§68. Analysis of Ignition Access in FFHR

Mitarai O. (Kyushu Tokai University)
Sagara A. and Motojima O.

In a high field helical system, the density limit is improved with the magnetic field. On the other hand, the H-mode regime determined by the H-mode power threshold becomes narrower with the magnetic field, which constrains the ignition access and ignited operation in a high field helical system. In this work, temporal evolution of ignition access in the D-T high field helical reactor FFHR (R = 20 m, $\bar{a}$ = 2 m, and B_0 = 12 T) with the fusion power around 3 GW and the confinement factor of γ_H = 1.5 has been analyzed using the time dependent zero-dimensional power balance equation with the LHD scaling law and the H-mode power threshold.

The formulae are the same as used in the ITER time dependent zero-dimensional ignition analysis for ITER.(1) The H-mode indicator M_{HL} is defined, referring to the Wenderstein 7-X H-mode power threshold, as

$$M_{HL} = \frac{P_{h,net}\,[MW]\,V_o[m^3]}{A_{HL}\,\bar{n}[10^{20}\,m^{-3}]\,B_t[T]\,S_o[m^2]} \tag{1}$$

where $P_{h,net}$ is the net heating power density given by $P_{h,net} = P_{EXT}/V_o + P_\alpha - \{P_b + P_s\}$, $S_o = 2\pi R 2\pi \bar{a}$ and $V_o = 2\pi^2 R \bar{a}^2$. The coefficient A_{HL} is the experimentally observed value of 0.024 during the main heating phase. The density limit is also calculated by the net heating power density.

The alpha particle heating efficiency or the confined alpha particle fraction η_α = 0.7 has been assumed in this study. For the magnetic field of 12 T, it is possible for FFHR to reach ignition with the low confinement factor of γ_H = 1.5. The temporal evolution of the plasma parameters to the equilibrium operating point for P_{EXT} = 250 MW is shown in Fig. 1. Initial plasma parameters before application of the main external heating are chosen arbitrary as $T(0) \sim 1$ keV and $n(0) \sim 3\times10^{19}\,m^{-3}$. H-mode transition has been assumed from the outset. The plasma temperature quickly increases up to 35 keV in a short time, and then decreases to the final point of $T(0) \sim 21$ keV with the increase in the density by fueling. As the H-mode indicator M_{HL} approaches unity at the final phase of the main heating with A_{HL} = 0.024, A_{HL} should be decreased to A_{LH} = 0.01 by the hysteresis effect after the step down of the main external heating power to 120 MW not to return to the L-mode. The H-mode regime is expanded at the time, therefore the operating point can access to the ignition regime with a fusion power of P_f = 3 GW. Thus, we have found that the hysteresis effect must exist in the H-mode power threshold to access ignition and to maintain the operating point in an ignition regime in FFHR based on the present data base. The plasma density steadily increases and finally approaches $n(0) \sim 2.0\times10^{-20}\,m^{-3}$. The operating point is found to exist within the density limit as indicated by $M_{DL} = n_{lim}/n > 1$. The alpha ash density fraction increases steadily and finally reaches $f_\alpha \sim 7.24$ %. The final alpha ash fraction depends on the assumed value of $\tau_\alpha^*/\tau_E = 3$, which is slightly smaller than the value of 4.5 in the recent ITER design.

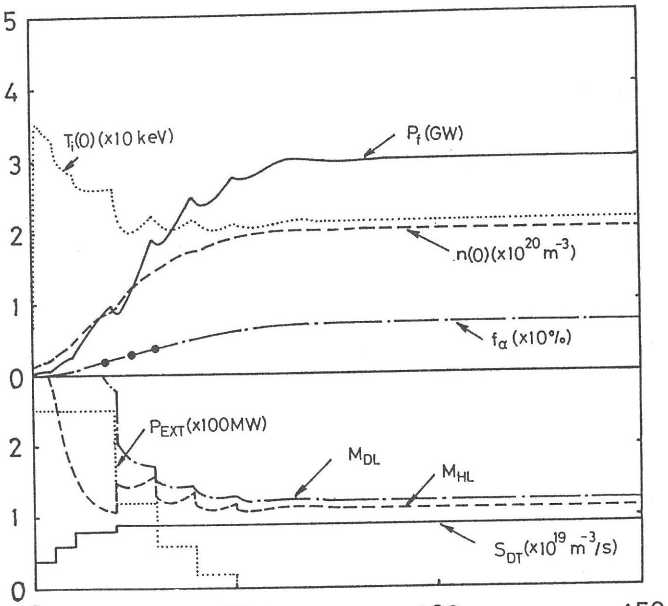

Fig. 1 The temporal evolution of the plasma parameters during the ignition access phase in FFHR

References

(1) O. Mitarai and K. Muraoka. " Ignition Analyses for Burn Control and Diagnostic Developments in ITER", Plasma Engineering Laboratory Report, Kyushu University, PEL-96-15 (Oct. 1996).