Magnetohydrodynamic-kinetic hybrid simulation of Alfvén instabilities in ICRF heating experiments on EAST

Pengjuan Su[1], Youjun Hu[1], Wei Zhang[1], Jialei Wang[2], Jiangyue Han[3], Nan Chu[1], Juan Huang[1], Zhiyong Qiu[1]

[1]Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, China
[2]National Institute for Fusion Science, National Institutes of Natural Sciences, Toki 509-5292, Japan
[3]Graduate School of Frontier Sciences, The University of Tokyo, Kashiwa, Chiba 277-8561, Japan

E-mail: pjsu@ipp.ac.cn

Ion cyclotron resonance heating (ICRH) is an important auxiliary heating method in tokamak devices. It also produces a large number of energetic particles (EPs) with energies up to MeV, which can potentially destabilize variety of instabilities such as Alfvén eigenmodes (AEs) or fishbone. Recently, several modes with frequencies ranging from 50 to 300 kHz have been observed in high β_{P} experiments with ICRF heating on EAST. In order to understand these experimental phenomena, we have carried out simulations of the ICRF heated scenario using the hybrid MHD-kinetic code MEGA.

In the simulations, experimentally measured equilibrium profiles ($q/n_e/T_e/T_i$) are used as input; and EPs are described by an anisotropic slowing-down distribution with $E_{birth} = 1\mathrm{MeV}, \Lambda_0 = 0.8, \Delta\Lambda = 0.3$ $(\Lambda \equiv \mu B_0/E)$; and we focus on AEs with the toroidal mode number $n \leq 4$. As shown in Fig. 1, the $n = 2$ mode is the most unstable during the linear growth stage, with the frequency of 77.5 kHz and the growth rate of $\gamma/\omega \approx 3.3\%$. According to the poloidal mode structure and the corresponding Alfvén continuum (Fig. 2), we conclude that it is a TAE. The statistics of the value of $|\delta f|$ show that most resonant particles have energies less than 300 keV, and the proportions of the trapped, co-current passing and counter-current passing particles are about 50%, 35% and 15%, respectively. During the nonlinear saturation stage, the $n = 1$ mode saturates with the largest amplitude, and the Fourier decomposition shows that it has three frequency components: 55 kHz, 73 kHz, and 86 kHz. Its magnetic field perturbation amplitude is about $|\delta B/B_0| \sim 2 \times 10^{-4}$, and it induces a very small radial transport of EPs. By scanning the parameters, it is found that, the saturation amplitude of AEs increased significantly with the initial beta of EPs, leading to a significant transport of EPs. It is also found that, changing the radial profile of β_{EP} will lead to consequent changes of the mode frequency and radial position.

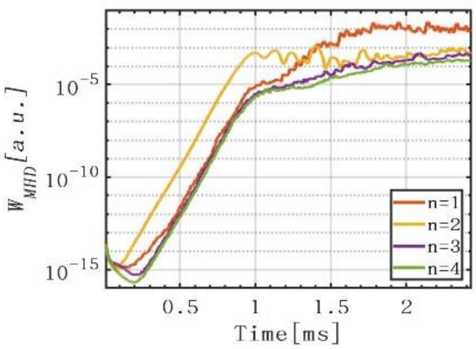

Fig1. Time evolution of the MHD fluctuation energy for different toroidal mode numbers.

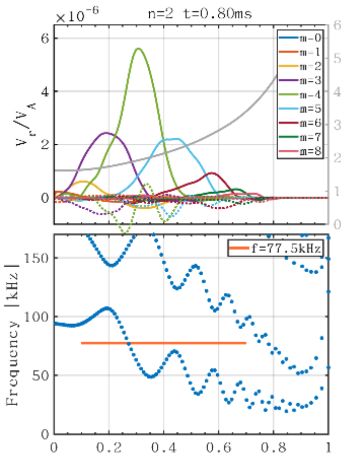

Fig2. The poloidal mode structure and Alfvén continuum of $n = 2$.