§3. Core Plasma Design of a Compact Sub-Ignition Helical Reactor FFHR-c1 II

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Recently, the All Japan Combined Team under the Fusion Research Development Working Group in the MEXT has invoked discussions on the targets of Japanese fusion DEMO reactor. The proposed targets are; 1) stable electrical output of more than a few hundreds of MW in steady state, 2) practical availability, and 3) realization of comprehensive tritium breeding to demonstrate the self-sufficiency of fusion fuel. The minimum design of a helical fusion DEMO reactor that can achieve these new targets has been considered.

FFHR-d1 [1] has an enough performance to achieve these targets, since it is designed to produce more than one GW of electricity in steady state. However, the device size of R_c = 15.6 m, where R_c is the helical coil major radius, and therefore the construction cost can be reduced if the electrical output is smaller. FFHR-c1, which has been proposed as a helical type nuclear test machine with small devise size [2,3], can be the candidate of helical DEMO reactor aimed at the new targets. Adding to FFHR-c1.0 and c1.1, of which R_c = 13.0 m, we propose a new version of FFHR-c1.2 with R_c = 10.4 m as shown in Fig. 1. The magnetic field strength at the helical coil center, B_c, is set to be 5.6 T, which is the same as FFHR-c1.1, and d1B. The magnetic stored energy of FFHR-c1.2 is ~72 GJ, which is similar to that of ITER of ~50 GJ.

The plasma parameters expected in FFHR-c1.2, which are estimated by the Direct Profile Extrapolation (DPE) method [4] using the temperature and the density profiles observed in LHD (#115787, t = 3.90 s), is summarized as a function of the central beta, β_0, in Fig. 2. The energy confinement enhancement factor, H, is varied as 1.0, 1.5, and 2.0. The central electron density, n_{e0}, increases with β_0, while the central electron temperature, T_{e0}, is kept constant. This is because the optimum temperature determined by the gyro-Bohm type parameter dependence is given as ~10 keV in the DPE method [4]. The energy confinement time, τ_E, is also independent of β_0. The axially heating power needed to achieve these parameters, P_{aux}, increases with β_0 in the low beta regime. As the beta increases and the fusion output, P_{fusion}, which is proportional to the beta squared, also increases, P_{aux} decreases with a help of the increased alpha heating power. The Q-value defined by P_{fusion} / P_{aux} increases with β_0. The impact of H can be seen in the β_0 needed to achieve a large Q-value, *i.e.*, β_0 should be larger than 7, 5, and 4 % for H = 1.0, 1.5, and 2.0, respectively, to achieve Q > 100. Note that this results depend on the profile data used in the DPE method. Therefore, further endeavor to obtain better profile data in LHD is still required.

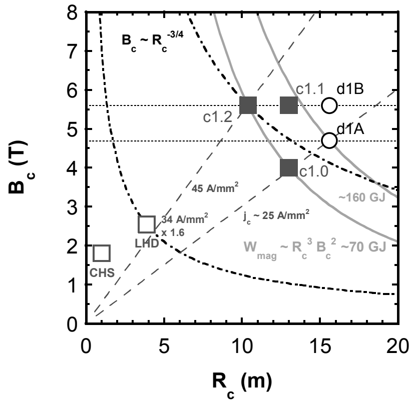

Fig. 1. The magnetic field strength at the helical coil center, B_c, with respect to the helical coil major radius, R_c, in FFHR-c1.0, c1.1, c1.2, d1A, and d1B. Thick gray curves, straight broken lines, and chain curves denote the magnetic stored energy, the current density of super conducting helical coils, and $B_c \propto R_c^{-3/4}$, respectively. Note that the gyro-Bohm type energy confinement time is kept constant if the relation of $B_c \propto R_c^{-3/4}$ is kept while the other parameters are fixed.

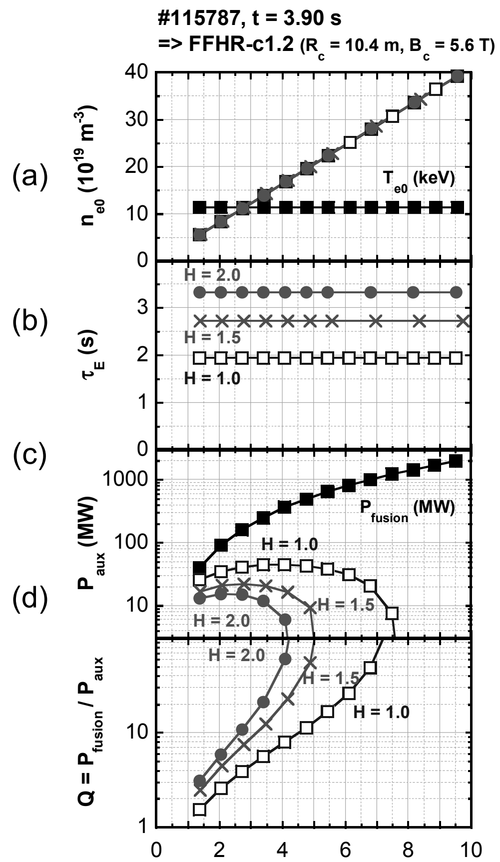

Fig. 2. Plasma parameters as a funciton of the central beta in FFHR-c1.2. These are extrapolated from the profile data of #115787 (t = 3.90 s) obtained in LHD.

1) A. Sagara, et al., Fusion Eng. Des. **87** (2013) 594.
2) J. Miyazawa, et al., Ann. Rep. NIFS (2013) 269.
3) J. Miyazawa, et al., Nucl. Fusion **54** (2014) 013014.
4) J. Miyazawa, et al., Fusion Eng. Des. **86** (2011) 2879.