Locked Modes Controlled on Alcator C-Mod

Experiments with non-axisymmetric control coils show favorable scaling for large tokamak reactors.

An ideal tokamak has magnetic fields that are perfectly axisymmetric, giving a plasma that looks exactly the same from every position around the torus. However, a practical tokamak has small deviations from this toroidal symmetry that can have dominant effects on the plasma by braking its toroidal rotation and by causing instabilities. Such an instability can grow into a large field disturbance called a "locked mode" which degrades the confinement and can lead to a plasma-terminating disruption. Because the underlying mechanisms that control locked modes are not understood, we must rely on experiments to establish how small the asymmetries in future experiments must be to avoid problems. The scaling with tokamak size is particularly difficult to establish, but critically important for a large machine such as the planned ITER.

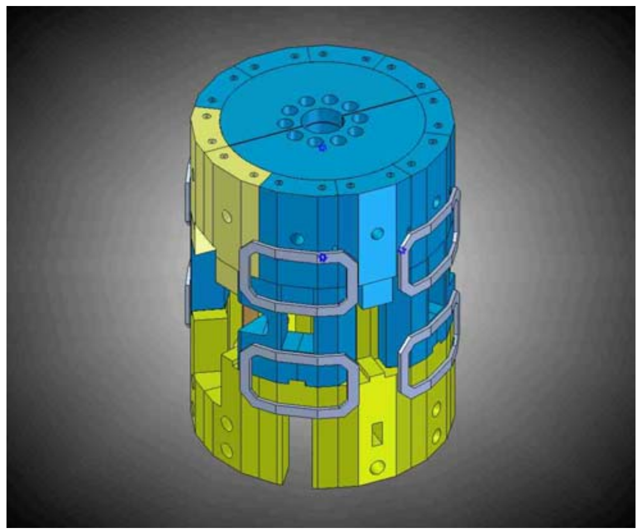

Fig. 1 –Controlled field perturbations are produced by an array of rectangular coils mounted outside the tokamak.

Alcator C-Mod has carried out experiments applying controlled field perturbations, using special coils constructed for this purpose (Fig 1), to determine the permissible asymmetry level. It is found that perturbations smaller than one part in 10,000 are sufficient to cause locked modes. This level is approximately 10 times smaller than was predicted by some versions of the size scaling derived from results elsewhere, and the fractional level is approximately the same as on JET, a tokamak 5 times larger. This is a highly favorable result for ITER because it implies there is no strong scaling of the required field accuracy with plasma size.

Using the perturbation coils to correct for intrinsic asymmetries, C-Mod has been able to avoid locked modes and disruptions and substantially extend its operating space (Fig 2).

Please see paper FP1.008, "Non-axisymmetric Field Effects on Alcator C-Mod"

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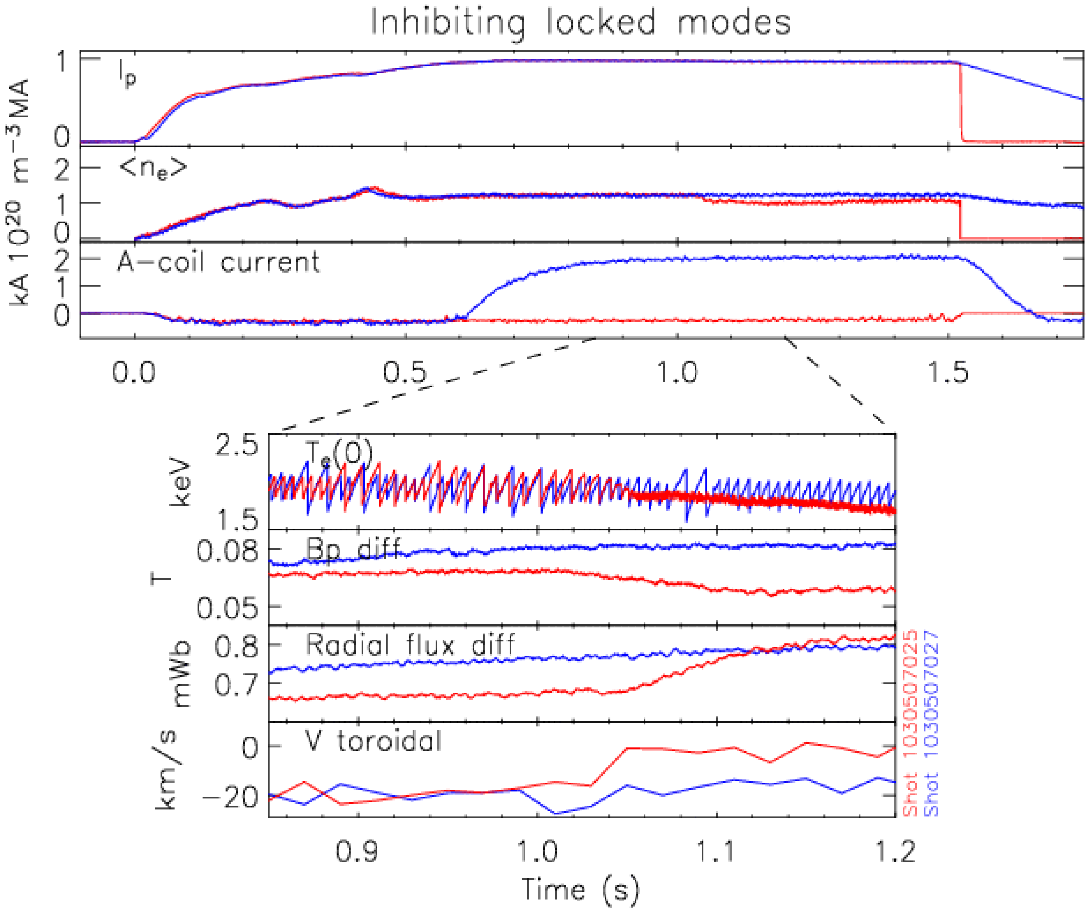

Fig 2 – Red case: A low-density, 1 MA discharge, exhibiting a naturally-occurring locked mode starting at t=1.05 s (note changes in plasma B-fields, sawteeth, plasma rotation), followed by a major disruption. Blue case: Same plasma parameters, but with control coils turned on. Mode locking and the ensuing disruption are avoided.