§7. Positional Stabilization of Torus Plasma with Simple Helical Coils

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The objective of this study is to stabilize vertical instabilities of elongated tokamak plasmas by the use of saddle coils which make helically perturbed fields. Although several studies have been made on the effects [1], they have been conducted in tokamaks with circular cross-sections. To demonstrate the vertical stabilizing effects on elongated plasmas, we have been constructing a small tokamak device (R = 0.33 m, a = 0.09 m, B_t = 0.3 T) which has elongated cross-sections up to κ = 1.8. We assembled the vacuum vessel and the toroidal field coils and succeeded in plasma production by ECR with 2.45-GHz RF power.

We extended the concept of the semi-stellarator configuration as shown in Fig. 1. This is composed of only conventional toroidal field (TF) coils and a set of parallelogram-shaped saddle (PS) coils. The arrows plotted on the PS coils indicate the direction of current flow which is in the opposite direction with each other. The slanting windings on the outboard side of torus corresponds to the semi-stellarator windings as mentioned above. The PS coils do not go through the inboard side of torus leaving sufficient space for an ohmic heating coil for current drive.

The most novel feature of this configuration is rotationally asymmetric. The PS coils are arranged at only one side of torus in the toroidal direction. One set of coils generate averaged vertical field B_{av} only near the PS coils. However, surprisingly, the force balance in horizontal direction can be achieved even in the opposite side of torus. We investigated 3-D equilibrium of current carrying plasma with semi-stellarator fields by using free boundary version of the VMEC code. Figure 2 shows poloidal cross-sections of MHD equilibria at different toroidal angles from ϕ = 0° to ϕ = 270° by 45° steps, which were obtained with VMEC. The blue and red lines shows two cases I_p = 5 kA and 2.5 kA, respectively, where the current of the PS coils I_{PS} = 10 kA in both cases. It is obvious that force balance in horizontal direction is achieved all along the torus even though the PS coils are mounted only in one side of torus. In other words, the rotationally asymmetric stellarator field can also function as conventional vertical field, in the same way as symmetric semi-stellarator field. There are little changes in the R_{axis} between the two cases even though I_p in the case of (a) is twice as large as that in small case (b).

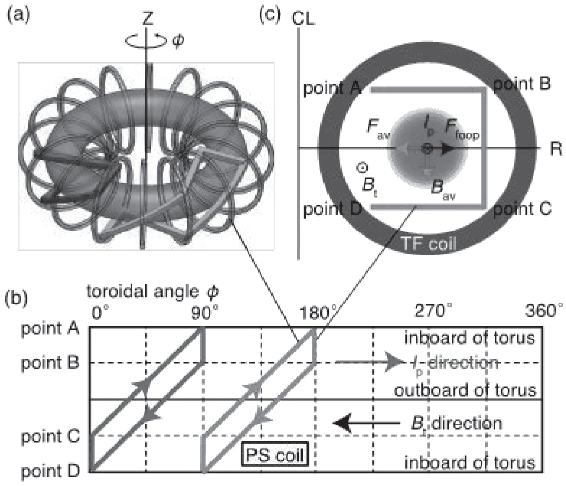

Fig. 1 Location of the parallelogram-shaped saddle (PS) coils corresponding to semi-stellarator windings. (a) bird's eyeview (b) development diagram (c) poloidal cross section.

It is conjectured that this effect provides the robustness against horizontal displacement due to rapid changes in plasma parameters, even without active control. As a result, active controlless start-up and the avoidance of major disruptions might be demonstrated in future.

1) Ikezi, H., Schwarzenegger, K. F.: Phys. Fluids 22 (1979) 2009.

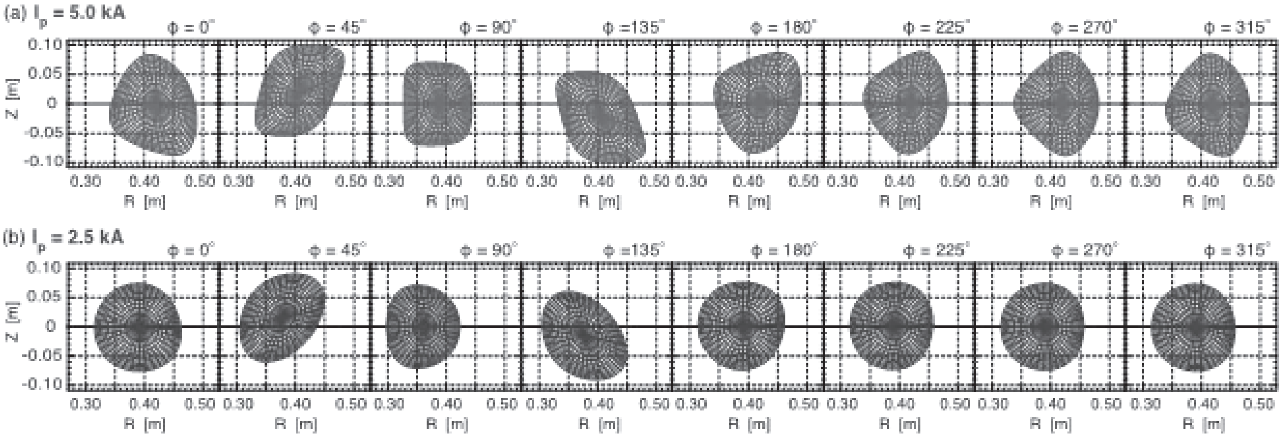

Fig. 2 Comparison of the flux surfaces between two cases of plasma current I_p = 5 kA and 2.5 kA calculated with the VMEC code in its free-boundary mode. I_{PS} = 10 kA in both cases. The PS coils are located between ϕ = 0° and ϕ = 180°.