§6. Configuration Studies on Split-Type Helical Coils for FFHR-2S

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Based on the successful progress of fusion relevant plasma experiments in the Large Helical Device (LHD), the conceptual design studies on the heliotron-type fusion energy reactor FFHR are being conducted on both physics and engineering issues [1]. Though configuration optimization is still being pursued, the present choice gives a major radius of 14-18 m with a toroidal magnetic field of 6-4 T in order to generate ~3 GW of fusion power. The stored magnetic energy of the superconducting coil system should be in the range of 120-150 GJ. In these studies, the helical pitch parameter γ defined by $(m / l)(a_c / R_c)$ for continuous helical coils (having the toroidal pitch number m, poloidal pole number l, average minor radius a_c and major radius R_c) is chosen to be lower than 1.25, the parameter adopted for LHD. This is effective in ensuring sufficient blanket space (thickness > 1 m) between the ergodic region of magnetic field lines and blankets. The configuration composed in 2005, "FFHR-2m1", has $m = 10$, $l = 2$, $R_c = 14$ m and $a_c = 3.22$ m with $\gamma = 1.15$. However, it was found that the clearances were not sufficient, and we later chose to have a larger radius by the configuration of "FFHR-2m2" with $R_c \sim 17$ m and $\gamma = 1.20$.

The other approach to secure good clearances is the optimization of magnetic configurations by modifying the winding laws of helical coils. In this respect, we found that favorable configurations could be obtained by splitting helical coils in the poloidal cross-section at the outboard side of the torus. This corresponds to the situation of having a higher current density at the inboard side and a lower one at the outboard side [2]. This kind of configuration is named "FFHR-2S", and presently two options, "Type-I" and "Type-II" are being examined with vacuum magnetic surfaces shown in Figs. 1 and 2. For FFHR-2S Type-I, symmetrical magnetic surfaces are obtained without shifting the magnetic axis inward. We should note that we here employ $\gamma = 1.0$ for the pitch parameter to obtain good clearances. This choice of γ is regarded as a new finding based on the knowledge that one is already close to the so-called forbidden zone [3].

On the other hand, FFHR-2S Type-II configuration has a larger major radius of $R_c = 17.33$ m and $\gamma = 1.20$ with outward shifted configurations. Fairly large magnetic surfaces can be obtained even with an outward shift and magnetic well is observed within the entire magnetic surfaces as shown in Fig. 3. Though the rotational transform and shear are lower with this configuration than those in FFHR-2S Type-I and FFHR-2m2, the well formation may stably sustain high-beta plasmas, as it was suggested with a similar concept proposed previously [4].

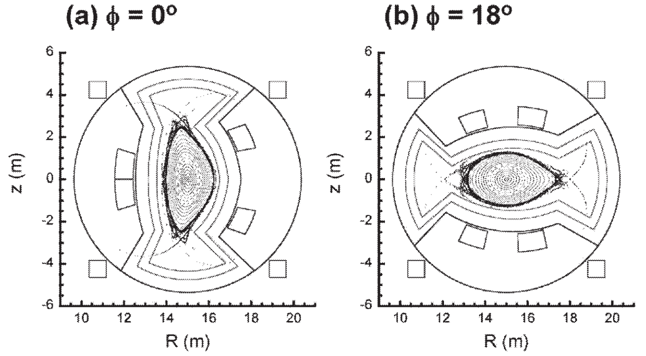

Fig. 1 Vacuum magnetic surfaces at (a) the toroidal angle $\phi = 0°$ and (b) $\phi = 18°$of FFHR-2S Type-I.

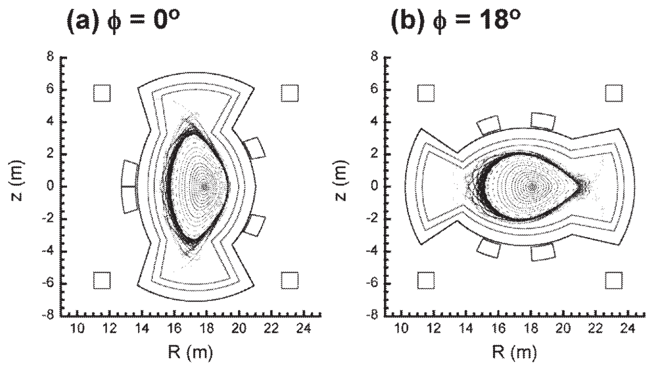

Fig. 2 Vacuum magnetic surfaces at (a) the toroidal angle $\phi = 0°$ and (b) $\phi = 18°$of FFHR-2S Type-II.

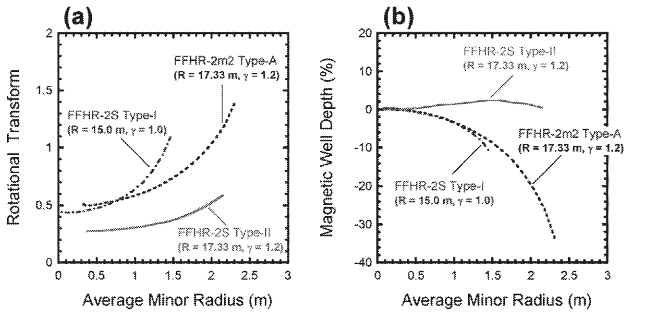

Fig. 3 Radial profiles of (a) rotational transform and (b) magnetic well depth for three configurations.

1) Sagara, A., et al., Fusion Eng. Des. 81 (2006) 2703.
2) Nishimura, K., Fujiwara, M., J. Phys. Soc. Japan 64 (1995) 1164.
3) Uo, K., Nuclear Fusion 13 (1973) 661.
4) H. Akao, T. Watanabe and K. Nishikawa, JSPS Report 63050027 (1988) 345 (in Japanese).