§47. Density Profile in the Ergodic (SHC) Boundary

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A new boundary control scheme (SHC boundary) has been proposed, which could allow simultaneous achievement of the H-mode type confinement improvement and radiative cooling with wide heat flux distribution. In our proposed configuration, a low m island layer sharply separates a plasma confining region from an open "ergodic" boundary. The degree of openness in the ergodic boundary must be high enough to make the plasma pressure constant along the field line, which in turn separates low density plasma just outside the plasma confining region (the key external condition for achieving a good H-mode discharge) from very high density, cold radiative plasma near the wall (required for effective edge radiative cooling). An example of such proposed SHC boundaries for Heliotron typed devices is shown in Fig.1.

We examine the constant pressure assumption in the ergodic boundary (one of the key assumption of the SHC concept). In TEXT and Tore Supra experiments, however, inversion of the density profile has not observed in the ergodic boundary, which the observed normal temperature gradient there is expected to accompany through the effect of the constant pressure. This may be due to high anomalous diffusion and viscosity or ion-neutral collision, as discussed below.

In the ergodic boundary, the temperature profile is determined mainly by the electron parallel thermal conductivity and the power dissipation. For simplicity, we assume the temperature profile as illustrated in Fig.2(a). The radial particle flux ($\Gamma_r(r)$) in a steady state is determined by div $\Gamma = S$ (particle source) and is high near the wall and becomes low beyond the ionization zone. The Γ_r consists of the anomalous diffusion ($-D\nabla_\perp n$) and the parallel flow ($nu_\parallel$),

$$\Gamma_r(r) = -D\nabla_\perp n + \langle\delta b/B\rangle n u_\parallel \qquad \text{--- (1)}$$

where $\langle\delta b/B\rangle$ is the average angle of the field line toward the radial direction. This parallel flow may cause parallel momentum loss due to the anomalous viscosity and the ion -neutral collision, described as

$$-\nabla_\parallel P - Mn D^* \nabla_\perp^2 u_\parallel - Mn\nu u_\parallel = 0 \qquad \text{--- (2)}$$

where M is the mass of the bulk ion and D^* and ν are the viscosity and the ion-neutral collision frequency, respectively. Replacing $\nabla_\perp^2$ and $\nabla_\parallel$ by Δ^{-2} and $\langle\delta b/B\rangle\nabla_\perp$ respectively, Eq.(4) becomes

$$n u_\parallel = -\langle\delta b/B\rangle\nabla_\perp P \,/\, M(D^*\Delta^{-2}+\nu) \qquad \text{-- (3)}$$

Eliminating $nu_\parallel$ from Eqs.(1) and (3), we obtain

$$-\nabla_\perp P/P = (\Gamma_r + D\nabla_\perp n)M(D^*\Delta^{-2}+\nu)/2nT\langle\delta b/B\rangle^2 \qquad \text{---- (4).}$$

Here $P = 2nT$ is assumed. Eq.(4) is rewritten as

$$\nabla_\perp n/n = [-\nabla_\perp T/T - \eta\Gamma_r/nD] \,/\, (1+\eta) \qquad \text{-(5)}$$

where $\eta = D(D^*\Delta^{-2}+\nu)/v_{thi}^2\langle\delta b/B\rangle^2$. The density scale length $(\nabla_\perp n/n)^{-1}$ is plotted as a function of η in the Fig.2(b). When $\eta \ll 1$, $\nabla_\perp n/n \approx -\nabla_\perp T/T$, i.e., the constant pressure assumption is valid. For the opposite extreme case ($\eta \gg 1$), the conventional relation $\Gamma_r \approx -D\nabla_\perp n$ is recovered. This constant pressure condition ($\eta \ll 1$) provides the key information as to how to generate a SHC boundary in real devices.

Fig.1

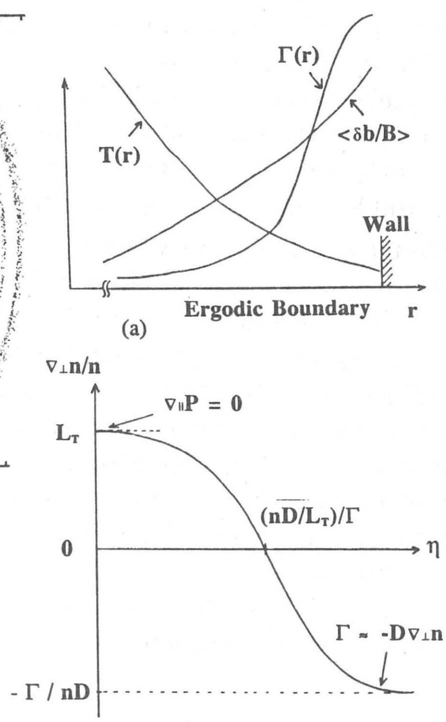

Fig.2 (b)