§2. Theoretical Considerations of Doublet-Like Configuration in LHD

Suzuki, Y., Yamada, H., Nakajima, N., Watanabe, K.Y., Hayashi, T.,
Nakamura, Y. (Kyoto University)

In recent experiments of JT-60U and LHD, MHD equilibrium, which has the separatrix and stochastic field line regions inside the plasma, has been observed as the tokamak current-hole equilibrium[1] and doublet-like equilibrium of LHD[2]. Since in those MHD equilibria not only there are cases in which high performance is obtained but also the concept of MHD equilibrium is beyond the conventional MHD theory, the theoretical consideration of those MHD equilibria is urgent and critical issue. In tokamaks without vacuum flux surfaces, equilibrium flows may play an essential role to create and sustain the separatrix structure. On the other hand, in helical systems, MHD equilibrium with the separatrix structure may be created and sustained not by plasma flows but by the external coil. Recently, doublet-like configurations were produced by the control of the external quadrupole field. The doublet-like equilibrium has two split axes and an eight-figured separatrix. Thus, in order to understand the basic physics of MHD equilibrium with the separatrix structure, as a first step, the doublet-like equilibrium of LHD is considered theoretically using the HINT code[3].

Figure 1 shows MHD equilibria of a vertically elongated doublet-like configuration (BQ=-100%) obtained from HINT Vacuum flux surfaces are shown for a comparison. For finite-β equilibrium, though the horizontal shift of two axes toward the outside of the torus is very small, the vertical shift from the equatorial plane is very large and the X-point of the separatrix moves slightly outward. The volume inside the eight-figured separatrix is increased with β, but closed flux surfaces still exist on the outside of the separatrix up to β_0~6%. Poincaré plots of the magnetic field lines are ergodized by finite-β effects.

The particle orbit on the separatrix is studied by solving the guiding-centre drift equation on the rectangular grid. Figure 2 shows Poincaré plots of drift orbits and magnetic field lines of a vertically elongated configuration for the vacuum and a finite-β equilibrium (β_0~2%). The particle indicated by red symbols is the passing particle and the deviation of the drift from the flux surface is small. Green symbols indicate the passing particle but it moves with the figure-eight structure. Though the particle is started from the upper region in the inside of the figure-eight separatrix, the particle moves along the figure-eight separatrix. Since there is a singular region on the separatrix, the orbit behaves stochastically and the particle alternately encloses both O-points. The particle indicated by purple symbols is initially trapped in the region above the X-point. Since the poloidal field is very small near the separatrix, the curvature drift moves in the Z direction. Thus, the particle comes and goes in both regions.

References

[1] Fujita T., *et al*., Phys. Rev. Lett. **87** (2001) 245001-1
[2] Yamada H., *et al*., *13th Int. Toki Conference*, (Toki,2003) I-10
[3] Suzuki Y., *et al*., Nucl. Fusion **46** (2006) 123

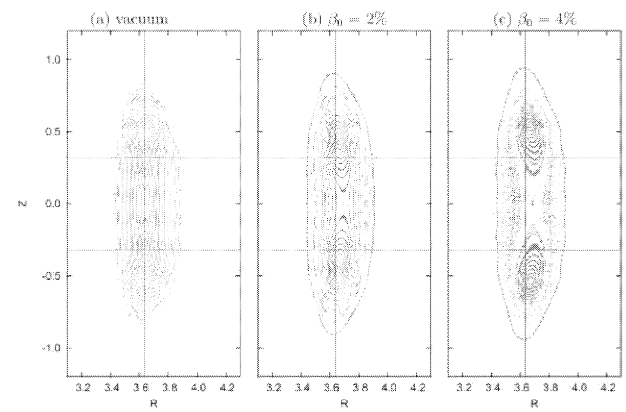

Fig. 1 Poincaré plots of magnetic field lines of a vertical elongated configuration in LHD for (a) the vacuum field, (b) β_0~2% and (c) β_0~4%.

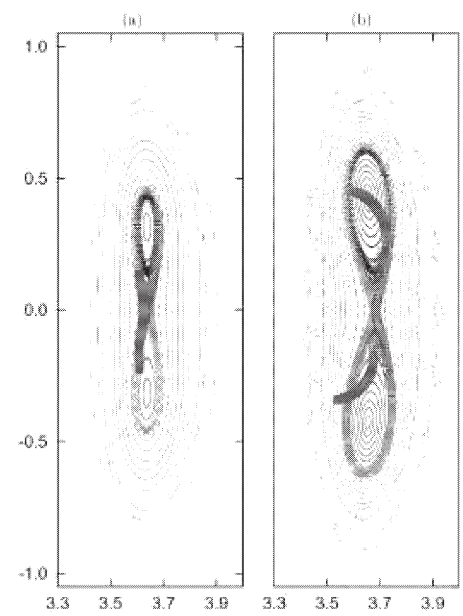

Fig. 2 Poincaré plots of drift orbits and magnetic field lines of a vertically elongated configuration in LHD are shown for (a) the vacuum and (b) finite-β fields (β_0=2%).