§13. Fast Responses in L/H Transition

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The plasma profile in core region was found to change in a much faster time scale than the diffusion time scale after the L/H transition [1]. Understanding of the mechanism of the fast response not only reveals the physics of H-mode but also provides a dependable prediction for the burning dynamics in the core plasma of a fusion reactor.

To investigate the transient response of the electron temperature, let us start with the transport equation for the electron temperature,

$$\frac{\partial}{\partial t}\left(\frac{3}{2}n_e(r,t)T_e(r,t)\right) = -\nabla\cdot q_e(r,t) + \Sigma Q(r) \quad (1)$$

where n_e, T_e, q_e and ΣQ represent the electron density, temperature, heat flux and sources/sinks, respectively. The boundary conditions are set to be $q_e(0,t) = 0$ and $T_e(a,t) = 0$, where a is the plasma minor radius. For simplicity, we assume that the density is constant in this model.

The non-local transport model [2] has been formulated and successfully applied to the problems of transient responses, i.e., power switching and power modulation experiments in W7-AS. Extending the analysis of the heat pulse propagation, we here study the fast responses in plasma profile after the L/H transition. A generalized formula of the heat flux is employed as,

$$q_e(r,t) =$$
$$-\int_0^a n_e(r',t)\chi_e(r',t)K_f(r,r')[\lambda\nabla T_e(r,t) + (1-\lambda)\nabla' T_e(r',t)]dr'$$

where χ_e is the heat diffusivity. The kernel is chosen as

$$K_f(r,r') \equiv \frac{r}{r'}\left[C_{local}\delta(r-r') + C_{global}\frac{1}{\sqrt{\pi}l}exp\left\{-\left(\frac{r-r'}{l}\right)^2\right\}\right]$$

where l is the half width of non-local interactions, $\delta(r-r')$ is a delta function, and $\lambda(0 \le \lambda \le 1)$, C_{local} and C_{global} ($C_{local} + C_{global} = 1$) are numerical constants. The interaction of fluctuations with a short radial correlation length and those with a long correlation length ($\sim l$) is modeled into the kernel of integral. In the following calculations, the parameters are chosen as $\lambda = 0.5$, $C_{global} = 0.1$ and $l / a = 0.5$, and the electron density is fixed as $n_e(r,t) = 5 \times 10^{19}\mathrm{m}^{-3}$.

The energy transport equation Eq. (1) is solved under the condition given in the previous section, and the temporal evolution of the temperature profile after the L/H transition is analyzed. In this calculation, JET-like parameters, i.e., major radius $R = 2.85$m, minor radius $a = 0.95$m and heating power $P = 10$MW, are used. In H-mode regime, the diffusivity is reduced only in the edge region of the plasma ($r / a \ge 0.8$). At the L/H transition, the reduction of diffusivity is set instantaneously.

We investigate the transient response after L/H transition. Fig. 1 shows the temporal evolution of the electron temperature ΔT in the core region (at $r / a = 0.1$), where ΔT is defined as $\Delta T \equiv (T - T^L) / (T^H - T^L)$, which represents the deviation from L-mode temperature profile. The solid line and dashed line correspond to the non-local model and local model, respectively. The horizontal axis is normalized to the typical energy confinement time, τ. Now we set to be $\tau = 40$ msec. L/H transition occurs at $t / \tau = 0$. As soon as the transition in χ_e occurs in the edge region, the temperature of the core plasma responds. It's time scale is much faster than that in diffusion process. The non-local transport model reproduces the fast response in the core plasma after L/H (or H/L) transition [3]. From our simulation, it is found that $C_{global} = 0.1$ is enough to reproduce the fast responses observed in experiment. The fast responses reproduced by the non-local model is almost independent of the functional form of χ_e.

In summary, a transport model, in which the non-local effect is taken into account, was used to analyze the fast response after L/H transition. The fast response in the core plasma after L/H (or H/L) transition was reproduced based on this model. Our method provides a general model, by which other types of transient phenomena could be explained in a unified way.

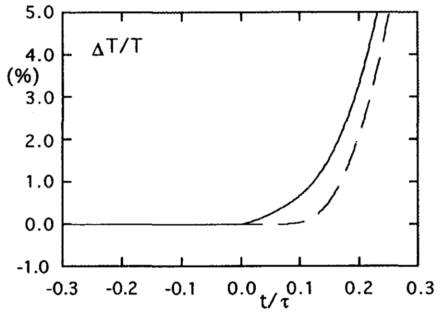

Fig.1 Transient response of the core temperature after the L/H transition. The result of the nonlocal model (solid line) reproduces a fast response, in comparison with conventional diffusive model (dashed line).

References
[1] Cordey, J. G., et al., Plasma Phys. Control. Fusion. **36** (1994) A267.
[2] Iwasaki, T., Itoh, S. -I., Yagi, M., Itoh, K., Stroth, U., J. Phys. Soc. Jpn. **68** (1999) 478.
[3] Iwasaki T., et al, IAEA-F1-CN-69/THP2/38 (1998).