§2. System Design of the Helical Fusion Reactor FFHR-d1

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i) Consideration of the construction and maintenance method of FFHR-d1

In the last fiscal year, "3rd round" of the conceptual design study of FFHR-d1, which is directed to the consideration of the construction and maintenance method, was started and general procedure of the construction was examined. In this fiscal year, detailed examination of the construction procedure was conducted with a fabrication of a miniature model in mind. Specific works and related development subjects for each step in the construction procedure were listed with a consideration of the anteroposterior relation between these steps and shortening of working hours. Consequently, construction procedure similar to that of LHD was selected as a primary option. More specifically, winding of the helical coils is done before the installation of in-vessel components by using the rigid winding core. Formation of vacuum boundary is realized by welding the gaps between leak-tight shielding blanket modules on plasma-facing side. Delicate works at the limited space between the helical coils and the shielding blankets can be avoided by this method.

In case of the segmentation of the blankets, the following simple methods were proposed with a consideration of manufacturability and workablility. For the shielding blankets, horizontal segmentation was proposed inview of ease of construction and ensuring the accuracy of installation. For the breeding blankets, a simple segmentation in a plane with a constant toroidal angle, which enables the replacement of breeding blanket modules only by a combination of uniaxial movements and poloidal rotation, was proposed[1] (Fig. 1).

ii) 1D integrated physics analysis towards self-consistent plasma operation control scenario

In the last fiscal year, baseline plasma operation control scenario with a simple, small number of diagnostics which is consistent with MHD equilibrium and neoclassical transport was proposed by 1D the integrated calculation tool[2]. In this fiscal year, further detailed analyses including MHD stability, neoclassical transport of multispecies ions, anomalous transport and boot-strap current were launched. Because direct coupling with detailed analysis tools is difficult in view of the calculation cost, establishment of simple models based on LHD experimental observations and numerical analysis results was attempted. Figure 2 shows the example of plasma operation scenario with the operation region which has been already achieved in LHD experiment: edge electron density below Sudo density limit, Mercier index D_I at the $m/n = 1/1$ rational surface below 0.25, neo-classical energy loss less than half of the total absorbed power (corresponds to the energy loss by anomalous transport as much as that by neo-classical transport). Fusion power and auxiliary heating power of the final operation point are 300 MW and $\sim$ 30 MW, respectively, i.e., fusion gain $Q \sim 10$ can be achieved. This kind of analysis also clarifies the direction of design and experimental/simulation research with a quantitative manner. For example, self-ignition operation regime is reachable with complete suppression of anomalous transport, suppression of MHD instability (corresponding to achievement of Mercier parameter $\sim$ 0.3) and confinement improvement factor of $\sim$ 1.5.

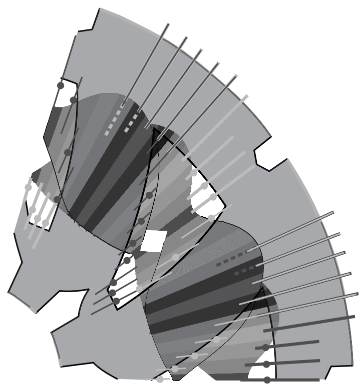

Fig. 1: Top view of the series of the breeder blanket modules on the bottom of helical coils.

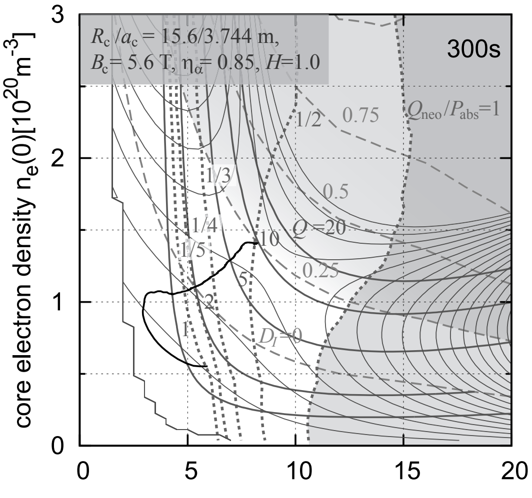

Fig. 2: POPCON plot of the plasma operation scenario of FFHR-d1 with the operation region which has been already achieved in LHD experiment.

1) T. Goto et al., Plasma Fusion Res. **11** (2015) 2405047.

2) T. Goto et al., "Sample of bibliograph", Nucl. Fusion **55** (2015) 063040.