§12. Electron Heat Transport Study by MECH in NBI Plasmas

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Transient transport analysis is recognized as a very powerful tool for understanding turbulence effects on transport. Thus, the heat pulse experiments have performed in LHD. In order to induce heat pulses, additional ECH power (400kW) is injected with 100%, 30Hz modulation. Typical parameters in this experiment are as follows: a major radius at the magnetic axis of 3.5m, a magnetic field at the axis of 2.83T, line-averaged density of $2 \times 10^{19} \text{m}^{-3}$, central electron temperature of 1.6keV and deposited beam power of 2.5MW. Fig.1 shows the radial profiles of amplitude and phase delay of heat pulses. The simulation results with a simple diffusive model are also shown. In this simulation, the perturbation equation written as:

$$\frac{3}{2} n_e \frac{\partial \delta T_e}{\partial t} = - \nabla \delta T_e$$  \hspace{1cm} (1)

is solved numerically by using the time-dependent boundary condition. Here $n_e$ is electron density, $\delta T_e$ is electron temperature perturbation and $\delta T_e$ is the perturbed electron heat flux modeled as:

$$\delta T_e = - n_e \chi_{e}^{\text{hp}} \frac{\partial \delta T_e}{\partial r} + \frac{3}{2} n_e V_e \delta T_e$$  \hspace{1cm} (2)

Here $\chi_{e}^{\text{hp}}$ is electron heat diffusivity and $V_e$ convective velocity for electron. The MECH power deposition is localized in the center of plasma ($r/a<0.2$) thus the heat source can be neglected for the study of heat pulse propagation in the region ($r/a>0.2$). For simulations the homogeneous $\chi_{e}^{\text{hp}}$ and $V_e$ are supposed to be homogenous in radial direction. The gradient length of temperature perturbation is assumed to be much larger than density perturbation, thus density perturbation is neglected.

The value of heat diffusivity $\chi_{e}^{\text{hp}}$ and convective velocity $V_e$ are obtained from the best fit of the simulation to the experimental result both in phase and amplitude. A simulation with heat diffusivity obtained from the power balance analysis is also performed.

The main results are as following:

1) The heat diffusivity $\chi_{e}^{\text{hp}}$ obtained from the power balance analysis can not explain both the amplitude and phase of the heat pulse propagation.

2) The $\chi_{e}^{\text{hp}}$ obtained from the transient analysis is larger than one from power balance analysis.

3) The best fit of simulation results with experimental data indicates that introduction of the convective term in

the electron heat flux is important to explain the observed the heat pulse propagation.

4) The heat diffusivity that obtained from transient analysis is much larger than the neoclassical diffusivity $\chi_{e}^{\text{nC}} \approx 10^{-2} \text{m}^2/\text{s}$.

The discrepancy between power balance analysis and transient analysis indicates that the heat diffusivity coefficient $\chi_{e}^{\text{hp}}$ has dependencies on plasma electron temperature gradient $\nabla T_e$ and electron temperature $T_e$ in LHD.

![Fig. 1. Radial profiles of phase delay and amplitude of heat pulses for discharge #45475. The phase delay is defined between $\delta T_e$ and modulated ECH power.](image-url)