§61. Optimization of a Closed Divertor Configuration for Effective Particle Control in LHD

Shoji, M.

The ambient neutral pressure in the LHD divertor region has been estimated to be in the order of about 1mPa which is measured with a fast ion gauge. Because of the present opened divertor configuration, the neutral pressure is not high enough for effective particle control. Enhancement of neutral particle density in the divertor region by more than one order of magnitude is required by optimizing a closed divertor configuration.

The behavior of neutral particles in the plasma periphery has been investigated by a three dimensional neutral particle transport simulation code (EIRENE) [1]. The measurements of the vertical profiles of H_α intensity and polarization resolved H_α spectra in various magnetic configurations quite agree with the calculations by the simulation [2], which indicates that the calculations by the simulation are reasonable and reliable for designing the closed divertor configuration [3].

The closed divertor configuration was optimized in order to enhance the density of neutral hydrogen molecules in the inboard side of the torus, which is a practical way for effective particle control for R_{ax}=3.60m. Figure 1 shows a three dimensional grid model for the closed divertor configuration for the neutral particle transport simulation code. EMC3-EIRENE code is widely used for the investigation of the plasma transport in the ergodic layer and the plasma edge in helical and tokamak devices. The sophisticated analysis by the fully 3-d plasma fluid code coupled with the neutral particle transport code is too time-consuming. Furthermore, the code does not include the divertor legs [4]. To overcome these restrictions, the calculation domain was extended so as to include the divertor legs with an assumption that the plasma parameter profiles inside of the ergodic layer are fixed during the iteration processes between the two codes. The plasma parameter profiles along the divertor legs are calculated by a one-dimensional plasma fluid analysis. Following three differential equations are solved by the Runge-Kutta method from the upstream position of the divertor legs,

$$\frac{d(nv_{//})}{ds} = S_p \quad (1)$$

$$\frac{d}{ds}(2nT + mnv_{//}^2) = -mv_{//} < \sigma v >_{cx} nn_0 \quad (2)$$

$$\frac{d}{ds}(5nTv_{//} - \kappa_{//}^0 T^{2.5} \frac{dT}{ds}) = Q_{loss} \quad (3)$$

where S_p, $<\sigma v>_{cx}$, n_0, Q_{loss} are the particle source, the rate coefficient of charge exchange, neutral density and energy loss via ionization, respectively. The following boundary conditions are adopted in the above differential equations:

1. The plasma flow velocity at the downstream of the magnetic field lines (on the divertor plates) is fixed to be a sound speed c_s for satisfying the Bohm criterion,
2. The particle/heat flux density at the upstream of the divertor legs are fixed to be the calculations by the EMC3-EIRENE (P_{input}=8MW, n_e^{LCFS}~3×10^{19}cm^{-3}, S_{total}=3.6×10^5A).

The profiles of three parameters (n, T, v) are derived by choosing an appropriate value of the plasma flow velocity at the upstream of the divertor leg so as to satisfy the first criterion. The plasma density and temperature at the upstream are adjusted for satisfying the second boundary condition during the iteration processes.

Figure 2 gives the calculations of the density profile of neutral hydrogen molecules in the inboard side of the torus in the opened and the optimized closed divertor configurations, showing that enhancement of the density in the inboard side by more than one order of magnitude (up to about 9.0×10^{12}cm^{-3} (~40mPa)) is expected.

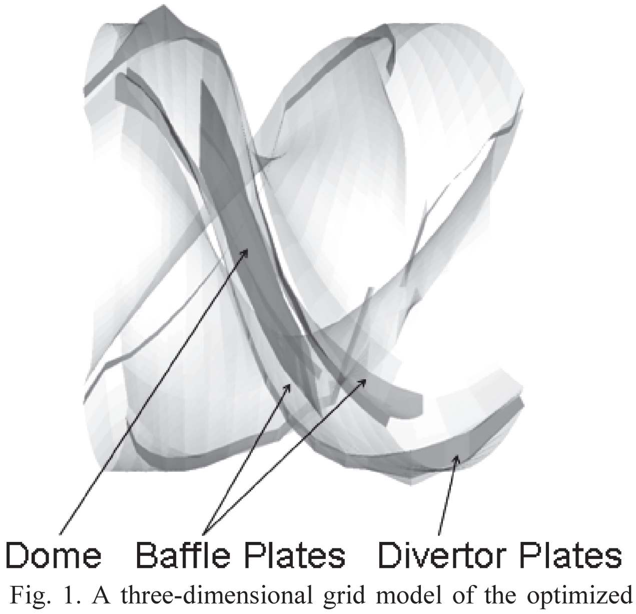

Fig. 1. A three-dimensional grid model of the optimized closed divertor configuration for the neutral particle transport simulation code (R_{ax}=3.60m).

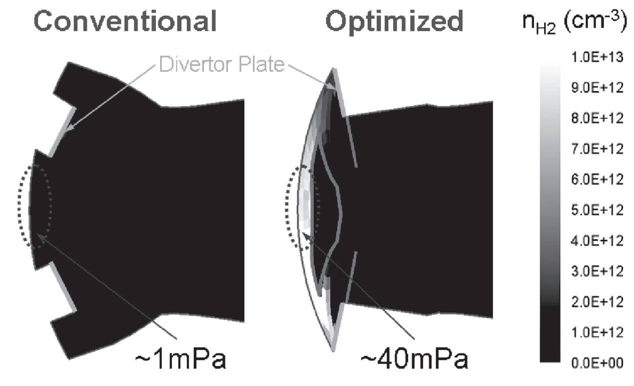

Fig. 2. Calculations of the density profile of neutral hydrogen molecules in the opened (left) and the optimized closed divertor configurations (right).

Reference

1) Reiter, D. et al.: J. Nucl. Mater. **196-198** (1992) 1059.
2) Iwamae, A. et al.: Phys. Plasmas **12** (2005) 042501.
3) Shoji, M. et al.: J. Nucl. Mater (to be published).
4) Kobayashi, M. et al., Contrib. Plasma Phys **46** (2006) 527.