§14. Core-SOL-Divertor Model and Application to Operation Space of EAST

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The transport models applied to Core-SOL-Divertor (C-S-D) model are a 0D core plasma model based on ITER physics guidelines and a usual two-point model for SOL-divertor region. The key issue of this C-S-D model is how to combine the two-point model with the 0D core plasma model. Usually, the upstream SOL density is a given parameter in the two-point model. In the C-S-D model, the particle balance for SOL-divertor region including the neutral transport is solved to evaluate the upstream SOL density n_s. We assume that all neutral particles are originated at the divertor plate. Its generation rate is supposed to be proportional to the particle flux to the divertor plate. Consequently, the following definition of the total neutral source rate N_n including gas puff N_{puff} at the edge region is applied;

$$N_n = n_d M_d C_s 2\pi R h \Delta_n \sin(\psi) + N_{puff}\,, \quad (1)$$

where n_d, M_d, C_s, R and ψ are density, mach number and sound velocity, major radius and the angle of the magnetic field at the divertor plate, respectively. The density decay length Δ_n is assumed to be twice of temperature decay length of SOL. By using this simple neutral model and the particle flux across the separatrix Γ_{core} from the 0D core plasma calculation, the particle balance equation for the SOL-divertor region becomes

$$\Gamma_{core} S_{core} + N_n^{sol} + N_n^{div} = n_d M_d C_s \sin(\psi) S_{div}\,, \quad (2)$$

where N_n^{sol} (N_n^{div}) is the total number of ionized particles in the SOL (divertor) region, and S_{core} and S_{div} are the areas for the core and divertor region normal to the particle flux. The ionized particle numbers are defined by the ionization fraction in the SOL and the divertor region (f_{ion}^{sol} and f_{ion}^{div}). Their definitions are $N_n^{sol} = f_{ion}^{sol}(1 - f_{ion}^{div})N_n$ and $N_n^{div} = f_{ion}^{div} N_n$. The ionization fraction in the divertor region is modeled by $f_{ion}^{div} = 1 - \exp\left(-(L_d \sin(\psi))/\lambda_{ion}^{div}\right)$, where L_d and λ_{ion}^{div} are the length of the divertor region and the mean free path of the neutral particle, respectively. The ionization fraction in the SOL region is defined by $f_{ion}^{sol} = A_{sol}/(A_{core} + A_{sol} + A_{pump})$, where A_j denotes the effective area for core plasma, SOL and pumping effect, respectively.

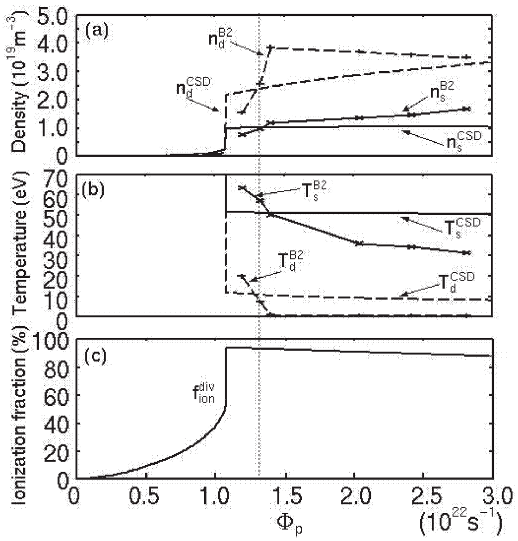

Fig.1 SOL-divertor parameters v.s. Φp (a) density, (b) temperature by the C-S-D model and the B2EIRENE, and (c) is the ionization fraction in the divertor region by C-S-D model

To check the validity of this C-S-D model, comparison with the edge transport code (B2-EIRENE) is carried out on JT-60U plasma configuration[1], and it is shown that the result by the C-S-D model is reasonable (Fig.1), however, other validation for the neutral transport should be carried out because of the simple neutral model.

By using this C-S-D model, we explore the possible operation space of EAST in the space of the total particle flux Φ_p and the total heat flux Q_{in} across the separatrix. The operational space is painted in Figure 2[1], and each boundary is the operation condition as for (1) max. heat load to the divertor $q_{div}<3.5$MW/m^2, (2)LH transition condition $Q_{in}>P_{thr,}$ (3) available LHCD power $P_{LHCD}<3.5$MW, and (4) power balance condition $P_{LHCD}<Q_{in}$.

Figure 2 indicates that the allowable heat flux to the divertor plate is a key parameter to extend the possible operation space. The upper boundary of Q_{in} is limited to 3.0~3.5MW by $q_{div}<3.5$MW/m^2. The boundary of $q_{div}<3.5$MW/m^2 for $Q_{in}<3.0$MW region implies the low recycling state. The upper boundary of the particle flux Φ_p is dominated by the power balance requirement for the low Q_{in} region, while it is limited by the available LHCD power for higher Q_{in}. In other words, the available power for the LHCD tends to be a key parameter to extend the operation density of the core plasma in this high Q_{in} regime. In this exploration, no gas puffing in the divertor region is assumed. The sudden changes of the curve for the required LHCD power and the power balance around Q_{in}~1.7MW are caused by the LH transition.

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Reference

1) Hiwatari, R. et al.: J. Nucl. Mater. **337-339,** (2005) 386-390

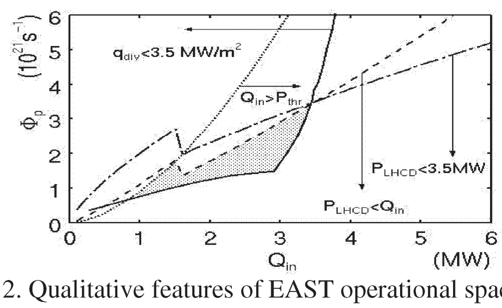

Fig. 2. Qualitative features of EAST operational space.