§26. Radial Electric Field Structure between Electrodes Separated by a Finite Distance in Tokamak Plasmas

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The transition from L-mode to H-mode is characterized by a sudden change of the radial electric field structure in tokamaks. Imposing a radial electric field at the plasma edge can also lead to an improved confinement state. In TEXTOR biasing experiments the spatial profile of the radial electric field measured at the plasma edge changed from a flat one before transition to a peaked one after transition.1) We analyze the radial electric field structure between electrodes to clarify the characteristic of improved confinement states.

A model equation for the radial electric field structure is derived from the charge conservation law. In stationary state a normalized form of the equation can be written as

$$\frac{\partial^2}{\partial x^2} X - f(X)X + I = 0, \qquad (1)$$

where $X = E_r/(v_{ti}B_\theta)$, $I = J_{ext}/(v_{ti}B_\theta\sigma(0))$, $x = (r-r_0)/l$, and $l = \sqrt{\mu_i\varepsilon_0\varepsilon_\perp/\sigma(0)}$. In the definition above, E_r is the radial electric field, J_{ext} is the electrode current, B_θ is the poloidal magnetic field, $\sigma(0)$ is the conductivity when the radial electric field is zero, and v_{ti} is the ion thermal velocity. Parameter X and I represent the normalized radial electric field and the normalized external current, respectively. The radius r_0 is chosen to be the mid-point between the two electrodes. Here all parameters that do not involve the radial electric field are treated as constants in space. The function $f(X)$ relates the conductivity and the radial electric field and has a dependency of the imaginary part of the plasma dispersion function. The first term on the left hand side of Eq.(1) is the contribution of anomalous shear viscosity. The radial electric field equation Eq. (1) is a nonlinear differential equation and is solved with the boundary condition $\partial X/\partial x = 0$.

The case of infinite distance between electrodes was described in Ref. 2 and a solitary radial electric field structure was derived. We extend the previous study to the case of finite distance between electrodes.3) In this case many structures with multiple peaks are allowed for the same boundary condition. The minimum value for the distance between electrodes exists, and this distance determines the number of solutions for the same applied voltage. Integrating the radial electric field gives the voltage between the electrodes. The relationship between the voltage and the current is obtained by numerical calculation, and the voltage and the current are determined by the intersection of this curve with the circuit equation (Fig.1). Both stable and unstable regions exist in stationary solutions, and these boundary points give critical points of transition from one state to the other. The existence of many solutions suggests the possibility of multiple transitions. Hysteresis is also predicted from this relationship.

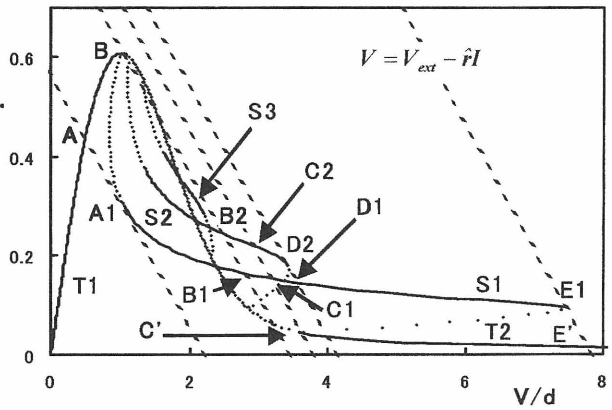

Fig.1 The relationship between voltage and current when $d=18$, $y=0.1$ and $\hat{r}=4.0$. A~E, A1, B', etc. denote intersections with or points of tangency to the circuit equation line $V=V_{ext}-\hat{r}I$ plotted as dashed lines. Solid lines are stable and dotted lines are unstable on each branch.

Reference

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2) K. Itoh, et al., Phys. Plasmas **5** (1998) 4121
3) N. Kasuya, et. al., J. Phys. Soc. Jpn. **71** (2002) 93