MARS-Q modeling of kink-peeling instabilities in DIII-D QH-mode plasma

G.Q. Dong[1], Y.Q. Liu[2], X. Chen[2], G.Z. Hao[1], Y. Liu[1], S. Wang[1], N. Zhang[1] and G.L. Xia[3]

[1] Southwestern Institute of Physics, P.O. Box 432, Chengdu 610041, China,

[2] General Atomics, P.O. Box 85608, San Diego, CA 92186-5608, United States of America

[3] CCFE, Culham Science Centre, Abingdon, OX14 3DB, United Kingdom of Great Britain and Northern Ireland

e-mail (speaker): donggq@swip.ac.cn

In quiescent H-mode (QH-mode) regime, edge harmonic oscillations (EHOs) are believed to provide necessary radial transport to prevent occurrence of large edge localized modes. A systematic modeling study is performed here on the low-n EHOs in a DIII-D QH-mode plasma, by utilizing the MARS-Q code [1]. All the n=1~3 instabilities are found to be strongly localized near the plasma edge, exhibiting the edge-peeling characteristics. The DIII-D resistive wall is found to have minor effects on these instabilities. The plasma resistivity is found to strongly modify the mode growth rate. Assuming the Spitzer model for the plasma resistivity, the computed mode growth rate scales as $S^{-1/3}$, similar scaling also holding for edge localized infernal mode[2,3], with S being the Lundquist number. Toroidal flow of the plasma slightly stabilizes these edge localized kink-peeling modes. Drift kinetic effects all have a destabilization effect on these modes. Non-perturbative MHD-kinetic hybrid computations find that the drift kinetic effects associated with thermal particle species push the peak location of the eigenmode radially inward but still in the pedestal region. The modeled plasma temperature and density fluctuations in the plasma edge region, as well as the poloidal magnetic field perturbations along both the low and high field sides of the plasma surface, are in good agreement with experimental measurements. Finally, the quasi-linear initial value simulations find a strong non-linear interplay between the kink-peeling instability and the toroidal flow near the plasma edge, as shown in Fig.1. The combined effect of the damping of the flow amplitude and change of the edge flow shear is found to be the stabilizing factor for the kink-peeling mode, leading to the mode saturation and thus EHOs.

References

[1] Y.Q. Liu et al, Phys. Plasmas **20**, 042503 (2013)

[2] G.Q. Dong et al, Phys. Plasmas **24**, 112510 (2017)

[3] G.Q. Dong et al, Nucl. Fusion **59**, 066011 (2019)

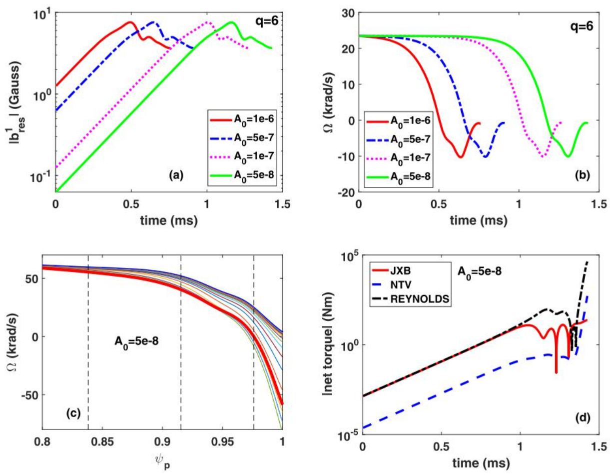

Figure 1. The MARS-Q simulated time traces of the initially unstable n = 1 resistive kink-peeling mode: (a) and (b) the perturbed m/n = 6/1 resonant radial field component and the toroidal rotation frequency, respectively, at the q = 6 rational surface, with different choices for the amplitude A0 of the initial perturbation; (c) and (d) evolution of the rotation profile and the time traces of three toroidal net torques, respectively. The thick blue (red) curve in (c) indicates the initial (final) rotation profile. The vertical dashed lines in (c) indicate locations of the rational surfaces associated with the n = 1 perturbation. Assumed are the toroidal momentum diffusion coefficient of $\chi_M = 0.1\ m^2\ s^{-1}$.