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

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Although tokamaks are the most promising magnetic confinement scheme for fusion reactors, it is difficult to avoid disruptions which can cause damages to reactors. At a disruption, large eddy currents are generated in thermal and current quench phases and a feedback system fails to keep the plasma at a desired position. Resulting contact of plasma with first wall will lead to the damages of a reactor by high heat flux and/or induced electromagnetic forces. We are investigating a simple helical coil system which passively stabilizes vertical displacements[1] and elongates the plasma. It has a potential to avoid an occurrence of VDE (vertical displacement event) which is a problem of vertically elongated tokamaks.

Figure 1 shows the coil configuration schematically. The directions of the current in adjacent coils are opposite with each other. The windings on the top and bottom sides of the plasma produce finite averaged horizontal field B_R [2] which stabilizes vertical displacements since it increases toward the coils. While the windings on the outer side of torus produce vertical magnetic field component as plotted in Fig. 2. The finite averaged vertical field pushes the plasma to the inner side of torus and elongates the plasma.

Furthermore, the proposed coils can form closed vacuum magnetic surfaces in combination with poloidal field coils. In the first phase of a disruption when the plasma current does not drop so much, the plasma position is maintained by the averaged B_R component. In the latter phase, the plasma confinement can be preserved and recovered by heating the plasma up again owing to the closed magnetic surfaces even with small plasma current.

We analyzed magnetic flux surfaces with VMEC with free boundary conditions. Figure 3 shows an example of MHD equilibrium with helical fields. Six helical coils are located around the torus except the innner side of torus as plotted in Fig. 1. The plasma parameters are R = 0.3 m, a = 0.08 m, B_T = 0.5 T, I_p = 5.5 kA. We confirmed that the cross section is elongated, whose averaged ellipticity κ is 1.6. We simulated a disruption as by dropping β and the plasma current and confirmed that the plasma position remains almost unchanged in the major radius direction.

Detailed design of a small tokamak device with simple helical windings is under way to demonstrate VDE suppression experimentally.

1) H. Ikezi, K. F. Schwarzenegger: Phys. Fluids 22, 2009 (1979).
2) Halold P. Furth, Charles W. Hartman: Phys. Fluids 11, 1110 (1968).

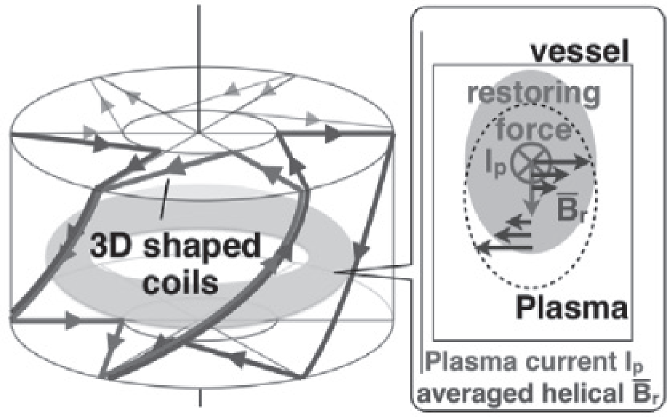

Fig. 1 Schematic illustration of the coil configuration. The arrows indicate the direction of coil currents. The blowup illustrates the physical mechanism for the positional stabilization.

Fig. 2 Poloidal projection plot of the magnetic lines of force with helical fields generated by outer side windings. Straight lines indicate the winding position.

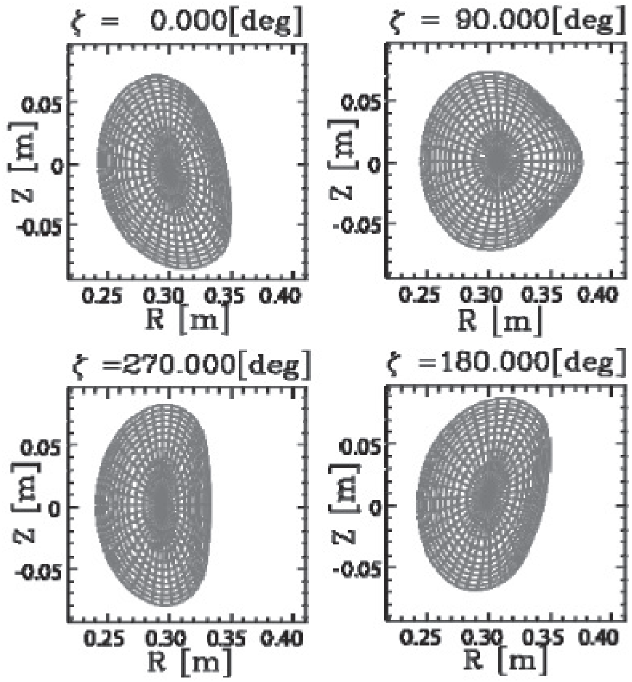

Fig. 3 Example of MHD equilibrium with helical fields computed with VMEC.