Helically self-organized pinches: dynamical regimes and magnetic chaos healing

Marco Veranda, Daniele Bonfiglio, Susanna Cappello, Giovanni di Giannatale and Dominique Frank Escande

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Abstract:
This paper deals with helical self-organization in current-carrying toroidal pinches for the magnetic confinement of fusion plasmas. We perform our study in the framework of 3D nonlinear visco-resistive magnetofluid modelling, where a large set of simulations is now available. A global picture is derived about how visco-resistive transport coefficients and magnetic boundary conditions rule the self-organized helical states for the reversed-field pinch configuration. Decreasing visco-resistive dissipation causes a transition from steady ohmic helical equilibria to intermittent states (sawtoothing activity), while selected helical magnetic perturbations applied at the boundary favor steady global quasi-helical solutions. The sawtoothing frequency decreases together with visco-resistive dissipation, while sawtoothing amplitude decreases when applying non-resonant magnetic perturbations. Simulations of the tokamak configuration allow us to draw a tight parallelism with reversed-field pinches: a similar role of dissipation and magnetic boundary conditions on the dynamics of the internal kink mode is found, with decreasing sawtoothing frequency and amplitude by decreasing dissipation and by applying suitable helical boundary conditions. Magnetic chaos healing is the topological feature of the transition from intermittent to quasi-quiescent helical states in reversed-field pinches. Bundles of Lagrangian coherent structures (LCS) in the weakly stochastic region surrounding the helical core constitute the skeleton of chaos healing, and behave as barriers to the transport of magnetic field lines. In this work, they are detected during the whole temporal evolution and it is proved that they can withstand the nonlinear dynamics even during sawtoothing activity. Furthermore, we show that LCS are connected to regions with strong gradients of the connection length of magnetic field lines to the edge. This provides a further indication of their possible role in the formation of electron temperature barriers. As a final result it is shown that a reasonable value of plasma rotation can further enhance the intensity of the dominant helical mode.