2C37

Nonlinear Resistive MHD Analysis of the Turbulent Dynamo and Pressure-Driven Transport in the Reversed-Field Pinch*

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For systems with only one invariant, *e.g.* energy, there are known statistical closure schemes which lead to manageable expressions for evolution of the turbulent spectrum. For ideal MHD, there can be two or more invariants, including also magnetic helicity and cross helicity. These complicate the task of finding such a closure scheme.[1]

We describe a new approach to the study of the turbulent dynamo and pressure-driven transport in a cylindrical-model reversed-field pinch (RFP). We expand the nonlinear resistive MHD equations, using the eigenfunctions of the linearized equations as basis functions. This yields a high-order nonlinear system of ordinary differential equations (ODEs) for the time-dependent amplitudes $\alpha_i(t)$ of the basis functions,

$$\sum_{j=0}^{n} M_{i,j}\left(\dot{\alpha}_j - \gamma_j \alpha_j\right) = \sum_{j,k=0}^{n} c_{i,j,k}\alpha_j\alpha_k \tag{1}$$

where the γ_j are linear growth rates; the $M_{i,j}$ are components of a 2nd-rank mass matrix; and the $c_{i,j,k}$ are components of a 3rd-rank coupling matrix. $\mathbf{M}$ and $\mathbf{c}$ are expressed as quadratures over quadratic and cubic products of the linear eigenfunctions. Numerical computation using matched asymptotic expansions for the linear eigenfunctions for a given instantaneous cylindrical equilibrium permits fast and accurate evaluation of these quantities for arbitrarily high values of the Lundquist number S. Numerical integration of Eq. (1) permits the study of dynamical saturation mechanisms much more efficiently than the commonly used approach of multidimensional simulation codes like DEBS and NIMROD. Statistical closure schemes for describing the saturated spectrum can be developed and tested against this direct numerical simulation. The reaction of the saturated spectrum on the slowly-evolving cylindrical equilibrium is used to make predictions about the evolution of field reversal and the level of turbulent transport.

* Work supported by U.S. Department of Energy

[1] L. Turner, "Cross-correlations in nonlinear dynamics," LA-UR 02-7833 (submitted for publication).