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EX/P4-22: Characterization of Neo-classical Tearing Modes in High-performance I-Mode Plasmas with ICRF Mode Conversion Flow Drive on Alcator C-Mod

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Neo-classical tearing modes (NTMs) have been observed definitely for the first time on Alcator C-Mod. The NTMs occur in high performance I-mode plasmas that are heated by a combination of ICRF D(H) minority heating at 80 MHz and D(He3) mode conversion (MC) heating at 50 MHz. I-mode plasmas have confinement as good as H-mode but lower collisionality [1]. Due to the stabilizing effect by the energetic minority hydrogen ions, long sawtooth (>=40 ms) and large sawtooth crashes (delta T_e0 >= 3 keV) are produced in these hot (T_e <= 9 keV) plasmas. A typical case is that soon after the plasma enters I-mode, a (m = 4, n = 3) mode (f = 40-60 kHz) appears following a large sawtooth crash, and then a (3, 2) mode (20-40 kHz) appears later at slightly higher beta_N. The (3, 2) mode can also occur without a preceding (4, 3) mode. In some plasmas, a (2, 1) mode may appear simultaneously with the (3, 2) mode, and lead to disruption. The onset criterion of the (3, 2) NTMs approximately follows that obtained from DIII-D and ASDEX Upgrade [2]. The onset parameters are beta_p ~ 0.4-0.7, beta_N ~ 1.0-1.4, beta_N/rho_i^* ~ 200-350, nu (q=3/2) ~ 0.04-0.25. The saturated magnetic island width of the (4, 3) mode is typically W_sat ~ 0.4-0.6 cm, and the mode usually has an insignificant effect on confinement. For the (3, 2) mode, W_sat ~ 0.8-1 cm, which is 3-4 times the ion banana width, and the mode can cause small confinement degradation (delta_beta/beta ~ a few percent). The NTMs have a strong effect on plasma rotation. MC flow drive generates large toroidal rotation above 100 km/sec in L-mode [3], and when the plasma enters I-mode, plasma rotation is expected to increase significantly due to the additional intrinsic rotation torque from the edge Te pedestal. However, the rotation almost always stops rising after the onset of the NTM(s). The appearance of the (3, 2) mode usually rapidly reduces the rotation speed, and the (2, 1) mode, if occurs, would completely halt the rotation. We will discuss the prospect of NTM avoidance and control using ICRF to modify sawtooth plus using lower hybrid waves to modify the local current profile.

[1] D.G. Whyte et al, Nucl. Fusion 50, 105005 (2010).
[2] R.J. La Haye, Physics of Plasmas 7, 3349 (2000).
[3] Y. Lin et al, Nucl. Fusion 51, 063002 (2011).

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