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Particle simulation of plasma-neutral interaction in divertor region

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The reduction of the power and particle load on divertor plates is one of the critical issues for future fusion reactors. The stable formation of the detached divertor plasma is considered an effective solution for this problem.

However, the physical mechanism in the detached divertor plasma, especially in the non-equilibrium state under the Edge Localized Modes (ELMs) is not fully understood. Therefore, understanding of the detailed plasma-neutral interactions in the divertor region is important to form the detached divertor plasma.

In the previous study[1], Particle-in-Cell model (PIC)with atomic-molecular processes has been developed and plasma-neutral interactions at low-density was investigated. The characteristics of the detached divertor, where the hydrogen ion density decreased steeply toward the divertor target by volume recombination, was reproduced.

In this study, the analysis is conducted over a wider temperature and density range with an increase in the number of reaction processes, such as molecular-activated recombination.

As, in the previous study, we used a particle simulation model[1], which is a 1D system with divertor plates at both ends, a plasma source in the center, and a neutral particle layer in front of the divertor plates. Since the analysis is aimed at the divertor region, plasma-neutral interactions are considered only in the divertor region. In the neutral particle layer, the neutral density is assumed to be uniform, and the plasma-neutral interactions, such as ionization, recombination, dissociation, and excitation, are taken into account.

In the preliminary analysis, pair of hydrogen ion and electron with their temperature of 100 eV was injected into the source region with the injection rate of $7.16 \times 10^{24}\ \mathrm{m^{-3} \cdot s^{-1}}$.

Figure 1 shows the plasma density profile. The horizontal axis is the normalized position: 80 ~ 120 is the plasma source region, 0 ~ 30 and 170 ~ 200 is the neutral particles layer.

The ionization reaction of the neutral particles occurred rapidly as the high-energy plasma entered the neutral layer, and the electron density near the boundary of the neutral particles layer was about five times greater than the density at the center region. Thereafter, the plasma density decreased toward the divertor target due to the volume recombination, and the plasma density in the neutral layer is about 10% of that in the source region. This result suggests that the detached divertor state is reproduced in the neutral particles layer.

The simulation taking into account the molecular-activated recombination contribution will be discussed in the presentation.

References
[1] Y.Tsubotani, et al., 17th International Workshop on Plasma Edge Theory in Fusion Devices, California, USA, 2019.
[2]K.Hoshino, et al., 39th annual meeting on The Japan Society of Plasma Science and Nuclear Fusion Research, Toyama, Japan, 2022.

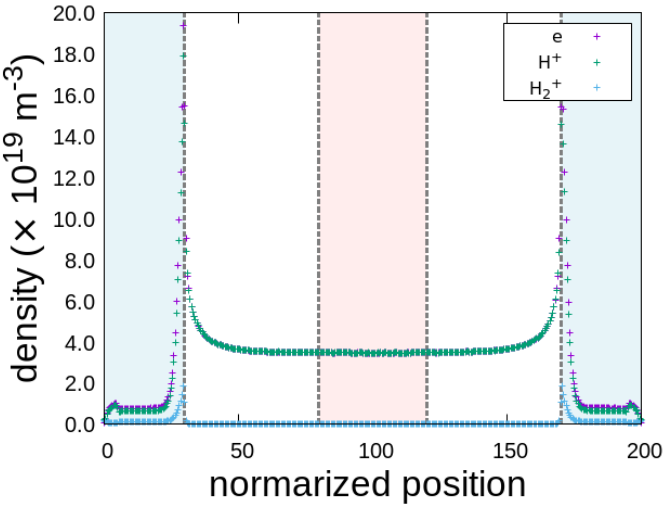

Fig. 1 Density profile of plasma. The red and blue regions are the source and the neutral particle regions, respectively. Both ends of the system correspond to the divertor target.