# §22. Frequency Sweeping of to Alfvén Eigenmode in a JT-60U Plasma

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Instabilities with frequency sweeping in the frequency range of Alfvén eigenmodes have been found with negative ion based neutral beam (NNB) injection in JT-60U [1]. One type of instability, which is called the fast frequency sweeping (fast FS) mode, appears at frequency inside the toroidal Alfvén eigenmode (TAE) gap [2]. Frequency shifts rapidly by 10-20 kHz in 1-5 ms both upward and downward. Since the plasma profile changes in a much longer time scale, some nonlinear effects of the interplay between the mode and the energetic ions created by the NNB injection must play an essential role in fast frequency sweeping.

Using the experimental q-profile, bulk pressure profile, and density profile of discharge E36379 [1], particle-magnetohydrodynamic (MHD) hybrid simulation [3] was carried out [4]. The major and minor radii are $R_0$=3.4m and a=1.0m, respectively. The plasma shape in the simulation is circular while the shape in the experiment was divertor-shaped. The magnetic field at the magnetic axis is 1.2T. The bulk plasma and the beam ions are deuterium. NNB injection energy is 346keV. Initial energetic ion distribution in the velocity space is assumed to be a slowing down distribution. The perpendicular velocity of energetic ions is neglected because the NNB injection is tangential. The maximum velocity is assumed to be 80% of the injection velocity as the injection is not completely parallel to the magnetic field. This maximum velocity in simulation corresponds roughly to the Alfvén velocity at the magnetic axis. A classical distribution which is formed by NNB injection and collisions (slowing down and pitch angle scattering) was calculated using the OFMC code [5]. The classical distribution, however, gives an overestimate of the energetic ion pressure and its gradient because in the experiments energetic ion loss and redistribution take place due to fast FS mode and another type of instability called abrupt large event with time intervals much shorter than the slowing down time.

We have found an unstable mode of which frequency is close to that of the fast FS mode. Primary harmonic of the unstable mode is m/n=2/1, where m, n are the poloidal and toroidal mode numbers. Nonlinear evolution was investigated for reduced distributions where energetic ion pressure is reduced to 1/5 or 2/5 of the classical distribution. We have found two types of evolution. Figure 1 shows the frequency spectrum evolution of the toroidal electric field m/n=2/1 harmonic for (a) the classical distribution and (b) a distribution reduced to 2/5. For the classical distribution, the frequency spectrum shifts only downward. For the reduced distribution, frequency shifts upward by 14% (~7kHz) and downward by 23% (~12kHz) of the linear frequency in 1000 Alfvén time (~0.8ms). These frequency shifts for the reduced distribution are close to those of the fast FS mode. Frequency upshift and downshift due to spontaneous hole-clump pair creation in a phase space was found by simulating a reduced kinetic equation when the linear damping rate ($\gamma_d$) is greater than 0.4 of the linear growth rate without damping ($\gamma_L$) [6]. The ratio $\gamma_d/\gamma_L$ in the present simulation is consistent with the spontaneous hole-clump pair creation. Transport of energetic ions in the aforementioned two simulation runs is compared in Fig. 2. A large redistribution of energetic ions takes place for the classical distribution, while the change in energetic ion beta profile is small for the reduced distribution. Change of the unstable mode spatial profile due to the large redistribution breaks down the perturbative approach.

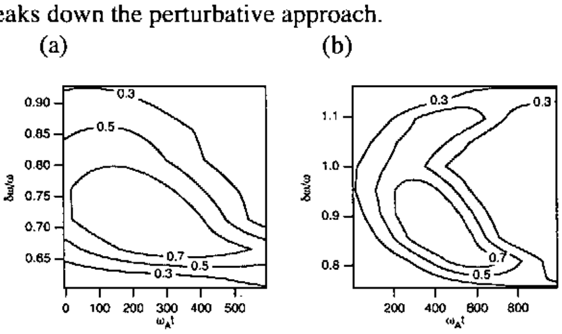


Fig. 1. Time evolution of frequency spectrum of the toroidal electric field with the mode number m/n=2/1 for (a) the classical energetic ion distribution and (b) the reduced distribution.

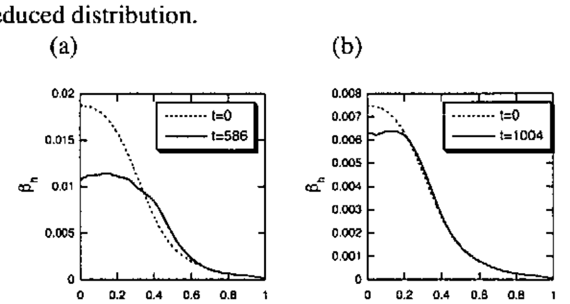


Fig. 2. Comparison of energetic ion redistribution between (a) the classical distribution run and (b) the reduced distribution run.

References
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