§ 9. Heat Pulse Propagation Study of Annular Crash in CHS

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Perturbative transport experiments have been carried out in many tokamak plasmas using the temperature or density perturbation induced by the $q = 1$ sawtooth crash. In those experiments, the incremental electron heat diffusivity which is the diagonal element of the transport matrix was determined. However, the analysis is limited to a region outside the $q = 1$ radius. On the other hand, the heat and density pulses propagate both inside and outside the $q = 2$ radius due to the $q = 2$ annular crash. It is interesting from the viewpoint of the transport studies. We have investigated transport processes of $q = 2$ annular crash using a equation of electron temperature perturbation on an appropriate initial condition.

We use the simple diffusion equation regarding electron temperature perturbation expressed as follows:

$$\frac{3}{2}a^2 n_{e0}\frac{\partial \tilde{T}_e}{\partial t} = \frac{1}{\rho}\frac{\partial}{\partial \rho}\left(\rho n_{e0}\chi_e \frac{\partial \tilde{T}_e}{\partial \rho}\right),$$

where χ_e is the electron heat diffusivity. The initial condition of $\tilde{T}_e(\rho, t)$ expected to describe the annular crash is illustrated by the thick solid curve in Fig.1(a). ρ_s is the $q = 2$ inversion radius. ρ_{m1} and ρ_{m2} are the "inner" and "outer" mixing radii. For the conservation of total heat content, we must satisfy $\int_0^1 \tilde{T}_e(\rho, 0)\rho d\rho = 0$. A simulation results for the annular crash are shown in Fig.1. As can be seen from Fig.1(a), the heat pulse propagates both inward and outward from the crash layer at $\rho \simeq 0.45-0.55$. The change in SX profile $\tilde{I}_{cal}(\rho_{tan}, t)$ obtained by the line-integration of local SX emissivity reconstructs the nature of the annular crash in the experimental results (Fig.1(b)).

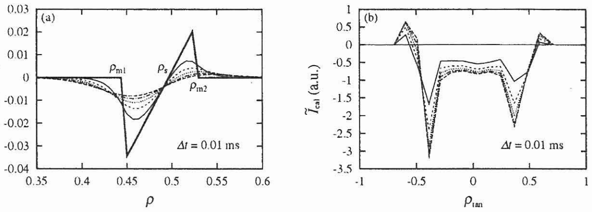

Figure 1 (a) Temporal evolutions of $\tilde{T}_e(\rho, t)$ due to the annular crash. (b) Temporal evolutions of $\tilde{I}_{cal}(\rho_{tan}, t)$. For these calculations, $\rho_{m1} = 0.45$, $\rho_s = 0.5$, $\rho_{m2} \simeq 0.53$ and $\chi_e = 1.0\,\mathrm{m^2/s}$, respectively.

For rough estimation of χ_e, we compare the arrival time of SX pulse peak t_p between experimental data and numerical one for various χ_e (uniform in space) in Fig.2(a). It should be noted that t_p in the experimental data around the $q = 2$ rational surface located on $\rho_{tan} \simeq 0.5$ is fairly long. This indicates the possibility for the reduction of χ_e around the $q = 2$ rational surface. On the other hand, χ_e is thought to be $1.0 - 2.0\,\mathrm{m^2/s}$ in the central region of $\rho_{tan} \leq 0.3$. Figure 2(c) shows the comparison of measured SX pulses with the best numerical fits, where χ_e profile shown in Fig.2(b) is used in calculation. The fitted data except neighborhood of the rational surface agree well with the experimental data. On the other hand, the discrepancy between measured data and numerical one is large around the rational surface. The numerical data near the rational surface is sensitive for the location and width of the initial $\tilde{T}_e$ profile. It is difficult to estimate initial $\tilde{T}_e$ profile due to the limitation of the spatial resolution of the SX signals ($\delta\rho \simeq 0.1$). The electron diffusivity profile which gives the best numerical fits in Fig.2(b) suggests the formation of ITB around the $q = 2$ rational surface. However, the electron temperature profile does not support the possibility of the formation of the ITB. Moreover, the obtained χ_e from the heat pulse propagation analysis is almost $\chi_e \simeq 1.0\,\mathrm{m^2/s}$ except $q = 2$ layer and is smaller than that expected from the equilibrium transport analysis χ_{pb} ($2.0 - 5.0\,\mathrm{m^2/s}$). The SX signal depends on the electron density, impurity levels and electron temperature. These contribution may slow down the radial propagation of the SX pulses.

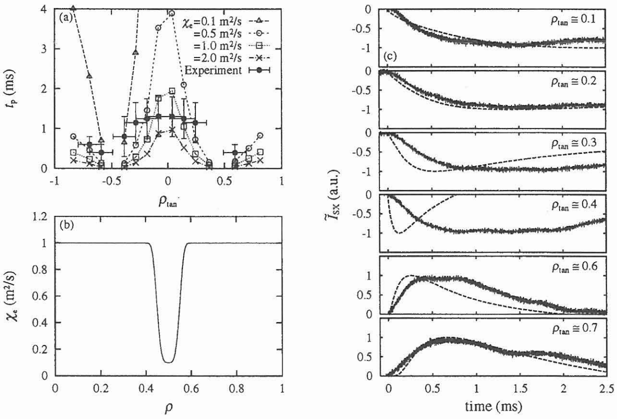

Figure 2 (a) Comparison of the arrival time of SX pulse between experimental data and numerical data (χ_e = 0.1, 0.5, 1.0 and $2.0\,\mathrm{m^2/s}$). (b) The electron diffusivity χ_e which gives the best numerical fits. (c) SX signals at various radial positions (solid curve), compared with the best numerical fits (broken curve).