26aEC-3

Linear and nonlinear dynamics of double tearing mode instability in the presence of shear flows

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The shear flows have been considered to be one of plausible candidates to suppress the double tearing mode (DTM), which is always unstable in the reversed magnetic shear configuration. However, strong shear flows may also be unstable for the Kelvin-Helmholtz (KH) mode so that the DTM and the KH mode may coexist and nonlinearly interact. In this work, based on reduced MHD model in slab geometry we systematically analyze the linear instability of the DTM in the presence of antisymmetric shear flows with maximum flow shear around the rational surfaces, where the KH modes may be excited. Then we simulate the nonlinear evolution of coexisting DTM and KH fluctuations to understand underlying mechanism of multi-mode interaction and the effect on the magnetic reconnection process.

Both initial value simulation and eigenvalue analysis show that weak shear flows stabilize the DTM with antisymmetric islands and destabilize that with symmetric islands. For strong shear flows, the KH mode with higher mode number is robustly unstable at two rational surfaces, which is characterized by electrostatic fluctuations. Simulations exhibit a complex interaction process between two instabilities with five phases: (1) linear KH growing phase with stabilized DTMs; (2) KH saturation due to zonal flow generation; (3) linear growing phase of the DTM; (4) nonlinear growing phase of the DTM (corresponding to the Rutherford regime); finally (5) full magnetic reconnection phase. It is observed that the linearly stabilized DTM by the shear flows can be destabilized again through the cancellation of the KH-generated zonal flows. The nonlinear interaction dynamics at each phase will be discussed in detail.