§1. Design Integration towards Size-Optimization of LHD-type Fusion Energy Reactor FFHR

Sagara, A., Imagawa, S., Kozaki, Y., Goto, T., Yanagi, N., Watanabe, T., Tamura, H., Tanaka, T., Mitarai, O. (Tokai Univ.), FFHR Group

On optimizing the reactor size of FFHR, one of main issues is the structural compatibility between blanket and divertor configurations. Recent design studies have focused on FFHR-2m2, which can avoid the interference between the first walls and ergodized layers of magnetic field lines and can adopt a magnetic configuration that is consistent with LHD high-beta operation (inner-shifted magnetic axis position R_{ax}/R_c = 3.6/3.9 and helical pitch parameter γ = 1.20) by increasing the reactor size [1].

To identify the design window of FFHR, parametric scans has been carried out with a system design code developed for heliotron reactors. By reference to design constraints of FFHR-2m2 (minimum blanket space ~ 1 m, helical coil current density of 25 A/mm^2, and stored magnetic energy < 160 GJ), a possible design window has been clarified for different helical pitch parameter values (Fig. 1). The effect of the position poloidal coils (PCs) on the design window has also been examined. Then the position of PCs was optimized from the viewpoint of maximizing the volume enclosed by the last closed flux surface (LCFS) in vacuum equilibrium with a constraint of magnetic stored energy. The design with this optimized PC position has been defined as FFHR-2m2 Type-D. Figure 2 shows the cross-sectional view at the poloidal cross-section with vertically- and horizontally-elongated plasma.

Finite-beta equilibrium analysis of FFHR-2m2 Type-D has been carried out using VMEC code. It was found that high-beta equilibrium with volume-averaged beta value of 5.6% and almost the same volume enclosed by the LCFS as that in vacuum equilibrium can be obtained by adding adequate vertical field by adjusting the current of PCs [2]. This equilibrium is consistent with the estimation obtained by the system design code.

Ramp-up and self-ignition access scenario of high density, thermally unstable SDC (super dense core) plasma has been examined. When NBI is used for heating method, the main issue is that its penetration length shortens with the increase of core plasma density. In the newly proposed scenario, the required beam energy is successfully reduced to 1 MeV by the way to raise density with a pellet fueling by utilizing alpha heating after accessing self-ignition with low density plasma using NBI heating.

Prior to the detailed 3-D design of the blanket system, the effect of the increase in the volumetric ratio of the structural material (JLF-1) in flow channels on local tritium breeding ratio (TBR) has been examined. It was found that degradation of local TBR is particularly large at the first-wall side of the breeding layers (Fig. 3).

NIFS06ULAA116 , NIFS 07KFDA009

[1] Sagara, A. et al., in press in Fusion Eng. and Design.
[2] Goto, T. et al., to be published in Contributions to Plasma Physics

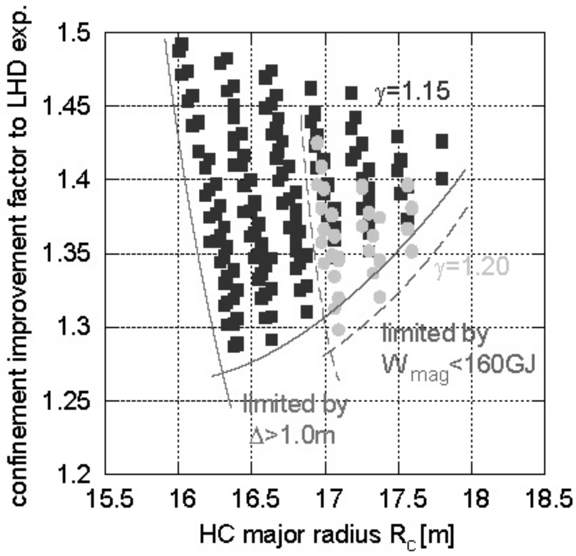

Fig. 1. Relation between the major radius and confinement improvement factor for γ = 1.15 and 1.20.

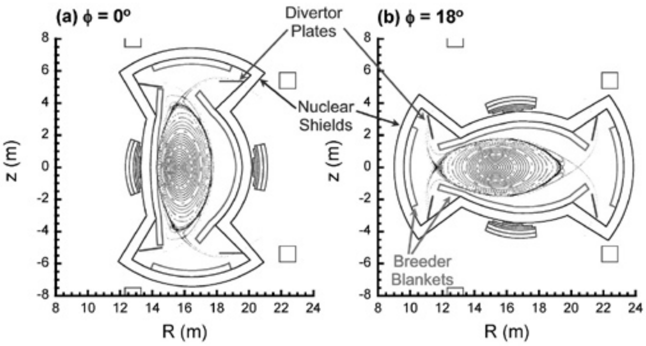

Fig. 2. Latest design "FFHR-2m2 Type-D" with maximized magnetic surfaces by optimization of poloidal coil positions and currents. R_c = 17 m, R_p = 15.7 m, $\langle a_p \rangle$=2.5m, γ = 1.2, α = +0.1, $B_{t,c}$ = 4.45 T, j_{HC} =25 A/mm^2, W_{mag}=160Gj, $\langle \beta \rangle$=5.6%,

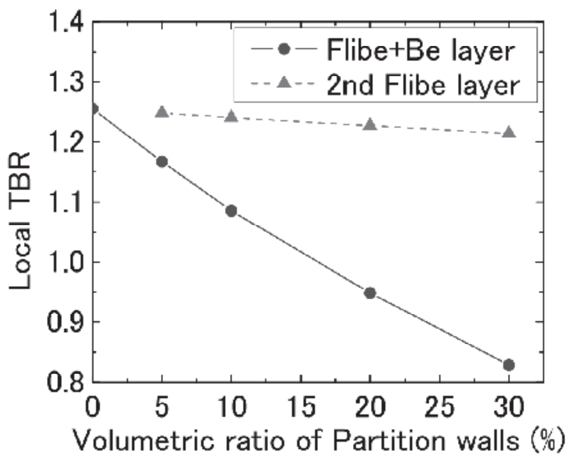

Fig. 3. Dependence of the local TBR on the volumetric ratio of partition walls material of JLF-1.