Computation of Singular MHD Instabilities with DCON

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ABSTRACT

The DCON code is in wide use for computing the ideal MHD stability of axisymmetric toroidal plasmas. It uses an adaptive numerical integrator to solve a system of ordinary differential equations for the radial dependence of complex Fourier coefficients of the normal displacement, a generalization of Newcomb's equation, from the magnetic axis to the plasma-vacuum interface. Fixed-boundary stability is determined by a toroidal generalization of Newcomb's criterion. Free-boundary stability is determined by the sign of the lowest eigenvalue of the sum of plasma and vacuum response matrices. DCON has been extended to compute the outer ideal region matching conditions for singular modes such as resistive and neoclassical tearing modes. A matching matrix is constructed from asymptotic coefficients of resonant and nonresonant solutions on either side of each singular surface and corresponding terms from any singular surface model. A dispersion relation for growth rates and eigenfunctions is obtained from the roots of the determinant of this matrix.

Two improvements have been introduced recently to make the code more robust, reliable, and accurate. First, the Frobenius expansion about the singular surface, previously carried out to first order in the distance from the singular surface, has now been extended to all orders. This has required systematizing the procedure by means of advanced matrix algebra, which is then used in the actual code. The maximum order used is an input parameter `norder`; it may be automated in the future. Systematically increasing `norder` is shown to produce more rapid convergence and smoother behavior in a scan over toroidal field strength. Finally, a more reliable procedure has been developed to stop the approach to the singular surface at the "sweet spot" where the error is a minimum.

The second improvement concerns the accuracy of the Grad-Shafranov equilibrium solution. DCON has interfaces to 17 different equilibrium codes. For ideal MHD stability, DCON obtains good, clean results for all of them. Resistive stability analysis is found to be much more sensitive to imperfections in the equilibrium, especially in the neighborhood of the magnetic axis. Highly converged and resolved equilibria yield clean results but require impractically long run times with most equilibrium codes. To deal with this problem, a new equilibrium code is being developed, to be incorporated into DCON, specifically to refine the given equilibrium to the standards required for accurate resistive stability analysis, based on the variational moment method.[1]

[1] L. L. Lao, S. P. Hirshman, and R. M. Wieland, Phys. Fluids **24**, 8, 1431 (1981).