§7. Monte Carlo Analysis of NBI Particles in LHD

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In helical devices, it is one of the important subjects to analyze the confinement and the behavior of the high-energy particles produced by NBI heating to realize the helical reactor. A fast-ion charge exchange spectroscopy (FICXS)[1] diagnostic has been applied to measure the distribution function of the particles produced by NB. In the previous studies, the distribution function obtained in FICXS measurement has been compared with the distribution function obtained by Monte Carlo codes based on the magnetic coordinate system, such as the Boozer coordinates. However, the number of the lost particles is over-estimated in such codes, since re-entering particles, which repeatedly go out and enter into the last closed magnetic surface, are regarded as the lost particles. We have developed a Monte Carlo code MORH[2,3], by which the distribution function after the relaxation of the high-energy particles are obtained. In the MORH code, the effect of re-entering particles on the distribution function can be taken into account, since the particle loss boundary is set at the vacuum vessel wall. Additionally, the effect of the charge exchange loss is also included in the code. The purpose of the present study is the evaluation of the distribution functions obtained by FICXS by use of the MORH code.

We improve MORH code by changing the guiding-center equations in vacuum to Liitlejohn's guiding-center equations[4], in which the plasma current effect on the particle orbit is included. The improved MORH code is applied to the low *B* and high β plasma in LHD and the effect of the plasma current on the high energy particles produced by the tangential NBI is studied. It is noted that the net plasma current is zero and that this sustains the equilibrium. The density distribution of the co-injected particles is shown in Fig. 1. As shown in Fig. 1, the density in the core region ($\rho < 0.5$) decreases and that in the peripheral region ($\rho > 0.5$) increases. This can be explained by the increase of the deviation of the co-injected particle orbit from the magnetic surface due to the plasma current. However, it is found that the effective heating power due to the co-injected particles is independent of the plasma current effect. On the other hand, it can be seen from Fig. 2 that the density of the counter-injected particles increases in the whole region ($\rho < 1$). This can be explained by the reduction of the deviation of the counter-injected particle orbit from the magnetic surface by the plasma current effect. As a result, the effective heating power due to the counted-injected particles is increased by the plasma current effect.

The plasma current effect on the re-entering particles is also investigated. It should be noted that the re-entering particles is regarded as the lost particles in the studies based on the magnetic coordinate system. It is found that both the number of re-entering particles and the effective heating power increase in the case of co-injected particles. In contrast, in the case of the counter-injected particles, both the number of re-entering particles and the effective heating power decrease. These results suggest that the re-entering particles the low *B* and high β plasma in LHD play an important role in the NBI heating.

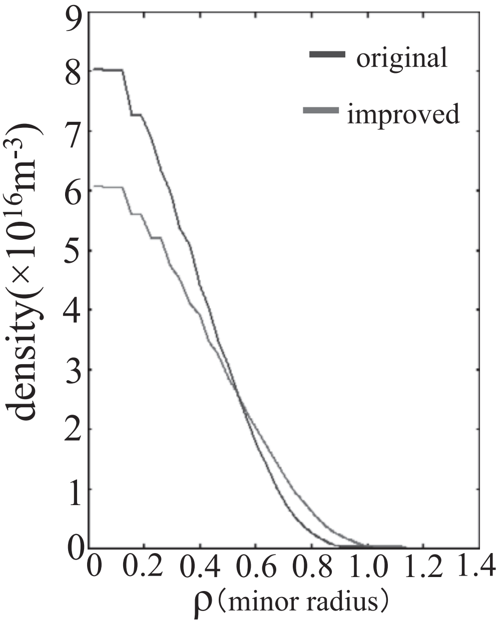

Fig. 1. Density distribution of the co-injected particles.

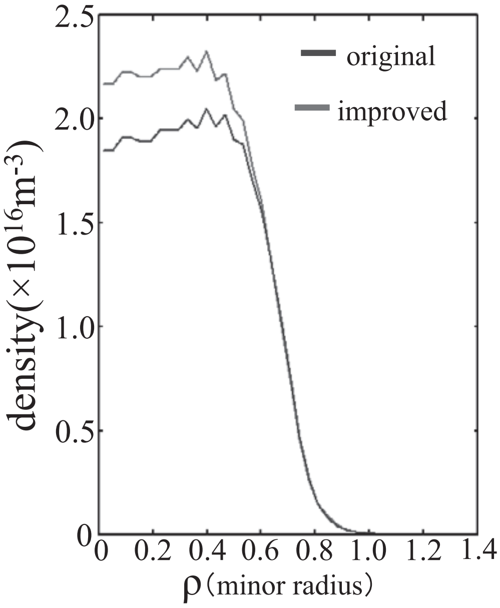

Fig. 2. Density distribution of the counter-injected particles.

1) Osakabe, M. et al.: Fusion Sci. Tech. **58** (2009) 131.
2) Seki, R. et al.: J. Plasma Fusion Res. **5** (2010) 014.
3) Seki, R. et al.: J. Plasma Fusion Res. **5** (2010) 027.
4) Littlejohn, R. G.: J. Plasma Phys. **29** (1983) 111.