§33. Particle Orbit Analysis in High Beta Plasma of LHD

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High beta plasmas more than 4 % have been obtained in the low magnetic field ($\simeq 0.5$ T) discharges of LHD[1]. Although the particle orbit analyses in such finite beta plasmas of LHD have been done, they are restricted inside the last closed flux surface (LCFS)[2]. However, it is pointed out that the peripheral flux surfaces in the helical systems like LHD are destroyed with rising the plasma beta[3]. Since the particle drift in the low magnetic field, in which the high beta LHD experiments have been done, becomes large, it can be predicted that the particle started from the core go out of the LCFS. In such cases, the re-entering particles[4] would play an important role. Thus, the particle orbit analysis including the peripheral region is required.

In this study, the particles in LHD are traced with the use of the real coordinate system. The particle behavior in the high/low magnetic field and/or the high/low beta plasma is investigated.

Particles are traced in the four magnetic field configurations (case 1: $B_{\rm ax} = 3$ T, $\beta = 0$ %, case 2: $B_{\rm ax} = 3$ T, $\beta = 3.2$ %, case 3: $B_{\rm ax} = 0.5$ T, $\beta = 0$ % and case 4: $B_{\rm ax} = 0.5$ T, $\beta = 3.2$ %). In these magnetic field configurations, the vacuum magnetic axes are located at $R_{\rm ax} = 3.6$m. The 100 keV protons are traced for a period of 30 ms by numerically solving the guiding-center equation. The particle loss boundary is set at the vacuum vessel wall. The starting points of particles are located at R axis on the horizontally elongated poloidal plane. Moreover, the initial pitch angels are varied from 0 to π with a step size of $\pi/20$.

We classify the particle orbit into four groups: passing particles, banana particles, chaotic orbit particles and prompt loss particles. By comparison in four cases, it is found that the particle orbit characteristics in the high beta plasma are almost the same as those in the vacuum magnetic field except the particles started from the inner side. In the low magnetic field cases, the number of prompt loss particles becomes large due to the large particle drift.

The summations of the pass length of the re-entering particles in the peripheral region are calculated. The pass length of the re-entering particles is up to 10 km. In addition, path length of the particles started from $R \simeq 4$ m is ~ 1 km. This indicates that even the particles started from the core also go out of and re-enter into the LCFS.

Moreover, the effect of the charge exchange on the re-entering particle orbit is studied. It is assumed that the neutrals exist only in the peripheral region of LHD on the constant density. The loss particle ratio is shown in Fig. 1. In all cases, the particle loss due to the charge exchange is small except for the particles started from the inner side of the torus. The numbers of loss particles due to the charge exchange in the high beta cases (2 and 4) are larger than those in the low beta cases. In cases 1 and 2, particles started from the LCFS neighborhood are lost due to the charge exchange. By contrast, in cases 3 and 4, the loss due to the charge exchange is incident for particles started from the core.

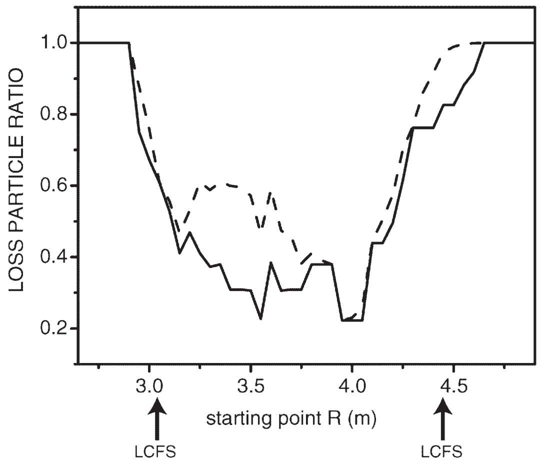

Figure 1: Loss particle ratio of particles in case 4. Values at each starting points are averaged over the pitch angle.

We analyze the particle orbit in the high/low beta plasma and/or the high/low magnetic field in LHD. Following information is obtained. The particle orbit characteristics in the high beta plasma are almost the same as those in the vacuum magnetic field. If the magnetic field strength is reduced, many particles with large $v_\perp$ become the prompt loss particles. Even in the high beta cases, particles can repeatedly re-enter many times. The particle loss due to the charge exchange is small except for the particles started from the inner side of the torus.

Reference

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