§6. Cross-comparison of Nonlocal Transport Phenomenon in LHD with that in HL-2A Tokamak

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An electron heat transport is one of the most vital aspects in magnetically confined toroidal plasmas, because it can govern the performance of a fusion reactor. Therefore the full understanding of the electron heat transport is absolutely essential for gaining a predictive capability to achieve high-performance fusion plasmas. Recent experiments and simulations in fusion research have revealed various features of the electron heat transport, such as its nonlinearity. However, there still are a number of outstanding issues in electron heat transport, such as its nonlocality. A surprising phenomenon, a core electron temperature rise in response to an edge electron temperature perturbation induced by a pellet injection and so on, which is extremely far from the local paradigm, is attributed to the nonlocality in transport. The core electron temperature rise in response to the edge perturbation has been firstly discovered in tokamak[1] and recently done in helical device, the LHD[2]. The studies on such a phenomenon have been performed extensively around the world, but the physical mechanisms on such a phenomenon still remain unclear. Therefore it is highly important to compare the experimental results from both devices related to the core electron temperature rise in response to the edge perturbation. Here, we shortly report results of cross-comparison of recently-revealed characteristics of the core electron temperature rise in response to the edge perturbation in between HL-2A tokamak[3] and helical device, the LHD.

Many similarities in the nonlocal core electron temperature rise in response to the edge perturbation between in LHD and HL-2A have been discovered. Firstly, the core electron temperature rise in response to the edge perturbation can be observed over and over again during one discharge and be prolonged by a sequential edge perturbation at short intervals. The prolongation of the core electron temperature rise was achieved by a combination of tracer-encapsulated solid pellet (TESPEL) injection and repetitive supersonic gas puff in LHD and by a consecutive supersonic molecular beam injection in HL-2A. It should be noted here that there are no observations in both devices so far that the core electron temperature rise effect builds up by the sequential edge perturbation at very short intervals. Secondly, the fluctuations are changed associated with the occurrence of the core electron temperature rise in response to the edge perturbation, although the details on those are different. In LHD, long-range fluctuations in electron temperature have been discovered in the plasma with the core electron temperature rise in response to the edge perturbation. The structural change in the long-range low-frequency fluctuation is observed after the edge perturbation. After the edge perturbation, the amplitude of that is reduced and the radial correlation length of that becomes shorter[4]. In HL-2A, turbulence spectra are changed rapidly after the edge perturbation. Just after the edge perturbation, the micro-scale turbulence is decreased and the meso-scale turbulence is increased. And the poloidal cross-correlation function of meso-scale turbulence is increased just after the edge perturbation. This suggests that meso-scale turbulence is elongated poloidally just after the edge perturbation. These results suggest that the spatial structure in the turbulence may play a significant role in the core electron temperature rise in response to the edge perturbation. Thirdly, the structural change in electron heat transport is observed after the edge perturbation. In LHD, a first-order transition (a discontinuity of the electron temperature gradient) of the electron heat transport is observed over a wide region in the peripheral plasma and a second-order transition (a discontinuity of the time-derivative of the electron temperature gradient) of the electron heat transport is also observed simultaneously over a wide region in the plasma core. Also in HL-2A, both the first- and second-order transitions of electron heat transport are observed in the plasma with the nonlocal core electron temperature rise in response to the edge perturbation, although the regions where those are observed are quite different from those in LHD. Nevertheless, experimental results from both devices clearly suggest the meta-stability of electron heat transport state have a crucial role on the core electron temperature rise in response to the edge perturbation.

Further detail analysis on the similarities and dissimilarities in the core electron temperature rise in response to the edge perturbation in both tokamak and helical device is a future task, which will definitely provide a clearer understanding on the nonlocality in electron heat transport.

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