§33. Possibility of Simultaneous Achievement of Edge Radiative Cooling and H-mode Type Confinement Improvement in the LID Configuration

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Simultaneous achievement of good H-mode and edge radiative cooling has been done in some of the present tokamak divertor discharges (Fig. 1(a)), but very unlikely in reactor grade devices because of expected higher heat flux in the divertor channel of small volume (~ 1 % of V_p (plasma core volume)). The LID configuration without divertor head appears to be ideal for this purpose, as discussed below. If the closed surface region is surrounded by a large volume (~ 10 % of V_p) ergodic boundary with $\nabla_{\parallel} p = 0$, then it is, in some sense, equivalent to the poloidal divertor configuration with large divertor volume and may achieve both H-mode and radiative cooling with wider heat spread. The major assumption here is that the key condition for generating and maintaining an H-mode is low density or short density scale length at the last closed flux surface (LCFS). In the ergodic region, the parallel electron heat transport is dominant and the temperature decrease towards the wall for the collisional divertor plasmas. If the pressure is constant in the ergodic region, the density, in turn, increases toward the wall, the key requirement of the edge radiative cooling. The pressure may be constant in the ergodic region when

$$\tilde{b}/B > (DD^*)^{1/2} / (v_{th}\Delta^*) \quad \text{---} \quad (1)$$

Here D and D* are coefficients of diffusion and viscosity, respectively, v_{th} is the ion thermal velocity and Δ^* is the radial characteristic length of the ergodic structure. This condition is derived as follows: If the density profile inversion exists, then inward anomalous perpendicular particle flow appears and thus the continuity of the particle flow generates outward parallel flow, which causes the viscous force in the parallel momentum balance and thus tends to make $\nabla_{\parallel} p$ non-zero.

In a simple ergodic boundary, the ergodic region may consist of two regions, depending upon degree of ergodicity, as illustrated in Fig.1(c) . In the outer ergodic region with $\tilde{b}/B$ high enough to satisfy Eq.1, the pressure is constant and hence a decrease in the temperature with radius means inversion of the density profile required for the radiative cooling. In the inner ergodic region, $\nabla_{\parallel} p$ is non-zero, but the induced electron thermal diffusivity (χ_{erg}) is still high compared with naturally existing $\chi_{natural}$ and thus the so called H-mode pedestal never appears in this region. Since the particle transport is less sensitive to the ergodic field, the density profile has negative gradient and the density at the LCFS (the boundary between the inner ergodic and the closed regions) may no longer be low, preventing formation of a stable H-mode. When a low m single island layer is located in the inner ergodic region (Fig.1(b)), then the temperature and density are constant along the island and thus a density at the LCFS can be maintained low. The low m island serves to sharply separate the closed surface region from the high density, radiative boundary with $\nabla_{\parallel} p = 0$. The local island divertor (LID) configuration in the LHD is one of divertor geometries with such a superior capability.

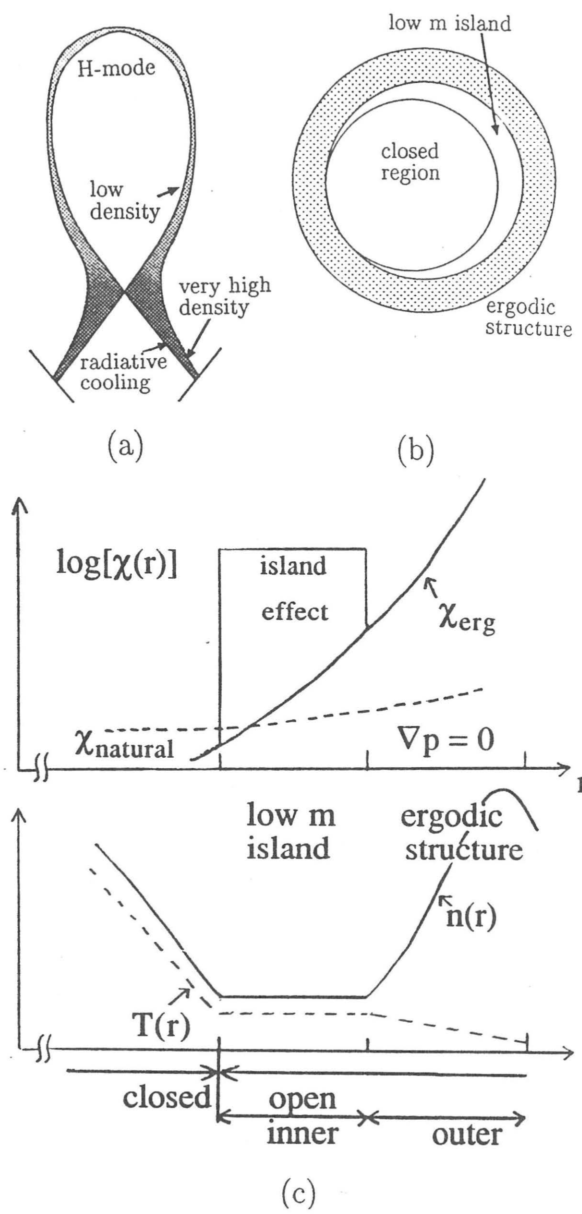

Fig.1 Sharp separation of the closed surface and the high density, radiative boundary.
(a) Conventinal poloidal divertor.
(b) Ergodic boundary with low m island.
(c) T, n, χ profiles in the proposed configuration.