

## §2. Feedback Control of Ignition Access in FFHR

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

The feedback control algorithm developed for ignition access in ITER<sup>(1)</sup> has been applied to FFHR. Here, the heating power is controlled by the H-mode power threshold to keep the H-mode and the fueling rate is controlled by the fusion power to keep it at the desired values.

An external heating power  $P_{EXT}(HL)$  to keep an H-mode is given by after rewriting the H-mode power threshold observed in Wenderstein 7-AS as,

$$P_{EXT}(HL) [W] = M_{HL0} A_{HL}(t) 10^6 \bar{n} [10^{20} m^{-3}] B_t [T] S_0 [m^2] - (\bar{P}_\alpha - \bar{P}_b - \bar{P}_s) V_0 \quad (1)$$

where  $M_{HL0}$  is the set value of H-mode indicator,  $\bar{n}$  is the line averaged density,  $B_t$  is the magnetic field strength,  $\bar{P}_\alpha$  is the alpha heating power density,  $\bar{P}_b$  is the bremsstrahlung loss per unit volume,  $\bar{P}_s$  is the synchrotron radiation loss per unit volume,  $V_0$  is the plasma volume and  $S_0$  is the plasma volume.

The temporal evolution of plasma parameters during the ignition access is shown in Fig. 1 for  $B_0 = 10$  T,  $\gamma_H = 2.5$  with hysteresis effect. When the preprogrammed heating power of 70 MW is initially applied, the temperature quickly increases up to 30 keV. After the feedback control is switched on at 10 sec, the heating power gradually decreases and reaches almost zero at 40 sec. The H-mode indicator  $M_{HL}$  is initially high and then kept at the set value of  $M_{HL0} = 1.05$  by reducing the heating power. Fueling feedback control is switched on at 5 sec, and then the electron density linearly increases to satisfy the desired fusion power and reaches  $3.2 \times 10^{20} m^{-3}$ . To take the hysteresis effect into account, the initial coefficient of the H-mode power threshold of  $A_{HL} = 0.024$  is assumed to start decreasing at 10 sec, and kept constant at  $A_{HLE} = 0.012$  after 40 sec. As the density limit indicator  $M_{DL}$  is always larger than 1, the density is within the limit. The alpha ash fraction reaches 6.0 %, the beta value up to  $\sim 1.8$  %, and the neutron wall loading up to  $1.8 MW/m^2$ . If the hysteresis effect is stronger as  $A_{HLE} = 0.01$ , the heating power is completely reduced to zero. Ignition is thus found to be sensitive to the hysteresis effect in FFHR.

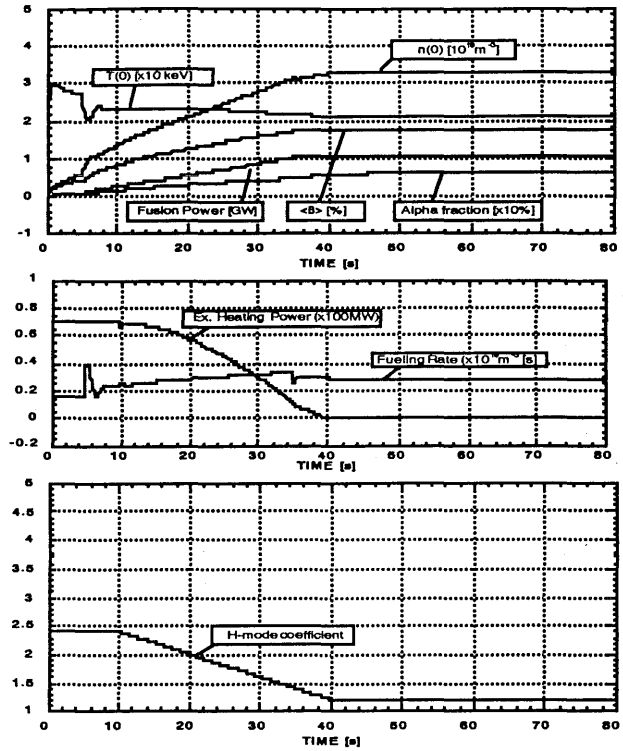


Fig. 1 Temporal evolution of plasma parameters during the ignition access phase with a feedback control in FFHR. The time variable hysteresis is expressed by  $A_{HLS} = 0.024$  and  $A_{HLE} = 0.012$ .

Table 1. Machine and plasma parameters for the small size of FFHR.

Major radius:	$R = 10$ m
Minor radius:	$\bar{a} = 1.0$ m
Magnetic field:	$B_0 = 10$ T
Fusion power:	$P_f = 1$ GW
Maximum external heating power:	$P_{EXT} = 100$ MW
Enhancement factor over LHD scaling :	$\gamma_H = 2.5$
Neutron wall loading:	$\Gamma_n = 1.8$ MW/m <sup>2</sup>
Alpha particle density fraction:	$f_\alpha = 6$ %
Oxygen impurity fraction:	$f_O = 0.5$ %
Effective charge:	$Z_{eff} = 1.4$
Alpha confinement time ratio:	$\tau_\alpha^*/\tau_E = 3$
Temperature ratio:	$T_i/T_e = 1$
Fuel ratio:	$n_D/n_T = 1$
Alpha particle heating efficiency:	$\eta_\alpha = 0.7$
Wall reflectivity:	$R_{eff} = 0.9$
Hole fraction:	$f_H = 0.1$
Density profile:	$\alpha_n = 1.0$
Temperature profile:	$\alpha_T = 1.0$

### References

- (1) O. Mitarai and K. Muraoka. "Ignition burn control and diagnostics in ITER", International Summer School of the Plasma Physics, (Varenna, Italy, Sep. 4-12, 1997), Diagnostics for International Thermonuclear Experimental Reactor, Plenum Press (1998, December) 93.