§7. Design of Split-Type Helical Coils for FFHR-2S

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The conceptual design studies on the LHD-type fusion energy reactor, FFHR, are progressing both on physics and engineering issues. In the design composed in 2005 as FFHR-2m1 [1], the major parameters are given as m = 10, l = 2, R_c = 14 m and a_c = 3.22 m, where m is the toroidal pitch number, l is the poloidal pole number, R_c is the major radius and a_c is the average minor radius of the helical coils. Here, the pitch parameter, γ, defined by $(m/l)(a_c/R_c)$ is 1.15, which is lower than the value of 1.25 adopted for LHD. This is effective in reducing the electromagnetic forces on the helical coils while ensuring larger space between the plasma and helical coils.

One of the difficult issues associated with this configuration is that the ergodic layers still interact with blankets (thickness: ~1.1 m) at the inboard side of the torus. Therefore, alpha particles cannot be confined efficiently, as they have excursions from the magnetic surfaces and bombard the blankets at the ergodic layers. In order to solve this problem, one idea is to seek for a new coil configuration that ensures much clearer blanket space while keeping the major radius below 16-17 m. In this connection, we are proposing split-type helical coils (named FFHR-2S) [2] and an example of the vacuum magnetic surfaces is shown in Fig. 1. As was found in the previous study [3], the symmetry of magnetic surfaces is improved, without shifting the magnetic axis inward, as the current density at the inboard side is increased while it is decreased at the outboard side. It should also be noted that we here employ γ = 1 for the pitch parameter. This is regarded as a new finding for generating magnetic surfaces with such a low pitch parameter, whereas one is already close to the forbidden-zone [4] without splitting the helical coils.

For the new configuration, various physics properties of the magnetic field are being investigated. One important study is the confinement of alpha particles. As an example of calculations is shown in Fig. 2, the general characteristics of drift orbits are not very different from those found in non-split configurations. At the same time, the optimization of the coil configuration should be done also from the engineering viewpoint. We note that by having a smaller γ, the helical coils are expected to experience less electromagnetic forces than the non-split cases. Moreover, the stored magnetic energy becomes lower as shown in Fig. 3. Since the winding process becomes more difficult, the helical coils can be assembled in segments using high-temperature superconductors [5].

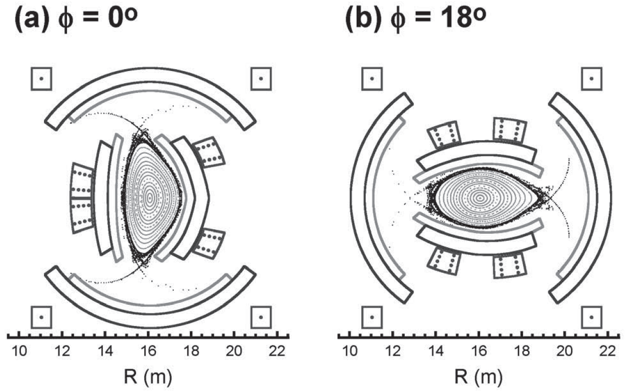

Fig. 1 Vacuum magnetic surfaces at two poloidal cross-sections of FFHR-2S (α = +0.1).

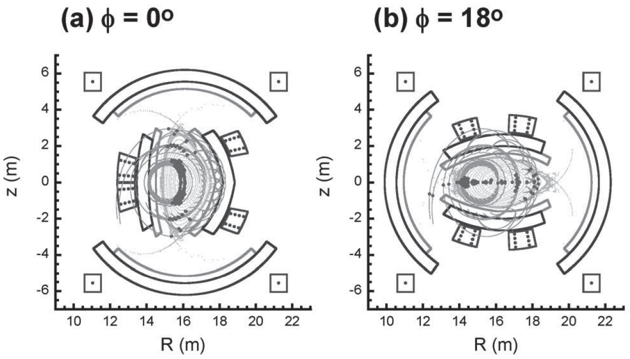

Fig. 2 Drift orbits of alpha particles with perpendicular pitch angles in FFHR-2S. Poloidal projections and Poincare plots are shown with curves and dots, respectively.

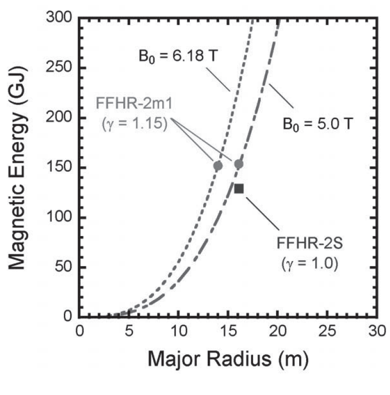

Fig. 3 Stored magnetic energy as a function of major radius.

1) Sagara, A., et al., Fusion Eng. Des. 81 (2006) 2703.
2) Yanagi, N. et al., NIFS Annual Report (2007).
3) Nishimura, K., Fujiwara, M., J. Phys. Soc. Japan 64 (1995) 1164.
4) Uo, K., Nuclear Fusion 13 (1973) 661.
5) Bansal, G. et al., to be published in Plasma and Fusion Research (2008).