Tearing Under Stress – The Collusion of 3D Fields and Resistivity in Low Torque H-modes*

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New processes have been identified in the interaction of 3-D fields with tearing mode stability in tokamaks that pose challenges for H-modes even at modest β. These arise from the plasma resistive response at the tearing resonant surface, and an interaction with the natural tearing instability.

Sensitivity to 3-D fields is found to depend on proximity to the natural tearing limit on DIII-D and NSTX. An increasing magnetic response develops as normalized β rises, even at very modest values ~1.4. The field required to induce modes tends to zero as the tearing limit is approached. The response is enhanced at low rotation, where fields of just 1-2 Gauss induce modes in ITER-like H-modes, well below thresholds in Ohmic plasmas, making ITER error field correction requirements even more stringent. The interpretation is confirmed by modeling with the MARS-F and M3D-C1 codes, which show the usual plasma screening response breaking down at low rotation, introducing a resistive response and further dependencies on β and the current profile.

Both resonant (n=1) and non-resonant (n=3) fields lead to modes at similar field amplitudes, and paradoxically, the interaction is found to lead to rotating modes more often in lower torque plasmas. This is attributed to the fields reducing flow shear, and decreasing inherent tearing stability. Thus mode onset can be considered in terms of a torque balance. On this basis new measurements of the main scalings for field thresholds to induce modes have been obtained in torque free H-modes. These have similar dependences to Ohmic plasmas, but with 7 times lower threshold at the ITER baseline β, and a linear dependence on proximity to the tearing normalized β limit (~2.2 at zero torque). This reinforces the needs to optimize error field correction and torque injection in ITER.

*Supported by the US DOE under DE-FC02-04ER54698.