§50. Divertor Transport Study of LHD

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The divertor transport characteristics of LHD has been analyzed using the 3D edge transport codes, EMC3-EIRENE [1][2], and a 1D model. In LHD, the experiment shows that the plasma temperature drop from the LCFS to the divertor is more than an order of magnitude [3], and the SOL collisionality,

$$\nu^{*}_{SOL} = L_C / \lambda_{ee}, \qquad (1)$$

is estimated at ~ 100, where L_C and λ_{ee} are the connection length of magnetic field lines and mean free path of electron self collision, respectively. Nevertheless, there is no evidence of high recycling regime, i.e. $n_d \propto n_u^3, T_d \propto n_u^{-2}$, here the subscript d and u denote downstream (divertor) and upstream values. But the dependence is rather modest, as shown in Fig.1 where electron temperature and density at the divertor and the LCFS are plotted as a function of line averaged density, together with the results of the 3D modelling. One sees that the code results are in a reasonable agreement with the experimental data.

In order to explain the modest change of T_d and n_d against the line averaged density, we introduce a cross field transport effect into the standard two point model [4]. The ratio of perpendicular and parallel transport scale is defined as,

$$\beta = \Delta x / L_C, \qquad (2)$$

where Δx is a thickness of ergodic layer, several centimeters. In the helical divertor configuration, $\beta \sim 10^{-4}$. In the ergodic layer, the energy transport equation could be written as,

$$\beta \frac{d}{dx}\left(-\kappa_0 T^{5/2} \beta \frac{dT}{dx}\right) + \frac{d}{dx}\left(-\chi_\perp n \frac{dT}{dx}\right) = 0, \qquad (3)$$

where x is a radial coordinate and it is assumed that $T_e = T_i = T$. The first term on the left hand side represents a projection of parallel transport onto x. The momentum equation is given by,

$$\beta \frac{d}{dx}\left(mnV_{//}^2 + p\right) = -D_\perp \frac{mn\Delta V_{//}}{\Delta^2}, \qquad (4)$$

where the right hand side is accounting for a momentum loss in perpendicular direction. Especially, in the ergodic layer, this term becomes important because of friction between counter flows which are induced by the ergodic field lines. $\Delta V_{//}$ and Δ are thus the relative velocity of two neighboring flows and the characteristic distance between the flow channels. The boundary condition at the down stream is given by Bohm condition,

$$q_{//} = \gamma n_d T_d c_{sd}, \quad V_{//} = c_{sd} \qquad (5)$$

with c_{sd} being a sound speed at the downstream. The equations (3)-(5) are solved to give the solutions,

$$T_u^{7/2} = T_d^{7/2} + \frac{7q_{//}L_C}{2\kappa_0} - \frac{7\chi_\perp n_u}{2\beta^2\kappa_0}(T_u - T_d), \qquad (6)$$

$$p_u = 2p_d(1 + f_m), \qquad (7)$$

where fm is a momentum loss factor,

$$f_m = \frac{D_\perp}{\beta c_{sd}}\left(\frac{1}{c_{sd} n_d}\int \frac{n\Delta V_{//}}{\Delta^2} dx\right). \qquad (8)$$

When $\beta \to \infty$, the third term on the right hand side of eq. (6) and f_m vanish, and the model becomes the standard two-ponit model for tokamaks. The results of eq.(6)-(8) are plotted in Fig.2 for different f_m's, together with the 3D results. It is found that the solution becomes closer to those of EMC3-EIRENE, indicating that the cross-field momentum loss as well as low β affect the transport characteristics in the ergodic layer.

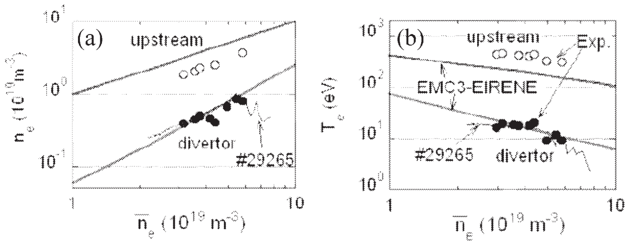

Fig.1 Plasma parameter dependence on the line averaged density, together with the 3D code results. (a) density, (b) electron temperature.

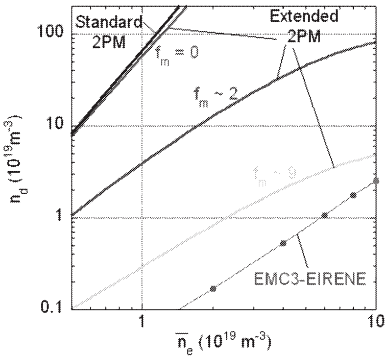

Fig. 2 Downstream density (n_d) as a function of the line averaged density for a comparison of eq.(6)-(8) (extended tow-point model) with the 3D modelling.

References

1) Feng, Y. et al., Cont. Plasma Phys. **44** (2004) 57.
2) Reiter, D. et al., Fusion Science and Technology **47** (2005) 172.
3) Masuzaki, S. et al., Nucl. Fusion **42** (2002) 750.
4) Feng, Y. et al., 10th PET 2005, to be published in Nucl. Fusion.