§9. Plasma Current Effect on Distribution Function of High Energy Ion in LHD

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It is one of the characteristics of helical devices, such as the Large Helical Device (LHD), that the magnetic field required for the plasma confinement can be produced without the net plasma current. However, it sometimes happens that the net plasma current flows when the experimental conditions are modified. Although the effects of the plasma current on the MHD equilibrium and/or stability have been studied, the effects on the high energy particles produced by Neutral Beam Injection (NBI) or Ion Cyclotron Range of Frequency (ICRF) heating. The purpose of the present study is to analyze the effect of the plasma current on the distribution function of the high energy particles produced by NBI by use of MORH code1,-3).

MORH is one of the Monte Carlo codes to calculate the steady state distribution function by tracing the high energy particle orbit including Coulomb collisions and charge exchange loss. In MORH code, the re-entering particles, which repeatedly go out and into the last closed magnetic surface (LCMS), can be treated appropriately since the real coordinate system is adopted. We improve MORH code by changing the guiding-center equations in vacuum to Littlejohn's guiding-center equations4), in which the plasma current effect on the particle orbit is included.

The improved MORH code is applied to the low magnetic field and high beta plasma in LHD and the effect of the plasma current on the high energy re-entering particles produced by the tangential NBI is studied. It is noted that the net plasma current is zero in the equilibrium used in this study.

Figure 1 shows the distribution of the re-entering particles for the normalized minor radius ρ. As shown in Fig. 1, the plasma current increases the number of the re-entering particles produced by the co-NB. On the other hand, the number of the re-entering particles produced by ctr-NB slightly decreases. This difference can be explained by the particle orbit characteristics in the LHD. About 70% starting points calculated by the HFREYA code are located in the region $R > R_{ax}$. By the plasma current effect, the co-NB particles traced from $R > R_{ax}$ form the larger drift surface than the magnetic surface on which the starting point is located. Since such particles can go out the LCMS the number of re-entering particles produced by co-NB increase. On the contrast, the plasma current shrinks the drift surface of the ctr-NB traced from $R > R_{ax}$. Thus, the number of the particles going out the LCMS becomes small. Consequently, the number of the re-entering particles produced by ctr-NB has reduced.

We also study the change of the effective heating power by the re-entering particles due to the plasma current. Table 1 shows the effective heating power by the re-entering particles. It can clearly seen that the effective heating power by the re-entering particles increase (reduces) in the case of co-NB (ctr-NB). This is due to the above mentioned change in the number of reentering particles.

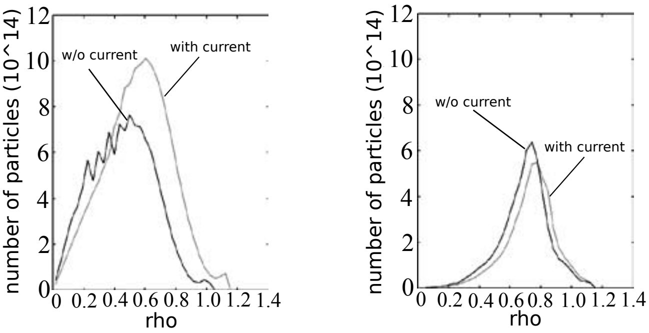

Fig. 1. Distribution of the re-entering particles for the normalized minor radius.

Table 1. Effective heating power by the re-entering particles.

	Effective heating power by the re-entering particles (MW)	
	Co-NB	Ctr-NB
with current	0.5529	0.01736
w/o current	0.4357	0.01793

We investigate the plasma current effect on the re-entering particles produced by NBI in the LHD. It is found that the plasma current increases (decreases) the number of the re-entering particles produced by the co-NB (ctr-NB) and that such changes in the number of re-entering particles affect the heating power.

1) Seki, R. et al.: J. Plasma Fusion Res. **5** (2010) 014.
2) Seki, R. et al.: J. Plasma Fusion Res. **5** (2010) 027.
3) Seki, R. et al.: Nucl. Fusion **53** (2013) 063016.
4) Littlejohn, R. G.: Plasma Phys. **29** (1983) 111.