§51. Ignition Access in FFHR

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In present experiments, the confinement enhancement factor over the LHD scaling is ~ 1.3, too small for ignition. This difficulty could be overcome by employing a higher magnetic field, which could be produced in force-free type helical field coils.(1) The temporal evolution of the ignition access in FFHR (R = 20 m, $\bar{a}$ = 2 m, and B_o~ 9 to 15 T) with a confinement factor of γ_H = 1.5 ~ 2.0 has been analyzed by using the time dependent zero-dimensional power balance equation with LHD scalings and with an H-mode power threshold. In this report, a ignition access for a high magnetic field of B_o = 12 T with the H-mode and 15 T with the L-mode ignition is presented.

The formulae are the same as used in the ITER time dependent zero-dimensional ignition analysis for ITER.(2) The H-mode indicator M_{HL} is defined, referring to the W7-AS H-mode power threshold, as

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

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 , but the large heating power of P_{EXT} = 250 MW is necessary.

Even if the confinement factor is enhanced up to 2.0, ignition access is not improved due to the H-L transition. As the contour line of 250 MW shifts to the high temperature L-mode regime due to the larger confinement factor, the operating point tends to enter into the high temperature L-mode regime. Therefore, careful operation is necessary not to enter into the L-mode regime during the main heating phase. This can be done by switching off the heating power earlier to reduce the temperature and avoids the H-L transition.

When a long pulse of 250 MW is applied, repetitive fusion power surges are observed due to cyclic H-L-H transitions as shown in Fig. 1 for S_{DT}=1.1x10^{19} m^{-3}/s. This is due to the fact that the "window to the ignition regime" made by the H-L power threshold cyclically opens and closes by the change in the helium ash fraction. The operating point oscillates between two contour lines of 250 MW in the H- and L-mode regime. When the fueling is slightly increased up to S_{DT}=1.18x10^{19} m^{-3}/s, the operating point goes to the higher density and returns to the L-mode. Therefore, no more oscillation exists.

Possibility of the L-mode operation with γ_H = 1 and B_o = 15 T was examined with the temporal analysis. The operating point goes into the L-mode and reaches the ignition regime by increasing the density up to 2.7x10^{20} m^{-3} with P_{EXT} = 100MW. This operation scenario has an advantage over the H-mode operation because an L-H transition is not required, if such high field can be achieved.

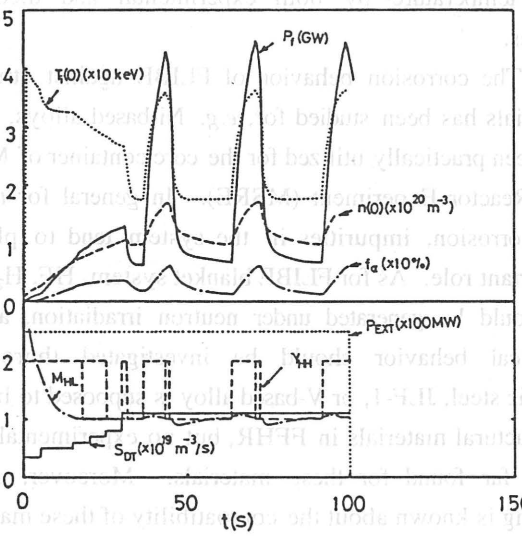

Fig. 1. The L-H-L cyclic transition during the long pulse heating phase of 250 MW for B_o = 12 T, γ_H = 2.0 and the steady fueling rate of S_{DT} = 1.10x10^{19} m^{-3}/s.

References

(1) A. Sagara, O. Motojima, and O. Mitarai, "Design Study of Helical-Type Fusion Reactor FFHR" in press in Fusion Eng. and Design (1997).
(2) O. Mitarai and K. Muraoka. " Ignition Analyses for Burn Control and Diagnostic Developments in ITER", Nucl. Fusion, Vol. 37, No11 (1997) 1523.