§70. Ignition Analyses for the Helical-type Fusion Reactor FFHR-2 with the H-mode Power Threshold

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Ignition characteristics in the D-T high field helical reactor, two times bigger than the LHD are analyzed by the "operation path method" on the $P_{ht}\tau_E^2$-T plane and "POPCON". Machine parameters of R = 8 to 10m, a = 1.0 to 1.3m and B_0= 10T are considered for the experimental demonstration of the ignited operation in a stellarator reactor. Based on the LHD scaling law, R = 10m, a = 1.0m and the magnetic field around B_0 =10T in FFHR with force-free helical coil configuration is chosen as a reference one. In this helical reactor, the ignited operation is possible down to the fusion power 1.0 GW and low beta value of about 2.0 % with the high confinement enhancement factor 3 over LHD scaling. The H-mode power threshold observed in W7-X must have a hysteresis effect to maintain the operating point in the ignition regime. While the high magnetic field makes the empirical density limit higher and then the ignited operation regime becomes wider, it makes the H-mode power threshold higher and the ignited operation regime narrower.

Table 1 Machine and plasma parameters for Compact FFHR. Major radius

Major radius :	R =10 m
Minor radius :	a = 1 m
External heating power :	P_{EXT} = 100 MW
Effective plasma volume :	$V_0 = 197\ m^3$
Effective plasma surface area :	$S_0 = 395\ m^2$
Enhancement factor over LHD scaling :	$\gamma_H = 3.0$
Effective ion charge:	$Z_{eff} = 1.5$
α density fraction:	f_α= 1 % for the start-up phase
	f_α= 5 % in the ignition regime
Alpha particle heating efficiency:	$\eta_\alpha = 0.7$
Reflectivity for synchrotron :	$R_{eff} = 0.9$
Hole fraction for synchrotron :	$f_H = 0.1$
Density profile:	$\alpha_n = 1.0$
Temperature profile:	$\alpha_T = 1.0$

Table 2 Operation points in the ignition regime

Toroidal field B_0	9 T	10	10
Fusion power P_f	1.0 GW	1.0	1.5
Neutron power P_n	0.8 GW	0.8	1.2
Alpha loss $P_{\alpha w}$	58 MW	59	63
Alpha heating $P_{\alpha p}$	142MW	141	210
Energy loss :			
Bremsstrhalung P_b	20 MW	20	26.5
Synchrotron P_s	0.5 MW	16.8	25.5
Conduction P_L	110 MW	104	156
Electron density n(0) ($\times 10^{20}\ m^{-3}$)	2.93	2.78	3.14
Temperature T(0)	24.5 keV	26.5	30.3
Beta value $<\beta>$	2.2 %	1.8	2.3
Neutron wall loading W_n (MW/m^2)	1.85	1.86	2.8

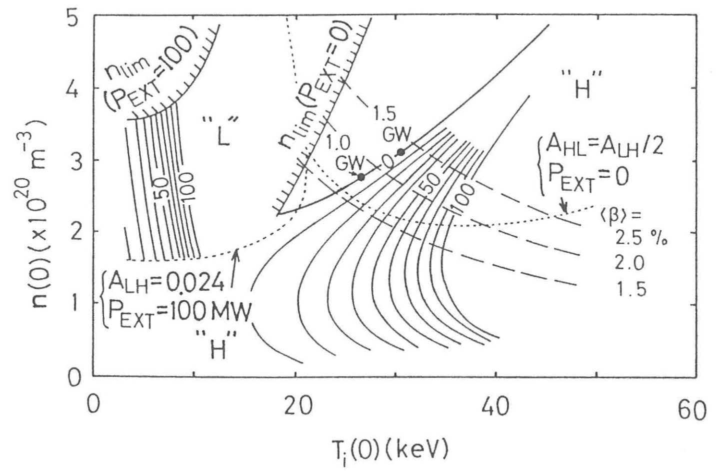

Fig. 1 POPCON analysis for R = 10 m, a = 1.0 m, B_0= 10 T and γ_H = 3.0. The H-L boundary shown by the dotted line for the hysteresis effect with $A_{HL} = A_{LH}/2$ = 0.012 and P_{EXT} = 0 MW divides the H and L-mode regimes. Ignition exists in the H-mode regime, and not in the L-mode regime. The density limit for the ignition boundary is also shown by the hatched line for P_{EXT} = 0 MW. The operating point is 1.0 GW. We note that the H-mode power threshold is given by

$$P_H[MW] > A_{LH}\ \bar{n}[\times 10^{20} m^{-3}]\ B_0[T]\ S_0[m^2],$$

with A_{LH} = 0.024.