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Destabilization of beta-induced Alfven eigenmodes excited by energetic ions in tokamak plasmas

Ruirui Ma[1], L. Chen[2,3], F. Zonca[4,2], and W. Chen[1]

[1] Southwestern Institute of Physics, P.O. Box 432 Chengdu 610041, China
[2] Institute for Fusion Theory and Simulation, Zhejiang Univ., Hangzhou 310027, China
[3] Department of Physics and Astronomy, Univ. of California, Irvine, California, 92697-4575, USA
[4] Associazione EURATOM-ENEA sulla Fusione, CP 65-00044 Frascati, Roma, Italy

In this work, we study the characteristics of beta-induced Alfven eigenmodes (BAEs) [1, 2] in the presence of energetic ions in large aspect-ratio, finite-β tokamaks with shifted circular flux surfaces.

First, in the theoretical framework of the generalized fishbone-like dispersion relation [3-5], the linear properties of BAEs by circulating and/or trapped energetic ions are investigated analytically and numerically. Here, we treat energetic-particles (EPs) dynamics non-perturbatively and consider the effects of finite Larmor radius and finite orbit width. Numerical results show the smooth transition between the EP continuous spectrum and BAE in the gap. EPMs and/or BAEs are destabilized by energetic ions, with real frequencies and growth rates strongly dependent on the energetic particle density and resonant frequency. Special emphasis is placed on delineating the stabilization roles played by finite orbit width effect of magnetically trapped ions on the stability of BAE in low magnetic shear equilibrium.

Secondly, in the framework of the WKB-ballooning mode representation [4, 6-8], the two-dimensional global stability and mode structures of high-n BAEs excited by energetic ions in tokamaks are examined. Analytical and numerical analyses demonstrate that, when the non-perturbative EP wave-particle resonant effect is considered, the BAE is radially localized into the EP-pressure-gradient potential well and it is most unstable in the lowest bound state; the BAE exhibits the twisting radial mode structure relative to the ideal MHD limit with the up-down symmetric characteristic. That is because the anti-Hermitian contributions due to wave-energetic particle resonance can twist the radial mode structure away from $\theta_* = 0$ with θ_* being the location of the mode maximum amplitude, resulting in the loss of up-down symmetry in the global mode structure. The present results offer the theoretic explanation of the existing experiment and numerical simulations about the asymmetric mode structure in the poloidal plane [9-11].

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