§22. LHD-type Stellarator with Reduced Shafranov Shift

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Although the present scientific achievements of LHD experiment are good, one of critical issues in the magnetic configuration is a large Shafranov shift for high beta equilibria. While the large Shafranov shift creates the magnetic well, which contributes largely to the MHD stability, the strong deformation of the magnetic surface structure causes the deterioration of the high-energy particle confinement and the enhancement of the neo-classical transport. Such a general characteristics of configuration is not controlled by the magnetic axis shift, which is one of major control knobs for the magnetic configurations in the LHD experiments.

We have been studying the configuration optimization based on the Fourier mode representation of the plasma boundary shape [1]. After analyzing the Fourier modes of three typical LHD configurations with different magnetic axis positions, it was found that a relatively small number of Fourier modes are essential to determine the different confinement characteristics of these configurations. In order to solve the essential problems of LHD experiment, a new space of Fourier mode distributions was explored. In this report, we show one example of improved configurations which have a reduced Shafranov shift. An important feature of this configuration is that the new confinement characteristics are produced with a small number of Fourier modes, which leaves a room of further steps of optimization in the physical properties and of the flexibility in the magnetic coil design.

Figure 1 shows the fixed boundary equibrium calculations (a) for vacuum and (b) with 2% averaged beta for the LHD inward shifted configuration (R_{ax} = 3.6 m). The position of the magnetic axis is shifted very much for 2% beta case. The results of the same calculations are shown in Fig. 2 for the boundary shape of the new configuration. The essential difference of the boundary shape is in the triangularity. The LHD inward shifted configuration has a week triangularity which is similar to the D-shape of standard tokamaks. On the other hand, the new configuration shown in Fig. 2 has a stronger triangularity of the opposite direction. Such a triangularity is not the axisymmetric one and it changes the direction in the cross section of the magnetic surfaces at a different toroidal angle.

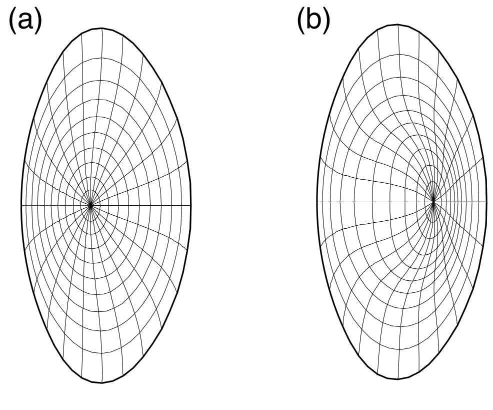

Fig. 1. Magnetic surfaces of (a) vacuum equilibria and (b) 2% averaged beta equilibria of LHD inward shifted configuration.

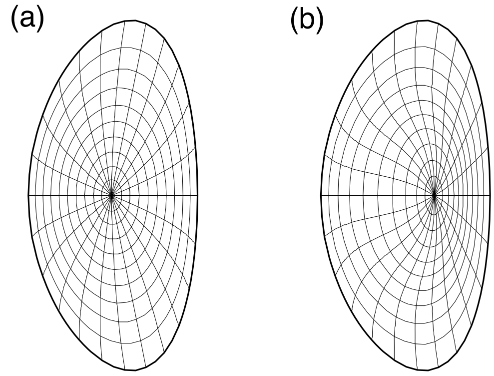

Fig. 2. Magnetic surfaces of (a) vacuum equilibria and (b) 2% averaged beta equilibria of a new configuration.

The variation of the Shafranov shift with increased beta is shown in Fig. 3. Relative positions of the magnetic axis are shown between the left edge and the right edge of the last closed magnetic surface of the vertically elongated cross section for the new configuration and the LHD inward shifted configuration. For the LHD case, the magnetic axis moves out rapidly for the beta increase from zero to 2% while the axis shift is small for the new configuration. With such a reduced Shafranov shift, the neo-classical transport in the new configuration is strongly reduced for the high-beta equilibria.

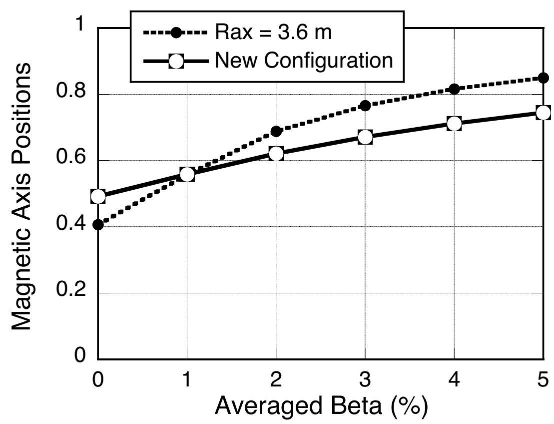

Fig. 3. Relative positions of magnetic axis with increased beta.

1) Okamura, S. and Suzuki, Y., Plasma Fusion Res. **6**, 42403048 (2011).