Stabilization of the Vertical Mode in Tokamaks by Localized Nonaxisymmetric Fields

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We find that vertical instability of tokamak plasmas can be controlled by nonaxisymmetric magnetic fields localized near the plasma edge at the bottom and top of the torus. The required magnetic fields can be produced by a relatively simple set of parallelogram-shaped coils (Fig. 1). By providing stable equilibria with more highly elongated cross-sections, the addition of these nonaxisymmetric fields can potentially lead to devices with improved confinement (empirically derived global confinement scaling laws for tokamaks find that confinement improves with increasing vertical elongation) and/or beta limits (the Troyon scaling law for plasma stability predicts an increase in the β limit for ballooning and kink modes with increasing elongation). There is evidence that the benefits of increasing elongation diminish and perhaps disappear altogether at sufficiently high elongation, but the elongation at which this occurs is well above that at which the largest present day tokamaks can routinely operate. Furth-Hartman coils [1] are calculated to have essentially the same vertical stabilization effect as the simple parallelogram-shaped coils described here, so that the vertical stabilization demonstrated experimentally by Furth-Hartman coils [2] supports the feasibility of stabilizing vertical modes by the simpler coil set. The analytical calculation assumes a large aspect ratio plasma that is well approximated by a cylinder, $\beta = 0$, and a uniform equilibrium current density. Stability is determined by a δW calculation, using the stellarator approximation [3] for both the equilibrium and stability calculations. The physical mechanism of the stabilization suggests that the stability properties do not depend on the precise shape of the coils, so that the coil winding surface can be curved to conform to the local shape of the plasma, if desired, or curvature of the coils can be introduced to optimize relative to other considerations.

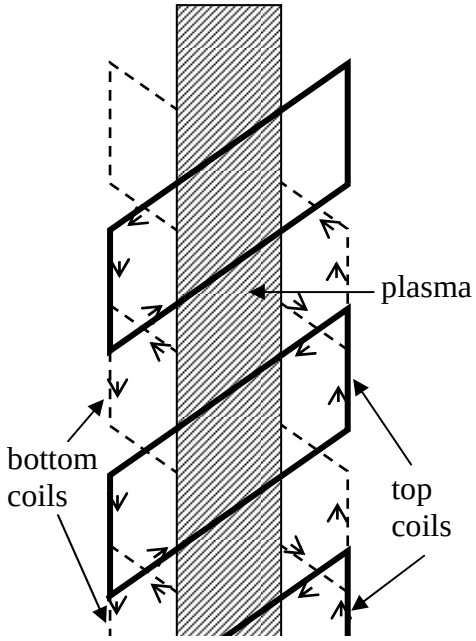

Fig. 1. View from above showing parallelogram-shaped coils above a length of cylindrical plasma, with portions of the coils below the plasma also visible (dashed lines). The arrows indicate the direction of current flow in the coils.

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[2] H. Ikezi, *et al.*, Phys. Fluids **22**, 2009 (1979); A. Janos, Ph.D. thesis, M.I.T., (1980).

[3] J. Greene and J. Johnson, Phys. Fluids **4**, 875 (1961); J. Johnson and J. Greene, Phys. Fluids **4**, 1417 (1961).