The effects of three-dimensional magnetic perturbations and finite beta on collissionless trapped electron mode and ion temperature gradient mode instabilities in tokamak plasmas

Zhangsheng Huang, Weixin Guo, Lu Wang
Huazhong University of Science and Technology
e-mail: zhangshhuang@hust.edu.cn

Plasmas with internal transport barriers (ITBs) have the benefit of better confinement. It has been found that the internal kink modes with non-axisymmetric flux surface have effects on the formation and evolution of ITBs[1,2]. In order to understand the corresponding mechanism, we have studied the effects of three-dimensional magnetic perturbations (3D MPs) and finite beta (β, the ratio between plasma kinetic pressure and magnetic pressure) on the linear instabilities of collisionless trapped electron mode (CTEM) and ion temperature gradient mode (ITG), respectively.

For the instability of CTEM, based on the local 3D equilibrium model[3], we have derived general expressions for longitudinal invariant and the corresponding precession drift frequency of trapped electrons, which include the synergetic effects of 3D MPs and finite β. Then, the dispersion equation of CTEM instability has been derived and solved by including the kinetic effects of trapped electrons[4]. The results show that the synergetic effects of 3D MPs and finite β can either stabilize or destabilize the CTEM instability due to the modification of the precession resonance between trapped electrons and electron drift wave. In the presence of MPs with destabilizing phase, the synergetic effects can weaken or even reverse the reduction of precession drift frequency by finite β effects in two-dimensional (2D) case, and then there is more trapped electrons resonant with the electron drift wave. This can enhance the excitation of CTEM instability, and the linear growth rate of CTEM is thus increased. While, in the presence of MPs with stabilizing phase, the synergetic effects can reduce the precession drift frequency and the number of resonant trapped electrons, and result in the suppression of CTEM instability. Moreover, the required absolute value of negative magnetic shear to completely stabilize CTEM instability could be also reduced as compared to the case without 3D MPs.

For the ITG instability, we are studying the effects of 3D MPs and finite beta with the consideration of elongation for it's impact on turbulent transport[4]. It has been found that the impact of 3D MPs on ITG instability which is induced by the resonance between drift wave and magnetic drift of ions is negligible for the position localized in outer middle plane. While the 3D MPs and finite beta have significant impact on the mode structure and linear instability of ITG under the condition of non-resonant and nonlocal position with consideration of fluid limit, more results are under analyzing. In conclusion, these results reveal the synergetic effects of 3D MPs and finite β on micro-instability. This is possible to contribute for the design and control of operation scenario with high performance plasmas in the future tokamak fusion reactors.

References
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