in electron density. Moreover, the electron temperature increases by a large extent with



(a) (b)

Fig. 2 Electron (a) and ion (b) temperature profiles for the quasi-steady-state H-mode scenarios

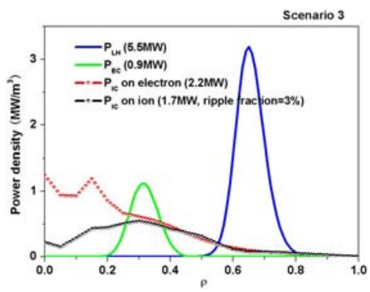


Fig. 3 Power deposition profiles for scenario 3.

respect to the first case. Differently from the previous two cases, the ion temperature for scenario 3 is increased significantly, which could be explained by the fact that 1.7MW ICRH power is absorbed by ions as shown in Fig 3.

4. Discussion and summary

CRONOS simulations with the mixed Bohm / gyro-Bohm heat transport model and the Kiauto pedestal model are performed to predict the performance of steady-state H-mode discharges in EAST. It is found that plasmas with more than 95% inductive current fraction could be obtained. The central T_e and T_i are predicted to be about 4.7keV and 2.3keV respectively with 10.4MW auxiliary heating power, provided by 5.5MW LH power, 0.9MW ECRH power and 4.0MW ICRH power. Just as expected, the simulations presented in this paper give a prospective prediction of EAST plasmas and can also provide some useful references for proposal design in future experiments. However, there are some uncertainties in the simulations contributed by the lack of precise edge values of temperature and the pedestal model, which is not validated for EAST. So the comparison between predictions and experiments should be done in future work to validate the transport models.

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