§16. Transient Response of Electron Temperature to Abrupt Plasma Edge Cooling on LHD

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The perturbative transport analysis, in which the dynamic response of the plasma to a perturbation is considered, can obtain the local transport coefficient. The value obtained from transient analysis, however, is often different from the one obtained from the steady-state (power-balance) analysis in a Tokamak. The transient analysis usually gives a larger value. A dependence of the transport coefficient on the temperature gradient is one of the candidates used to explain this enhancement of the transport coefficient. Such a dependence on the temperature gradient leads to power degradation of energy confinement. In small-middle sized helical systems, the power degradation has been reported, however, such an enhancement of transport coefficient has not been observed[1]. Thus it is hoped that perturbative transport analysis in the LHD will clarify the enhancement of transient transport coefficient in a helical plasma.

To induce electron temperature perturbations, tracer encapsulated solid pellets (TESPELs) are injected to NBI plasmas on LHD, which have the following parameters: NBI power $\sim$ 2 MW, R_{ax} = 3.5-3.6m, B_{ax} = 2.75-2.95T, minor radius $\sim$ 0.6m, $\bar{n}_e = 1-2\times10^{19}\text{m}^{-3}$, $T_e(0)\sim$ 2keV, $\tau_E\sim$ 0.15s. The injected TESPEL ablates for the duration of 1-2 ms. After ablation, the line averaged density increases about 10%. This increase is consistent with the contribution from the total electrons brought to the plasma by the TESPEL. The total input power is kept constant and the change in the stored energy is less than 3% and thereby the global confinement is not affected by TESPEL injection. The TESPEL typically penetrates into the radial region of $r/a\sim$ 0.6. It provides cold electrons and impurity ions and thus reduce the electron temperature. The cold pulse resulting from the cooling of plasma travels inward on a time-scale of 10 ms. The relative T_e perturbation is 3-5% in the region of interest ($r/a<0.6$). A 32-channel heterodyne radiometer is used to track this small electron temperature perturbation. The local electron density increases in the ablation region ($r/a>$ 0.6) while it doesn't change in core region within the accuracy of the Abel inversion. The typical particle diffusivity $\sim 0.1\text{m}^2/\text{s}$, which is obtained from gas-puff modulation experiments[2], is much smaller than the typical heat diffusivity $\sim 1-3\text{m}^2/\text{s}$, and therefore the convection is neglected. The radiation loss is also unaffected in the region of interest. The perturbation of particle source and heat source are therefore negligible in this region. Hence the transport equation for the perturbation can be written as

$$\frac{3}{2}n_e\frac{\partial\delta T_e}{\partial t}=\frac{\partial}{r\partial r}\left(rn_e\chi\frac{\partial\delta T_e}{\partial r}\right). \quad (1)$$

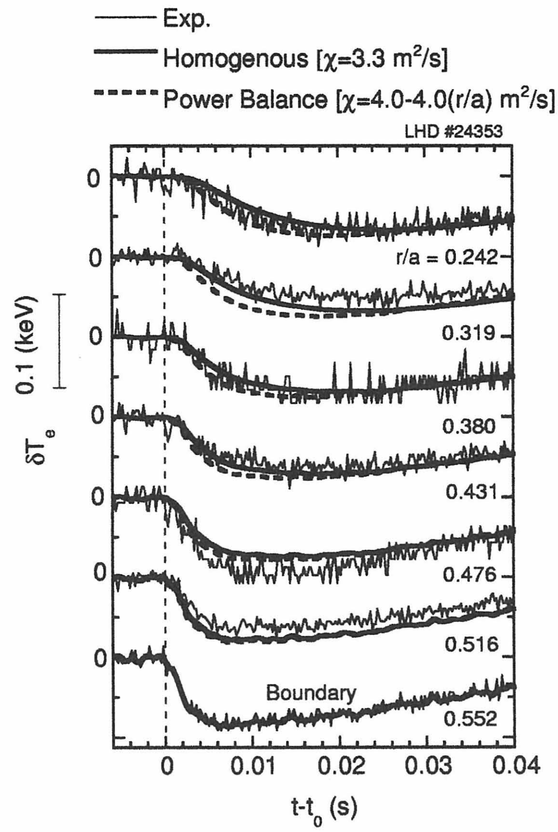

Fig. 1: Time evolution of electron temperature perturbation measured with heterodyne radiometer. The TESPEL is injected at $t=t_0$. The simulation results are also shown.

This equation is solved numerically and compared with the experimental result as shown in Fig. 1. The two different types of heat diffusivity model (homogenous, power balance) are assumed in the simulations. The power balance model is obtained from the radial profile of χ estimated from the power balance analysis in the same discharge. In the present circumstance, the homogenous model is better than the power balance χ. The heat diffusivity from transient analysis may depend on the employed model of χ. A more suitable model is left to future work. It must be emphasized still that the difference in the magnitude of χ between the homogenous model and the power balance model is small in the region of $0.552\geq r/a\geq 0.242$. Thus, an clear enhancement of heat diffusivity has not been observed in the cold pulse experiments on LHD.

[1]L. Giannone, et al. Nucl. Fusion **32**, 1985 (1992).

[2]K. Tanaka, et al. J. Plasma Fusion Res. Series **4**, 427 (2001).