

§25. Study on Double Hysteresis Characteristic in L/H Transition

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Transition phenomena in plasmas (e.g., L/H Transition) are widely observed in various toroidal confinement devices. The hysteresis characteristic has been observed in the L/H transition. The model based on the electric field bifurcation has been proposed to understand the H-mode. In this study, multi-fold relation between the gradient and flux is predicted, i.e., the hysteresis characteristic was derived, considering the loss cone loss of ions and the anomalous loss. The transport barrier is predicted by this model, when the spatial structure was examined by use of the 1-dimensional model equation. At the edge, the periodic oscillation of the particle flux is obtained which corresponds to the dithering ELMs.

The hysteresis in the gradient-flux relation could be more complicated, when these mechanisms are simultaneously analyzed. For example, the 0-dimensional analysis in ref. [1] have compared the impacts from the loss cone loss, collisional bulk viscosity loss of ions and the anomalous loss. This study has shown that there exists a parameter regime where the five-fold solutions at the fixed gradient appear. This characteristic is namely called 'double hysteresis'. Due to double hysteresis, it was predicted the existence of 'compound dithers' in experiments. This result was obtained by use of the 0-d model. It is necessary to investigate what kind of dynamics and spatial structure is generated from these three important mechanisms in 1-d transport equations.

The plasma of our interest is restricted to the plasma boundary $-L < r - a < 0$. Plasma profiles are described by keeping the x -dependence, and the one-dimensional transport equation is employed.

We adopt two basic equations: One is the temporal evolution of the density. The other equation is the temporal evolution of the radial electric field. The set of equations is shown in dimensionless form as

$$\frac{\partial n}{\partial t} = \frac{\partial}{\partial x} (d(Z) \frac{\partial n}{\partial x}) \quad (1)$$

and

$$\epsilon \frac{\partial Z}{\partial t} = \hat{\Gamma}_e - \hat{\Gamma}_i + \mu \frac{\partial^2 Z}{\partial x^2}, \quad (2)$$

where $Z = e \rho_{pi} E_r / T_i$, E_r is the radial electric field, ρ_{pi} is the poloidal gyroradius and μ is the normalized value of the shear viscosity of ions. Here, $\hat{\Gamma}_e - \hat{\Gamma}_i$ represents the bipolar component of the particle flux. Here d is the normalized diffusivity of electrons which is modelled as the function of Z . The appropriate normalizations are done. We choose three mechanisms that causes the bipolar particle flux. At the plasma surface (i.e., $x=0$), we impose the boundary condition $n'/n = \text{const.}$ ($x=0$). From the core side, plasma flux is assumed to be constant. The particle flux from the core region (at $x=-L$) is treated as a parameter with $\Gamma = \Gamma_{in}$.

We solve Eqs. (1) and (2) with the boundary conditions. We find a solution with a limit cycle of the edge density $n(x=0)$ and the particle flux at the edge Γ_{out} . The temporal evolution of Γ_{out} is shown in Fig. 1. The L mode corresponds to the branch of the large flux and H mode is the branch of the reduced flux. If anomalous loss becomes small, then the contribution of the bulk viscosity loss of ions increases, so that the new hysteresis (C→D) is generated combined with the other hysteresis. In this way, the double hysteresis appears. The compound dither is again predicted in the case of the 1-D transport model equations, theoretically. In Fig. 2, temporal variation of the radial dependence of the effective diffusivity d is shown. The steep gradient of the effective diffusivity d is shown, which corresponds to H mode. The profile of the effective diffusivity d shows that the H mode is only recognized near the edge. In this case, a transport barrier with finite length can be seen in the radial profile of d . The transition from C to D obtained here occurs due to the bulk viscosity loss of ions. The radial width where the change of d can be seen do not change in the temporal evolution. Furthermore, even if the bulk viscosity flux of ions is neglected, the radial extent of the transport barrier is same as the case including the bulk viscosity flux of ions. It is found that the spatial-temporal evolution does not give the large change of the condition for the double hysteresis.

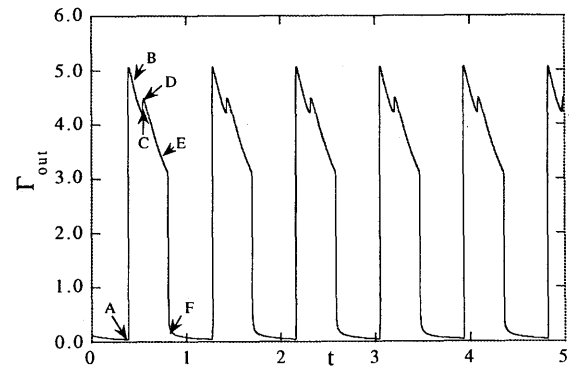


Fig. 1 Time trace for the outflux Γ_{out} .

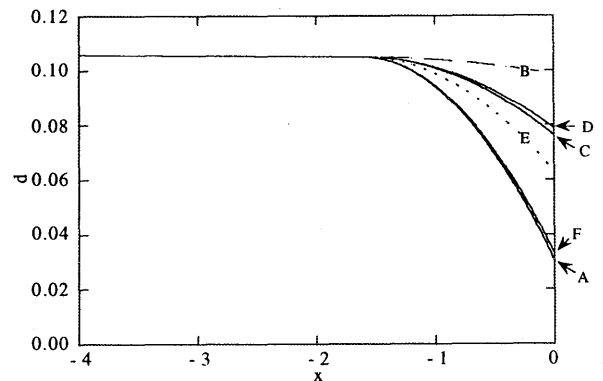


Fig. 2 The spatial profile of the effective diffusivity d .

Reference

- [1] S. Toda, et al.: Plasma Phys. Contr. Fusion. **38** (1996) 1337.