New Control Coils Improve Plasma Stability

Internal control coils recently installed in the DIII–D tokamak may open a new path to sustained operation of high-pressure plasma.

The DIII–D tokamak has received a set of internal control coils. Controlled by a high-speed computer system, the coils actively "balance" a plasma that would otherwise be unstable, allowing it to operate beyond the conventional limits.

As a tokamak plasma is heated and its pressure increases, the plasma gains enough energy to bend the magnetic field that confines it. The resulting large-scale deformation of the magnetic field and plasma, known as a "kink instability," can lead to rapid loss of the plasma's energy.

Fig. 1. Control coils (long rectangular objects) being installed in DIII–D.

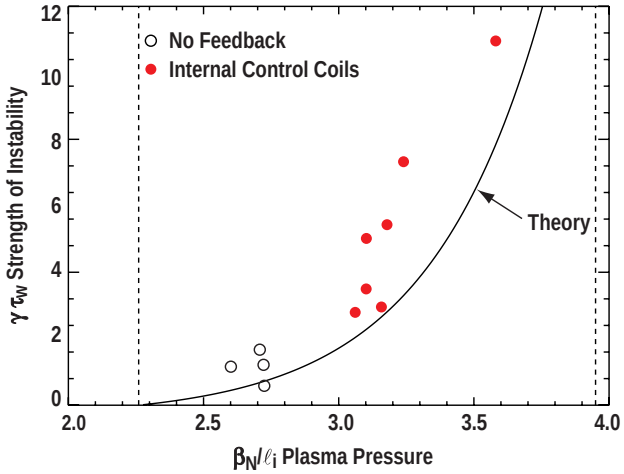

Fig. 2. The strength (growth rate) of the instability increases with plasma pressure, as predicted by theory. The internal control coils allow the pressure to reach values greater than without feedback control.

One approach to stabilizing the plasma uses direct intervention with a set of control coils such as those in DIII–D (Fig. 1), distributed outside the plasma near the metal wall. These coils push and pull the plasma back into shape wherever it starts to deform, thus preventing the kink instability from growing. A nearby metal wall serves to slow down the instability, so that the coils have time to respond.

Controlled stabilization of an otherwise unstable plasma is much like balancing an upended broom in the palm of your hand; it requires constant attention and constant small corrections. In the tokamak, the plasma is "watched" by magnetic sensors that detect tiny deformations of the plasma; a sophisticated digital control system then quickly calculates the corrective action needed from the coils.

The first experiments using the new coils for controlled stabilization show promising results (Fig. 2). The control coils allow the plasma to reach pressures up to 40% higher before becoming unstable (E.J. Strait, "Resistive Wall Mode Stabilization with Internal Feedback Coils in DIII–D," to be published in Bull. Am. Phys. Soc., 2003). The observed strength of the kink instability increases with pressure, in agreement with theoretical predictions. The maximum stable pressure in these experiments is probably limited by the speed of the control system, and further improvements should be possible.

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