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Nonlocal transport hysteresis in torus plasmas

T. Kobayashi[1,2]

[1] National Institute for Fusion Science, [2] The Graduate University of Advanced Studies, SOKENDAI

e-mail (speaker): kobayashi.tatsuya@nifs.ac.jp

Transient response of the electron thermal transport in the magnetically confined torus plasmas is one of the long-standing unsolved mysteries. Recently, emergence of the hysteresis in the flux-gradient relation was discovered [1, 2], involving rapid responses of turbulence intensity and turbulent transport to heating. A model that can describe the transport hysteresis was developed [3]. In order to examine the theoretical model, we performed several parameter scan experiments, including the heating power scan [1], the density scan [2], and the isotope mass scan [4]. In this paper, an overview of these activities in the Large Helical Device (LHD) is presented.

The transport hysteresis is analyzed in the flux-gradient relation. The core-focused modulation electron cyclotron resonance heating (MECH) is applied as the heat source perturbation, and the heat flux is evaluated using the energy conservation equation with the measured electron temperature response and the ECH deposition profile calculated by the ray-tracing scheme. In the heating power scan experiment, the MECH amplitude is scanned in 1 MW, 2 MW, and 3 MW. When the heating power is increased, the hysteresis widths in the flux-gradient relation and in the turbulence-gradient relation simultaneously increase [1]. This observation agrees well the theoretical prediction [3].

In the density scan experiment, the line averaged density is scanned by controlling the gas puff intensity in shot-to-shot manner. As the line averaged density increases, the hysteresis width almost monotonically decreases [2]. This density dependence in the hysteresis width is incorporated in the theoretical model by the density dependence on the ECH power absorption. The experimental results are qualitatively consistent with the prediction [3].

Finally, the experiments with different hydrogen isotope fuels, i.e., hydrogen (H), deuterium (D), and H-D mixed gas, are performed. Figure 1 (a) shows the flux-gradient relation for H, D, and mixed plasmas at just outside the ECH deposition radius. It is found that the hysteresis width does not depend on the isotope mass. Figure 1 (b) exhibits the line averaged density dependence of the transport hysteresis width. All three cases show an almost identical density dependence. In the prediction, a larger hysteresis is predicted in lighter hydrogen isotope plasmas with the assumption that the base plasma confinement is determined by the Bohm/gyro-Bohm model. However, in LHD, the thermal transport is considered not to follow the Bohm/gyro-Bohm scaling, and the confinement time is insensitive to the isotope mass [5]. Therefore, the strong isotope effect is not seen in the hysteresis width.

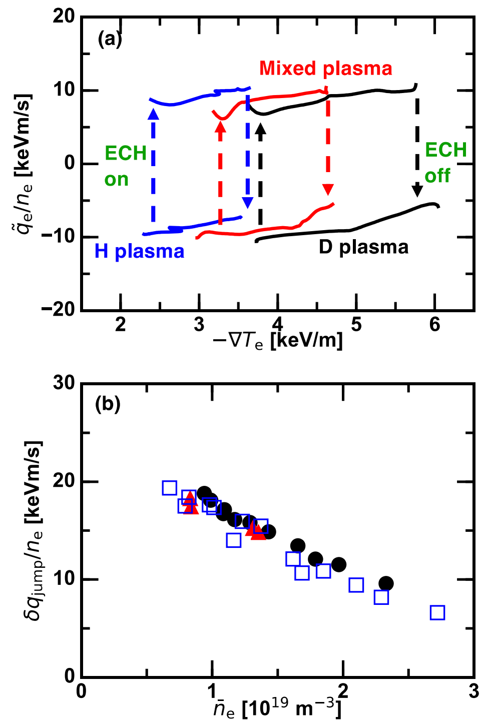

Figure 1. (a) Flux-gradient relation and (b) line averaged density dependence of the transport hysteresis width for H, D, and mixed plasmas at just outside the ECH deposition radius.

References

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