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Hysteresis and Fast Timescale in Transport Relation of Toroidal Plasmas

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This article assesses the understanding of and impacts by the hysteresis of transport relation. The rapid changes of fluxes compared to slow changes of plasma parameters are overviewed for both edge barrier and core plasmas. The theoretical approaches to understand the direct influence of heating power on turbulent transport are addressed. The advanced data analysis method to search the hysteresis in gradient-flux relation is explained. Finally, the importance of transport hysteresis on the control system of fusion device is discussed.

The modulation ECH experiment, in which the heating power repeats on-and-off periodically, revealed the hysteresis and fast changes in gradient-flux relation. The decisive progress is that both the hystereses in the gradient-flux and gradient-fluctuation relations were observed simultaneously. Analyses of observations that can be interpreted as the hysteresis have been undertaken on various experiments: LHD, ASDXE-U, DIII-D, HL-2A, JFT-2M, JT-60U, KSTAR, TJ-II, and W7-AS. Hysteresis with rapid timescale exists in the channels of energy, electron and impurity, and plausibly in momentum.

The causes of hysteresis and fast timescale are discussed. The nonlocal-in-space coupling works here, but does not suffice. One mechanism for 'the heating heats turbulence'is that the external source S in phase space for heating has its fluctuation in turbulent plasma: S[f] = S[f0] + (dS/df) δf, where δf is the perturbation of distribution function. This coupling can induce the direct input of heating power into fluctuations. The height of the jump in transport hysteresis is smaller for heavier hydrogen isotope, and is one of origins of isotope effect on confinement.

Advanced methods of data analysis are overviewed. The transport hysteresis can be studied by observing the higher harmonics of temperature perturbation δTm in heating modulation experiments. The hysteresis introduces the term δTm , which depends on the harmonic number m in algebraic manner (not exponential decay).

The impacts of transport hysteresis on the control system are assessed. The control system must be designed so as to protect the system from sudden plasma loss. Thermonuclear instability due to fusion power is also discussed.

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