§21. The Radial Electric Field in a Tokamak with Reversed Magnetic Shear

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Neoclassical theory with the impurity rotational velocity is used to evaluate the radial electric field, E_r, in a tokamak [1]. Two transport measures of the effect of the E_r shear are compared for the reversed shear (RS) and enhanced reversed shear (ERS) discharges in Tokamak Fusion Test Reactor (TFTR) [2]. It is shown that the combined E_r and magnetic shear measure, Υ_s, from linear stability theory gives a higher correlation with the observed transition between the two discharges than the vorticity measure ω_s from E_r shear alone.

Figure 1 shows the radial electric field E_r calculated for the RS and ERS discharges. In both discharges, E_r radial profile has a 'well' structure inside the central region where the safety factor q is minimum. As time evolves, E_r 'well' develops from a rather shallow 'well' to much deeper one in both the RS and the ERS discharges. The E_r in the ERS discharge is significantly larger and steeper than that in the RS discharge at all the time stages.

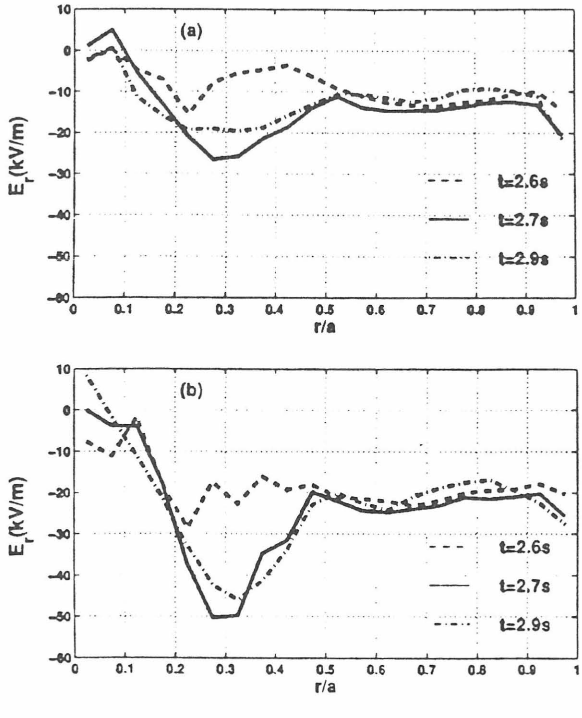

Fig.1. The time evolution of $E_r(r,t)$ for (a) the RS discharge and for (b) the ERS discharge at times before ($t = 2.6\,\mathrm{s}$) and after ($t = 2.7\,\mathrm{s}$, $2.9\,\mathrm{s}$) the bifurcation.

The Hahm–Burrell $\mathbf{E}\times\mathbf{B}$ flow shearing rate ω_s is given by

$$\omega_s = \frac{\Delta\psi_0}{\Delta\phi_0}\frac{\partial^2\Phi_0(\psi)}{\partial\psi^2} \simeq \left|\frac{RB_\theta}{B_\phi}\frac{\partial}{\partial r}\left(\frac{E_r}{RB_\theta}\right)\right|$$

where $\Delta\psi_0$ and $\Delta\phi_0$ are the ambient radial and toroidal correlation lengths measured in units of poloidal flux and radians respectively [3]. The other relevant measure of E_r shearing rate is the linear stability theory parameter

$$\Upsilon_s = \frac{\text{flow shear}}{\text{magnetic shear}} = \frac{L_{V_E}^{-1}}{L_s^{-1}} \simeq \sqrt{\frac{m_i}{T_e}}\left|\frac{R\partial_\psi(E_r/RB_\theta)}{\partial_\psi \ln q}\right|$$

which measures the stabilizing effects of $\mathbf{E}\times\mathbf{B}$ flow shear in sheared magnetic fields [4]. Figure 2 shows these two measures in the RS and ERS discharges.

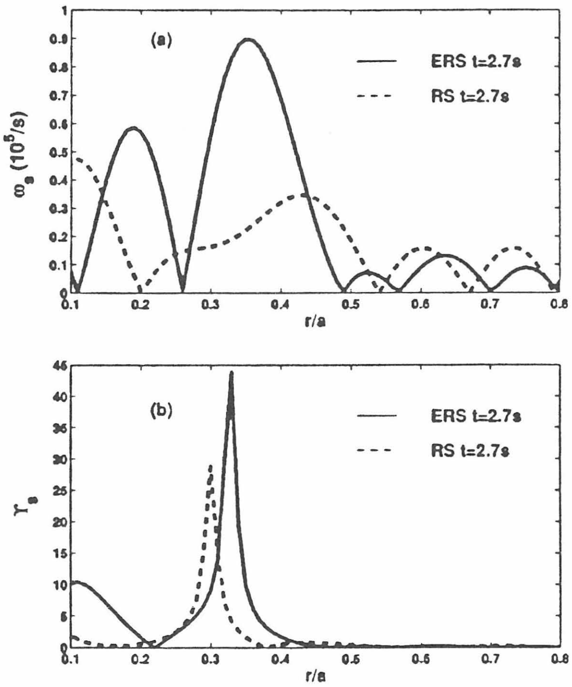

Fig.2 T(a) Comparison of the Hahm–Burrell shear rate in the RS and ERS discharge at $t = 2.7\,\mathrm{s}$. (b) Comparison of the linear stability measure Υ_s for the RS and ERS discharges.

References

1) Zhu, P., Horton, W., and Sugama, H. : Phys. Plasmas **6** (1999) 2503.
2) Mazzucato, E., *al.* : Phys. Rev. Lett. **77** (1996) 3145.
3) Hahm, T. S., and Burrell, K. H. : Phys. Plasmas **2** (1995) 1648.
4) Hamaguchi, S., and Horton, W. : Phys. Fluids B **4** (1992) 319.