

Verification and validation of gyrokinetic and kinetic-MHD simulations for internal kink and fishbone instabilities in DIII-D

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Abstract

Verification and validation of the internal kink instability in tokamak have been performed for both gyrokinetic (GTC) and kinetic-MHD codes (GAM-solver, M3D-C1-K, NOVA, XTOR-K). Using realistic magnetic geometry and plasma profiles from the same equilibrium reconstruction of the DIII-D shot #141216, these codes exhibit excellent agreements for the growth rate and mode structure of the $n=1$ internal kink mode in ideal MHD simulations by suppressing all kinetic effects. The simulated radial mode structure agrees quantitatively with the electron cyclotron emission measurement after adjusting, within the experimental uncertainty, the $q=1$ flux-surface location in the equilibrium reconstruction. Equilibrium plasma pressure gradient and compressible magnetic perturbation strongly destabilize the kink, while poloidal variations of the equilibrium current density stabilize the kink. Furthermore, kinetic effects of thermal ions are found to decrease the kink growth rate in kinetic-MHD simulations, but increase the kink growth rate in gyrokinetic simulations, due to the additional drive of the ion temperature gradient and parallel electric field. Kinetic thermal electrons are found to have negligible effects on the internal kink instability.