§19. Role of Pfirsch-Schlüter Current in Edge Transport Barrier Region with Resonant Magnetic Perturbations

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Suppression or mitigation of edge localized modes (ELMs) excited in edge transport barrier region (ETB) is successfully done in many large tokamaks [1] and LHD [2] by application of resonant magnetic perturbations (RMPs). It is of importance to clarify the interaction between ETB and RMPs for development of an optimized control technique. With an increase in applied RMP amplitude in ETB/pedestal region, magnetic islands in ETB tend to overlap with neighboring islands. This leads to generation of stochastic field region there.

In the magnetic configuration R_{ax}=3.9 m (R_{ax}: magnetic axis position in the vacuum field) on LHD, large amplitude ELMs are excited by resistive interchange modes destabilized at the $\iota/2\pi$=1 surface [2]. When RMPs with m=1/n=1 (m, n: poloidal and toroidal mode numbers) are applied to the H-mode plasmas above a certain threshold magnitude, large ELMs with low repetition frequency are converted to high frequency and small ELMs without substantial loss of confinement improvement [2]. Figure 1 shows the MHD equilibrium which is calculated by the HINT2 code [3] using experimentally data without an

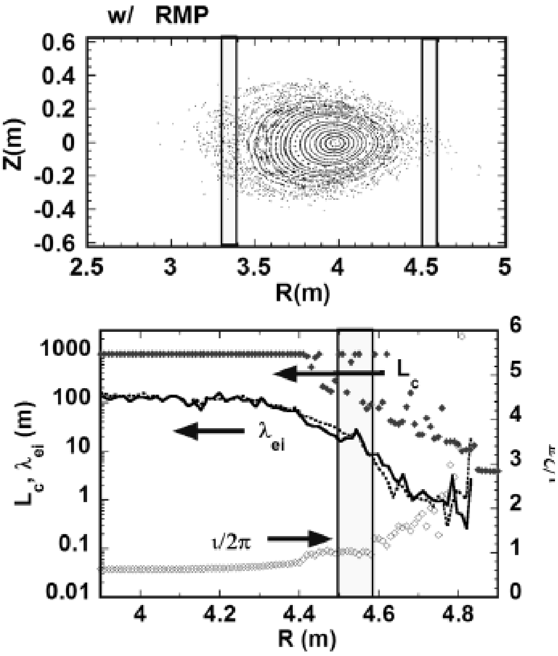

Fig.1 (Upper) Poincaré plot of field lines. (Lower) Radial profiles of the rotational transform ($\iota/2\pi$), connection length (L_c) and electron mean free path(λ_{ei}). The vertical bands in the figures indicate the ETB location.

assumption of the existence of nested magnetic surfaces. RMPs generate stochastic field region (SFR) around the $\iota/2\pi$=1 rational surface which locates at the foot of ETB [2]. Note that the penetration depth of applied RMPs is estimated to be comparable to the ETB width [2]. The SFR is formed due to overlapping of higher order islands such as m=11/n=10, m=9/n=10 and so on, which are generated by Pfirsch-Schüter (P-S) current in ETB having an N=10 field period. P-S current plays a critical role in generation of SFR around ETB in a helical device with large N such as LHD.

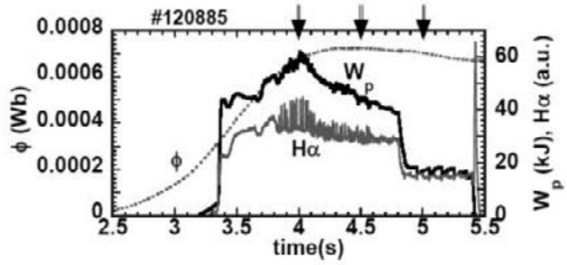

Fig.2 Time evolutions of plasma stored energy, Hα-emission and radial flux loop signal.

The above-mentioned effect of P-S current in edge plasma becomes clear in an H-mode plasma where RMPs are applied with a ramp-up wave form, as shown in Fig.2. In this H-mode, RMPs increase from t=2 s and reach the flat-top at t~4 s. The plasma is heated by NBI till t=4.8s, and its power is stepped down to less than 30% of the initial power. Radial profiles of electron pressure (P_e) obtained by a multi-channel Thomson scattering system are shown in Fig.3, at three time slices: t=4.0 s, 4.5s and 5.0 s. The P_e profiles at t=4.0 s and 4.5s in the H-phase exhibit

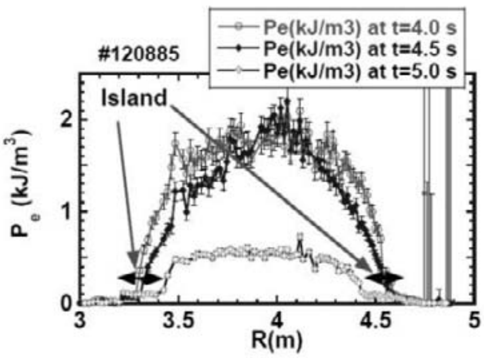

Fig.3 Radial profiles of electron pressure at three time slices: t=4.0 s and 4.5 s in H-phases and t=5.0s in low plasma pressure phase.

steep pressure gradient in ETB region with appreciable magnitude of RMPs. These are similar to the case shown in Fig.1, and the SFR is thought to be formed in ETB region having steep pressure gradient. On the other hand, P_e profile has a sizable magnetic island at the $\iota/2\pi$=1 rational surface at t=5.0s where plasma pressure is very low. That is, SFR is not formed due to very small P-S current and only a sizable island is formed by applied RMPs.

1) A. Loarte et al., Nucl. Fusion **54** (2014) 03307.
2) K. Toi et al., Nucl. Fusion **54** (2014) 033001.
3) Y. Suzuki et al., Nucl. Fusion **46** (2006) L19.