§1. Simulations of Energetic Particle Driven Geodesic Acoustic Mode in 3-dimensional LHD Equilibrium

Wang, H., Todo, Y., Suzuki, Y.

Energetic particle driven geodesic acoustic mode (EGAM) in 3-dimensional Large Helical Device (LHD) equilibrium is investigated with a hybrid simulation code for energetic particles and magnetohydrodynamics (MHD). In this work, the EGAM in 3-dimensional helical configuration and the EGAM in tokamak configuration are compared. MEGA[1)], which is a hybrid code for energetic particles interacting with a magnetohydrodynamic fluid, is used for the simulations. It is demonstrated that the spatial profile of the EGAM in LHD is a combination of m/n=0/0 (strong), 1/0 (medium) and 2/10 (weak) components, which is different with that in tokamak. The 2/10 component appears from the 3-dimensional LHD configuration.

MEGA code is used to simulate the EGAMs in LHD. The realistic 3-dimensional equilibrium data is generated by HINT2 code for LHD discharge #109031, and this data is at t=4.94 s. In the experiment, the EGAM activity is very strong at this moment, and the mode frequency chirps up[2)]. The neutral beam injection (NBI) energy is 170 keV. The energetic-particle distribution function is the slowing-down type, and the slowing-down time is 10 s. In addition, a Gaussian-type pitch angle distribution $f(\Lambda)=exp[-(\Lambda-\Lambda_{peak}))^2/\Delta\Lambda^2]$ is assumed for the energetic ions, where $\Lambda=\mu B_0/E$ is the particle pitch angle variable, Λ_{peak} = 0.1 represents the pitch angle for the distribution peak, and $\Delta\Lambda$ = 0.2 is a parameter to control the distribution width. The safety factor q profile monotonically decreases in radius with q_0=2.8 on the magnetic axis, and q_{edge}=0.8 on the plasma edge.

The EGAM in LHD is reproduced by MEGA code, as shown in Fig. 1. This figure shows the poloidal flow velocity evolution, and also the frequency spectrum analyzed by Fast Fourier transform. The mode is oscillating, and it is excited in very short time, less than 0.2 ms. The mode frequency is 60 kHz in the linear phase, and chirps up to 75 kHz with chirping rate 20 kHz/ms. The initial frequency is the same as the experimental observation, the fast excitation and the high chirping rate are also roughly consistent with the experiment. In the simulation model, the NBI is not continually injected, but the mode amplitude is kept constant, does not decay. This happens because the mode can continually obtain the energy from particles in the chirping process[3)].

The poloidal flow velocity v_θ of the mode in the 3-dimentional configuration is shown in Fig. 2. The mode is located near the magnetic axis, and the v_θ oscillation profile is a combination of m/n=0/0 (strong), 1/0 (medium) and 2/10 (weak) components. The ratio of the 2/10 component intensity to the 0/0 component intensity is about 17%. The m/n=2/10 components exists due to the LHD configuration. In LHD, there are 10 twists in the toroidal direction, and there are 2 high field regions and 2 low field regions in the poloidal cross section. This is the first simulation of EGAM in the 3-dimentional LHD configuration. The mode number is different from the tokamak case, where the v_θ oscillation is a combination of m/n=0/0 and 1/0 components. The mode number of pressure perturbation is m/n=1/0, which is similar with the tokamak case. The pressure perturbation rotates poloidally in the nonlinear phase, and the rotation direction changes periodically. This rotation is caused by the convection of the EGAM poloidal flow. The phase of pressure time derivative $\partial P/\partial t$ and the phase of v_θ are the same. In addition, in the linear growth phase, the mode does not propagate radially, and in the saturated phase, the mode propagates radially inward.

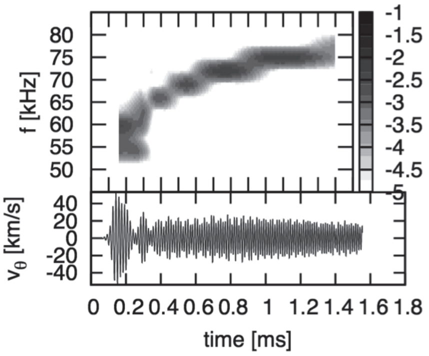

Fig. 1. The time evolution of EGAM oscillation (bottom panel) and frequency spectrum (top panel).

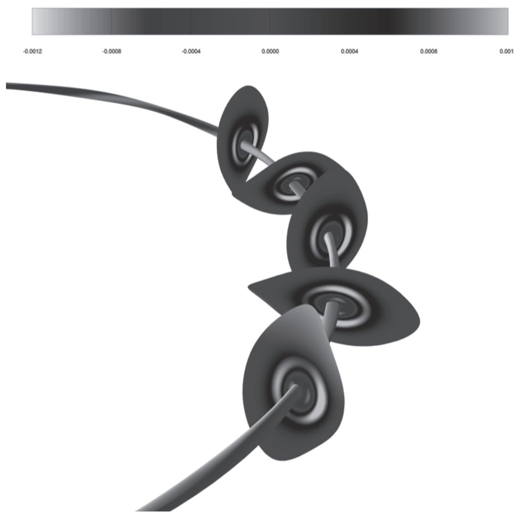

Fig. 2. The v_θ profile is a combination of m/n=0/0 (strong), 1/0 (medium) and 2/10 (weak) components.

1) Todo, Y.: Phys. Plasmas 13 (2006) 082503.
2) Osakabe, M. et al.: 25th IAEA-FEC.
3) Berk, H. et al.: Phys. Lett. A 234 (1997) 213.