Nonlinear Simulations of Peeling-Ballooning Modes with Flow Shear and RF Sources

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The fast-reconnection simulation of ELMs in high-confinement mode tokamak discharges with non-ideal physics effects has been reported by Xu, et al with a minimum set of three-field two-fluid equations [1]. Here we improve the simulation by adding the perturbed parallel flow and Hall effect, then extend the model to a set of four-field two-fluid equations to describe the pedestal collapse with the BOUT++ simulation code. Compared to the former results, we find that the perturbed parallel velocity can decrease the growth rate by 20%, and the ELM size is decreased by 12.1%. The Hall effect has a strong effect on the linear growth rate effectively. Without parallel flow, the Hall effect will increase the growth rate by 9.8%. It is increased by 19.1% if the parallel velocity is considered. These results are consistent with the qualitative theoretical analysis.

We developed the formalism for modeling the inclusion of external applied RF sources in the four-field two-fluid equations to simulate ELM recover phase. In this work, we specified a model RF source with a Gaussian shape localized in the pedestal. In order to smooth the perturbed zigzags of the profiles of variables, we add the hyper-diffusion terms in the equations. We use the hyper-diffusion of pressure and vorticity which do not affect the linear growth rate and the ELM structure obviously, but they can smooth the profiles effectively on grid scales. We compare the cases of the different rf input positions on radial direction. The rf waves can generate parallel flow at their input region.

[1] X.Q.Xu, B.Dudson, P.B.Snyder, M.V.Umansky, and H.Wilson, PRL , VOL. 105, 175005 (2010).