Threshold Effect In Tearing Mode Stabilization

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Since the suggestion that magnetic islands produced by tokamak tearing modes might be stabilized by non-inductive currents [1], a great number of experimental, theoretical, and computational efforts have been exerted. The most studied non-ohmically produced currents for stabilizing the tearing mode, particularly the neoclassical tearing mode, are the lower hybrid current drive (LHCD) [2] or the electron cyclotron current drive (ECCD) [3]. Both exploit the fact that a high current drive efficiency is obtained when the rf waves are damped in plasma by superthermal electrons. The stabilization effect relies upon rf waves driving current preferentially at the island center. There is some geometrical advantage in that there is more area to drive current near the O-point than near the X-point, but to improve the differential absorption might require precise steering and modulation of the rf waves to coincide with a rotating island.

The islands will affect the wave propagation and damping, and, most importantly, the islands thermally insulate the plasma contained within them [1]. This insulation has a profound effect, because it allows an important feedback mechanism for the dissipation, with stark differentiation between the island interior and the island periphery. Absent radiation, the island is always hottest in the center, since it can only lose heat through its boundary, while the heating occurs internal to the boundary. The island boundary, comprised of the same field line, is thus necessarily at one temperature, namely the lowest temperature. A second effect arises from the very sensitive dependence of the rf wave power deposition on the electron temperature, either in the case of LHCD or ECCD. The combined effects produce positive feedback, since the hot center attracts more power deposition which in turn makes it hotter yet. In fact, the strength of the stabilizing effect of rf-driven currents displays a sharp threshold in the rf power density, with the stabilizing effect dramatically enhanced when the threshold power density is exceeded.

Why is this important? Among other reasons, meeting this threshold through the combined effect can reduce the dependence of the stabilization on accurate steering of the RF wave deposition layer. Considering the complications in steering these waves, reducing this dependency, if not eliminating entirely its necessity, could be critical in stabilizing plasma in a reactor.

References

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