03pA04

LHDにおける共鳴磁場摂動による大振幅ELM制御実験結果のトカマクとの比較検討

Comparison Study of ELM Control Results by Resonant Magnetic Perturbations in LHD Plasmas with Those in Tokamaks

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In D-T burning plasmas having high pedestal temperature, suppression or mitigation of edge localized modes (ELMs) is required for machine safety and good plasma performance. Various ELM control techniques are being developed in many tokamaks. In particular, 3D magnetic field perturbations (MPs) applied externally can successfully suppress or mitigates large amplitude ELMs[1-3]. The results are interpreted that field stochastization in the pedestal region by the MPs would control ELMs. However, the mechanisms are still unclear. Study of 3D MP effects on ELMs in helical plasmas may give us insights into the understanding. Recently, large amplitude ELMs were clearly mitigated by application of resonant magnetic perturbations (RMPs) on LHD [4]. The ELMs on LHD are thought to be induced by resistive interchange modes (RICs), instead of peeling/ballooning modes in tokamak H-modes[5].

In Fig.1, discharge behavior with m=1/n=1 RMP application is compared with that without RMPs, where ELMs are induced by RICs destabilized at the rational surface $\iota/2\pi=1$ near the foot of edge transport barrier (ETB). RMPs clearly mitigate impacts of ELMs, that is, the relative drop of stored energy $\Delta W_p/W_p$ is reduced from ~20% down to ~5% or less, having an increased ELM repetition frequency by more than a factor of 5. The ETB is most prominent in density profile but is not clear in electron and ion temperature profiles. The ETB width is r/a~0.1(a: averaged minor plasma radius). The ETB is destroyed by each large ELM in the case without RMPs. In the case with RMPs, the ETB is partially destroyed by mitigated ELMs. MHD equilibrium was calculated by the HINT2 code [6] in order to infer how much radial extent RMPs penetrate into plasma edge region and affect magnetic field structure there. Figure 2 shows the calculated Poincare plot of field lines and radial profile of the connection length in the H-mode with RMPs. The ETB indicated by shaded zones near the edge is in stochastic field region (SFR). This result that ETB is in SFR is consistent with the experiment, because applied RMPs obviously modify the pressure profile in the ETB region. Note that as seen from Fig.2 SFR and island chain zone expands further interior beyond the ETB region (R<4.5m). This is caused by Pfirsh-Schlüter current in 3D plasma with large field period number N=10. The existence of such extended SFR is not clarified experimentally yet, so far. In this talk, details of ELM mitigation on LHD are presented and the differences and similarities to the results in tokamaks will be discussed.

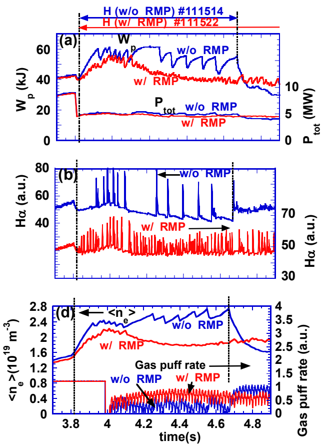

Fig.1 Discharge behaviors with and without RMPs, where the plasma stored energy W_p, total absorbed power P_{tot}, H_α emission, line averaged electron density $<n_e>$ and gas puff rate are shown.

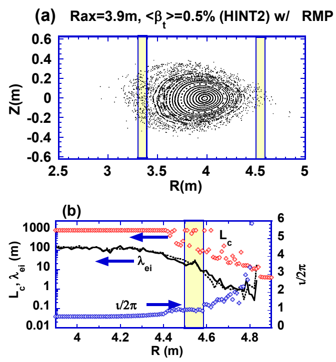

Fig.2 (a)Poincare plot of the plasma with RMPs calculated by HINT2 code, (b)profiles of the calculated connection length and $\iota/2\pi$ together with electron mean free path.

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