§4. Theoretical Considerations of Doublet-Like Configuration in Stellarators

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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. 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[2].

In Fig.1, flux surfaces of a vertically elongated doublet-like configuration (BQ=-100%) obtained from HINT are shown for a vacuum field and a finite-β equilibrium (β_0~4%). For a 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. On the other hand, flux surfaces of horizontally elongated configuration (BQ=300%) are shown in fig. 2 for a vacuum field and a finite-β equilibrium (β_0~4%). For the horizontal configuration, since the Shafranov shift is very large, the magnetic axis is shifted toward the outside of the torus. In addition, although the magnetic axis is not split at the vacuum field, it is split for finite-β equilibria (β_0~3%).

References

[1] Fujita, T. *et al.*, Phys. Rev. Lett. **87** (2001) 245001.
[2] Harafuji, K. et al.,J.Comput.Phys. **81** (1989) 169.

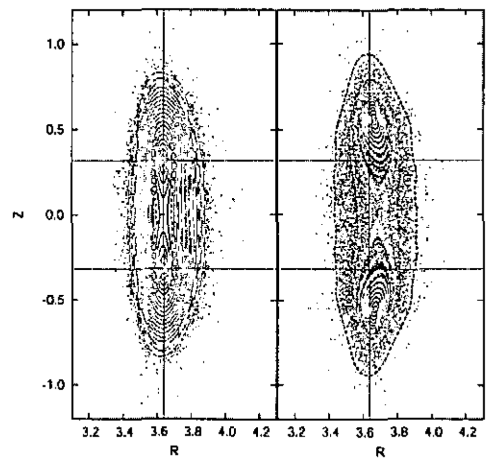

Figure 1 Flux surfaces of a vertical doublet-like configuration in LHD for the vacuum field (left) and β0~4% (right).

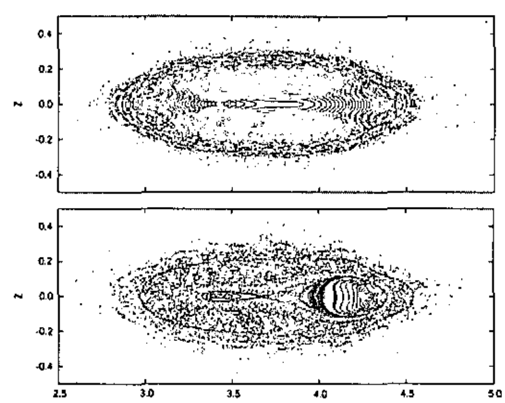

Figure 2 Flux surfaces of a horizontal doublet-like configuration in LHD for the vacuum field (upper) and β0~4% (bottom).