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

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i) 1D integrated physics analysis of plasma operation control scenario

In the last fiscal year, the 1D code to calculate temporal evolution of radial profiles of electron density and temperature was developed and the baseline plasma operation control scenario by feedback control of the pellet fueling rate based on the measurement of the line-averaged electron density was established[1]. In this fiscal year, the code was upgraded and coupled with several detailed physics analysis tools provided by the integrated transport analysis suite TASK3D[2] by the collaboration with the integrated transport simulation group and the neoclassical and turbulent transport simulation group in the Numerical Simulation Reactor Research Project.

Using this upgraded analysis tool, the consistency of the baseline operation scenario with MHD equilbrium and neo-classical transport was examined. The prerequisites of the calculation are the same as those in the calculation of the last fiscal year: a peaked density profile with inward-shifted, high aspect ratio configuration ($R_{\mathrm{ax}}/R_{\mathrm{c}} = 3.55/3.9, \gamma_{\mathrm{c}} = 1.2$), a pellet containing 10^{23} particles with an injection velocity of 1.5 km/s.

The control method of the external heating power based on the measurement of the edge electron density and the fusion power was newly introduced. As shown in Fig. 1, smooth change of the fusion power and steady-state sustainment with the target fusion power of 3 GW was confirmed in the view point of the consistency with MHD equilibrium and neo-classical transport[3].

ii) Improvement of the systems code

To enhance the design feasibility, the multi-path design strategy with a flexible selection of the primary design parameters was proposed[4]. Considering the design option with a small electric output, parametric analysis of the cost and plant power flow is required. Thus, cost and plant power plow evaluation model of the systems code HELIOSCOPE was improved. The developed cost model is mainly based on the Generomak model, but mass unit cost of each component and construction cost of buildings or facilities are closely examined in reference to the data of LHD and ITER. The mass of component is evaluated as accurate as possible using the actual 3D shape defined by the design study of FFHR-d1. In the evaluation of the plant power flow, the required cryogenic power, which accounts for a substantial fraction of the recirculation power, is evaluated from the actual shape of the blanket.

Figure 2 shows the result of the design window analysis. Here core plasma performance is fixed: peak beta value of 7%, confinement enhancement factor of 1.5 times of reference LHD data and alpha heating efficiency of 85%. Although the absolute value of the total construction cost needs to be carefully examined by considering the effect of the price change or technical innovation, parametric analysis including the evaluation of the cost and engineering Q value will contribute the system design with the multi-path strategy.

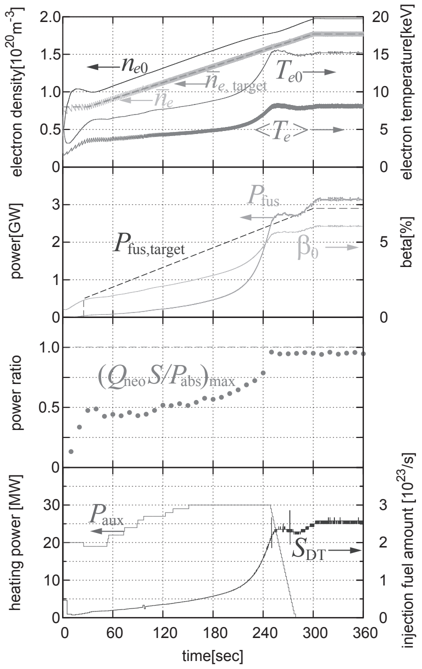

Fig. 1: Time evolution of the plasma and external control parameters of the baseline scenario.

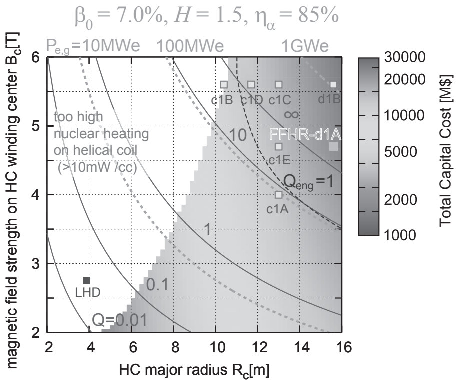

Fig. 2: Result of parametric analysis of the design window of the LHD-type reactor.

1) Goto, T. et al.: Fusion Eng. Des. **89** (2014) 2451.

2) Yokoyama, M. et al.: Plasma Fusion Res. **8** (2014) 2403016.

3) Goto, T. et al.: *Proc. of 25th Fusion Energy Conference*, Oct 13-18, 2014, St. Petersburg, Russia, FIP/P7-16, to be published in Nucl. Fusion (2015).

4) Sagara, A. et al.: Fusion Eng. Des. **89** (2014) 2114.