Features of ion and electron fishbone instabilities on HL-2A


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The features of ion and electron fishbone instabilities have been investigated during Neutral Beam Injection (NBI) and Electron Cyclotron Resonance Heating (ECRH) on HL-2A. Some new phenomena, such as frequency jumps and V-font-style sweeping, have been present in the paper. Three kinds of i-fishbones, including hybrid sawtooth-fishbone (sawbone), run-on fishbone and classical fishbone, have been identified during NBI. During high power (P_{ECRH}>0.7 MW) ECRH, the experimental results indicate that the e-fishbone frequencies are higher than that during low power ECRH, and are provided with up- and down-chirping behaviors, sometimes, also with V-font-style sweeping. The periodic mode frequency jumps have also been detected by soft x-ray array. These phenomena are possible to correlate with the redistribution of the energetic electrons.

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1. Introduction

The physics of energetic-particle driven instabilities is of particular importance for understanding fast-particle dynamics and transport in future burning plasma devices, such as ITER and DEMO, where energetic-particles will be abundantly produced by large-power additional heating systems and fusion reaction [1]. The wave-particle dynamics in thermal plasma can lead to complex nonlinear behaviors, including particle redistribution, phase-space mixing, trapping and hole-clump pair formation [1-2]. Frequency chirping is associated with the energy losses and redistribution of fast particles, and frequency sweeping is linked to the formation of hole-clump pairs that evolve in the phase-space and support nonlinear waves with time-varying frequencies. Chirping and sweeping events driven by fast ions, i.e., TAE- and CAE-pitch-fork, G-GAM and E-GAM, ALE and fast FS mode, and ion-fishbone, have been observed and investigated widely in many fusion devices [3-9]. Whereas, study of modes related to energetic-electrons remains actually a much less explored issue than energetic ions. The energetic-electron behaviors should provide a strong contribution burning plasma research because their effect on low-frequency MHD modes can be used to simulate and analyze the analogous effect of alpha particles characterized by small dimensionless orbits similar to energetic-electrons in tokamak plasma [10].

The classical fishbone activity was observed in toroidal plasma experiments with NBI, both tangentially and near perpendicularly, and also in ion cyclotron resonance heating (ICRH) experiments [9,11-13]. The structure of the unstable mode was identified as the m/n=1/1 internal kink mode. However, under some condition, most of the m=1 bursts terminated in a sawtooth crash. The hybrid phenomenon, so