Suppression of Tearing Modes by Means of Localized Electron Cyclotron Current Drive in the DIII-D Tokamak*

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Tearing modes with a poloidal mode number (m) of 3 and a toroidal mode number (n) of 2 have been suppressed successfully using electron cyclotron current drive (ECCD) in the ASDEX-Upgrade [1], JT-60U [2], and DIII-D [3] tokamaks. Of these, only the DIII-D experiments show suppression in the presence of large amplitude sawtooth instabilities which play a role in the triggering of the tearing modes. A theoretical description of the effects of ECCD on the tearing mode amplitude is given by the modified Rutherford equation [4,5]. The two basic elements of the interaction of the ECCD with the islands have been verified in DIII-D experiments. The current must be localized spatially at the island O-point. Furthermore, the power required for stabilization is a sensitive function of both the relative location of the ECCD and the island and the characteristic widths of the island and the ECCD.

The sensitivity of the suppression to the relative locations of the ECCD and island motivated the development of a closed-loop feedback scheme to optimize the suppression. The scheme works by initiating either a rigid body shift of the plasma or a variation of the toroidal magnetic field. The change in amplitude of the tearing mode is detected and the shifted plasma or the field changed to minimize the amplitude. Both methods of optimizing the suppression have been successfully demonstrated in DIII-D. The weakness of this scheme is that changes in the relative location of the q=1.5 flux surface where the m=3/n=2 island would form and the ECCD location go undetected during periods of full suppression. A real-time equilibrium reconstruction has been implemented in the DIII-D control system, which will allow predictive tracking of the q=1.5 surface. A feedback system employing this additional capability is under testing.

The benefits of active tearing mode suppression include the potential for operation at higher β while maintaining high confinement. An increase in plasma β up to 50% higher than the level obtained with the saturated m=3/n=2 island has been demonstrated. Further increases in β may be possible using the real-time tracking system described above. The increased β in the absence of tracking resulted in a return of the m=3/n=2 island rather than a different mode, such as the m=2/n=1 mode.

Initial attempts to suppress the more dangerous m=2/n=1 mode with ECCD resulted in only a partial decrease in the mode amplitude. Calculations of the power requirements to suppress the mode indicate the power available at the time of the experiments was marginal. Experiments with higher power will be reported.

[1] G. Gantenbein, et al., Phys. Rev. Lett. **85**, 1242 (2000).
[2] A. Isayama, et al., Plasma Phys. Control. Fusion **42**, L37 (2001).
[3] R.J. La Haye, et al., accepted for publication in Phys. Plasmas (2002).
[4] C.C. Hegna, J.D. Callen, Phys. Plasmas **4**, 2940 (1997).
[5] H. Zohm, Phys. Plasmas **4**, 3433 (1997).

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