L-H Transition Dynamics with Applied n=3 Resonant Magnetic Perturbations*

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In ITER-similar plasmas in DIII-D ($<n_e>$=1.5-5x10^{19}m^{-3}, B_t=1.9-2T, I_p=1.5MA, q_{95}~3.6), the L-H threshold power P_{LH} with n=3 Resonant Magnetic Perturbations (RMP) is found to increase strongly with decreasing collisionality, a concern for H-mode access in primarily ECH-heated ITER plasmas since RMP may be applied before the L-H transition in ITER to safely suppress the first ELM. Low edge collisionality is thought to lead to substantial additional thermal losses across the last closed flux surface in ITER, potentially increasing the L-H power threshold [1]. Figure 1 clearly shows that P_{LH} increases at low collisionality, and that the collisionality dependence of P_{LH} is much more pronounced with applied RMP [P_{LH}~$(\nu^*)^{-0.3}$] compared to non-RMP plasmas [P_{LH}~$(\nu^*)^{-0.1}$]. Pronounced non-axisymmetric modifications of the L-mode shear layer with RMP include a substantial local reduction of the E_r well and ***E*x*B*** shear [in particular the outboard ***E*x*B*** shear layer is locally "eroded" for flux tubes connecting to high I-coil perturbation field]. Two-fluid modeling with the M3D-C1 code [2] shows that the normalized radial density gradient a/L_n is toroidally modulated and periodically increased on the outboard midplane with RMP. Low-wave-number turbulence is spatially modulated with RMP and increases substantially in amplitude on field lines connecting to high RMP perturbation field. We conjecture that the increase in P_{LH} with RMP results from the combined effects on locally enhanced instability drive (via increased normalized density gradient) and reduced ***E*x*B*** shear. Theoretically, increased Reynolds stress would be required to initiate the L-H transition with RMP active [3], as the Reynolds stress [4] is counteracted by radial forces related to the RMP field structure. The observed increase of the L-H power threshold may be consistent with this picture, as the observed local turbulence increase with applied RMP may not substantially increase the flux-surface-averaged Reynolds stress. Non-resonant n=3 perturbations do not affect P_{LH} significantly, and the modifications in turbulence level and ***E*x*B*** shear are minimal.

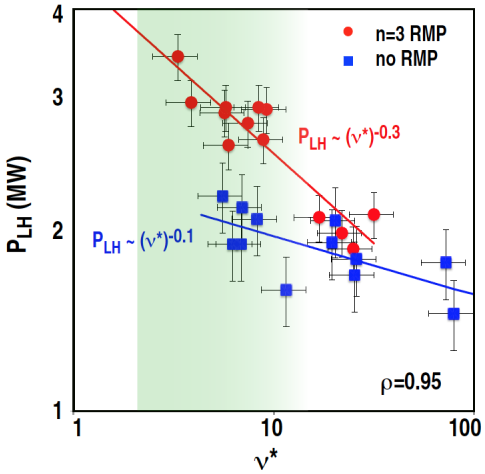

Fig. 1: L-H transition power threshold P_{LH} vs. collisionality ν^* ($\rho = 0.95$) without and with applied n=3 RMP ($3.3\times10^{-4} \le \delta B/B \le 4.6\times10^{-4}$ The expected ITER L-mode edge collisionality range is shaded.

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[2] R.S. Wilcox et al. Nucl. Fusion **57** 116003 (2017).
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