§22. Simulation Analysis of Effects of the Closed Divertor on Peripheral Plasma and Neutral Transport

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The peripheral plasma of the LHD has been modeled by EMC3-EIRENE code[1),2)]. Extension of the simulation[3)] to the closed divertor configuration realized analysis of its effect on neutral gas pressure, which has been investigated in an experiment study[4)]. The plasma mesh system of EMC3 covers the peripheral plasma which has long connection length. The core region is excluded from the simulation and modeled as boundary conditions at the last closed flux surface (LCFS). The magnetic axis is located at R_{ax}=3.6m.

Cryopumps have been installed under the dome structure and evaluation of their efficiency started in the 2013 experiment campaign. In order to know the effect of the gas pumping, we carried out simulations with pumps. We introduced pumping panels on the backside of the dome plates. We ignore the effect of wall-pumping to focus on the cryopumps. Particle source and sink must be balanced in the simulation box, and therefore we modeled two types of sources: gas-puffing and core fueling. In the actual device, both of them exist in a discharge, but we employ the two extreme conditions of 100% gas-puffing and 100% core fueling. The gas puffing is implemented as an increase of recycling flux from the divertor plates. Approximately 20% of neutral gas input is pumped out in both cases. Simulation parameters are as follows: input power, P=8MW, perpendicular particle and heat transport coefficients, D=1m^2/s, $\chi_e=\chi_i$=3m^2/s, electron density at LCFS, $n_e=2\times10^{19}$/m^3.

Neutral gas pressure distribution in the closed configuration is given in Fig.1: (a) no pumping, (b) pumping and gas-puffing and (c) pumping and core fueling. The most obvious difference between them is the significant reduction of the pressure in the case of core fueling (c). That change is linked to the boundary condition of electron density. The core fueling increases the LCFS density directly if the perpendicular transport coefficient D is constant. The density is, however, fixed as a boundary condition and therefore ionization source in the ergodic/divertor regions must be reduced. The difference between no pumping and pumping with gas-puffing is not clear except under the dome.

Figures 2(a) and (b) show distribution of electron density and temperature along z=0 line for three cases; without pump (red solid line), with pump and gas-puffing (green dashed line), and with pump and core fueling (blue dotted line). The gas-puffing condition causes almost the same plasma distribution as without the pump. That is a reasonable result because neutral particles pumped out are injected again and therefore the recycling flux does not change. On the other hand, the core fueling condition causes significantly lower density and higher temperature by a factor of two in the outer region, R>4.6m because of increase of the plasma source in the core and decrease of recycling flux.

Figures 2(c) and (d) show distribution of H_2 molecules and H atoms. The difference between conditions without pump and with gas-puffing is not significant. Molecule and atom densities increase a little in this case, but how the density increases depends on measurement position. In fact, we observe an opposite result at a different position. This subtle difference arises from the different distribution of the neutral source. The change caused by core fueling is clear and not dependent on the measurement position. Molecule density decreases due to less recycling. Since the electron density becomes low, molecules can penetrate deeper into the ergodic plasma, and that causes increase of molecule density in the inner ergodic region, R<4.8m. The atom density and the total ionization source decrease.

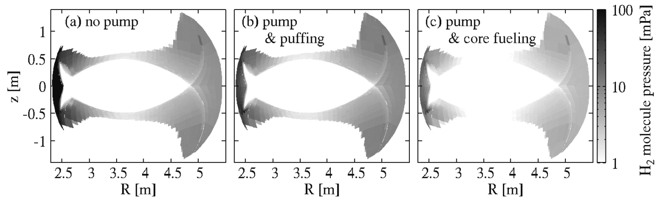

Fig. 1: Distribution of H_2 molecule pressure of the closed divertor configuration.

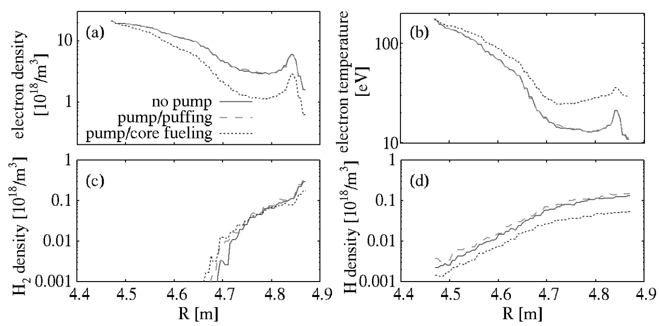

Fig. 2: Distributions of (a) electrons density, (b) temperature, (c) H_2 molecule density, and (d) H atom density along z=0 line on the horizontally elongated plane.

1) Y. Feng et al., Contrib. Plasma Phys. **44** (2004) 57.
2) D. Reiter et al., Nucl. Fusion **47** (2005) 172.
3) G. Kawamura, et al., Contrib. Plasma Phys. **54** (2014) 437.
4) T. Morisaki, et al., Nucl. Fusion **53** (2013) 063014.