Destabilization of Beta-induced Alfvén Eigenmodes in the HL-2A Tokamak


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Abstract: It is presented that the experimental results are correspond to the Beta-induced Alfvén eigenmode (BAE) during a strong tearing mode activity in this paper. The BAE excited by energetic electrons (termed as e-BAE) has been identified for the first time both in the Ohmic and ECRH plasma in HL-2A. The hard X-ray (HXR) spectrum detected by Cadmium-telluride (CdTe) and the non-thermal radiation measured by the ECE are used to analyze the behaviors of the energetic electrons. Experimental results show that the e-BAE is related not only with the populations of the energetic electrons, but also their energy distribution. To assess the identification of these instabilities with the BAE modes, the generalized fishbone-like dispersion relation (GFLDR) and magnetic-island-induced BAE dispersion relation have been solved near marginal stability, respectively. Comparing with experimental results, the calculation analysis shows that the observed frequencies are all close to the theoretical results.

1. Introduction

Alfvénic instabilities can be driven by the energetic particle in future burning plasma devices, such as ITER and DEMO, where energetic particles will be abundantly produced by high power heating and fusion reaction. These instabilities can lead to significant loss of energetic particles, which are very harmful for plasma heating and reactor’s first wall. So it is very important to study them theoretically and experimentally in present day tokamak plasmas. The instabilities driven by fast ions, such as toroidicity-induced Alfvén eigenmodes (TAEs), have been observed and investigated widely in many fusion devices [1]. In contrast, the modes related to energetic-electrons are much less explored. The study of energetic-electron behaviors would provide a strong contribution to the physics of burning plasma 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 present day tokamak plasmas [2].

The BAEs were firstly observed in DIII-D and then TFTR plasmas with fast ions [3-5]. Subsequently, the BAEs (termed as m-BAEs) have also been observed during a strong tearing mode (TM) activity in FTU and TEXTOR Ohmic plasmas without fast ions [6-8]. Recently, the BAEs have also been reported during a sawtooth cycle in ASDEX-U and TORE-SUPRA plasmas with fast ions [9-10]. The excitation mechanism of the BAEs is not well understood due to many effects, such as ion diamagnetic drift, thermal ion compression, finite Larmor radius (FLR)/finite orbit width (FOW), and energetic-particle effects. The most probable theoretic identifications of the BAE excited by beam ions have been proposed: a discrete shear Alfvén eigenmode (AE), a kinetic ballooning mode (KBM) and a hybrid mode between Alfvénic and KBM branches or between Alfvénic and ion acoustics branches [11-12].