§3. Simulation Study of Alfvén-eigenmode-induced Energetic Ion Transport in LHD

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To achieve magnetic confinement fusion, the interaction between Alfvén eigenmodes and energetic ions is an important issue to be resolved. In the Large Helical Device (LHD), bursts of toroidal Alfvén eigenmode (TAE) and associated energetic ion transport and losses have been observed during neutral beam injection.

In this study, we approach this problem using a *reduced* version of the MEGA code. In this code, data from the HINT code, which solves the resistive magnetohydrodynamic (MHD) equations, is used to obtain the realistic equilibrium magnetic field in the LHD. The TAE spatial profile in the equilibrium field is given by the AE3D code[1)], which solves the reduced MHD equations for stellarators. The energetic ion orbits in the superposition of the equilibrium and perturbed fields are calculated by the particle-in-cell method with the so-called δf method. Using the code, the time evolution of the TAE amplitude and the consequent energetic ion transport in the LHD are simulated[2)].

Figure 1 shows the implementation of the TAE data by the AE3D code in the MEGA code. An example of a contour plot of the electrostatic potential of the TAE in the poloidal plane and isosurface plots are shown. Note that the rippled structure in Fig. 1 is due to the helically wound equilibrium magnetic field.

Firstly, we performed nonlinear simulations of the interaction between the TAE and energetic particles, and checked the nonlinear saturation level of TAE amplitude B_{TAE}/B_0, where B_{TAE} is TAE-induced magnetic field and B_0 is equilibrium magnetic field. Next, test particle simulations with fixed TAE amplitude and frequency are performed.

Figure 2 shows a Poincaré plot of the test particles in a horizontally elongated poloidal plane. It is observed that the orbit strongly fluctuated by the TAE.

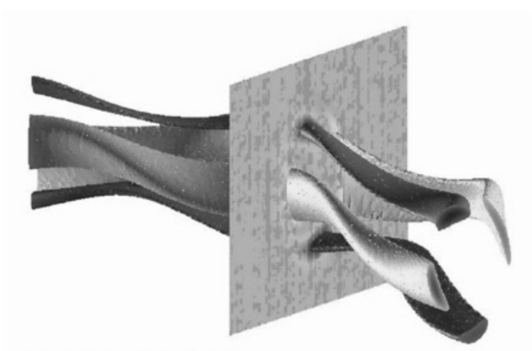

Fig. 1: Contour and isosurface plots of the electrostatic potential of the TAE by the AE3D code implemented in the MEGA code (arbitrary units).

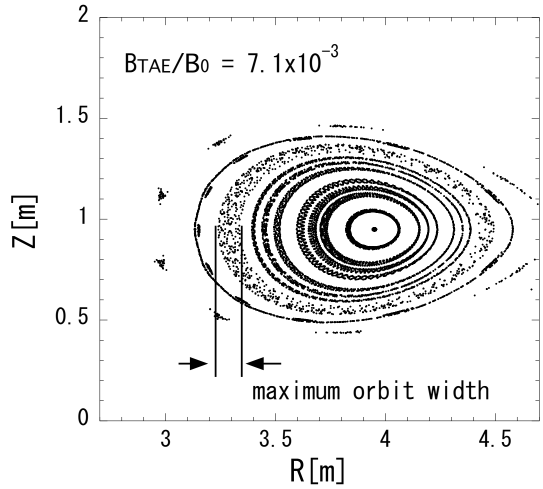

Fig. 2: Poincaré plot of test particles in a horizontally elongated poloidal plane.

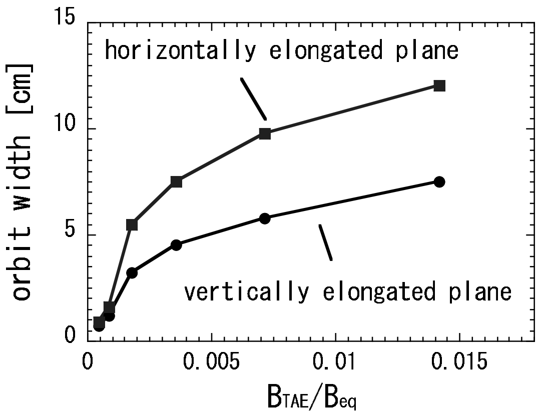

Fig. 3: TAE amplitude dependence of the maximum orbit width of test particles in the horizontally elongated and the vertically elongated planes.

Figure 3 shows the maximum orbit width in the horizontally elongated plane, where the width is measured on the interior equatorial plane as shown in Fig. 2. The orbit width in the horizontally elongated plane is larger than that in the vertically elongated plane.

In LHD experiments, the radial transport of energetic ions sometimes reaches 10% of the average minor radius. A comparison with experimental data is necessary to check the validity of our results; this is left as a future work.

1) Spong D.A., D'Azevedo E., and Todo Y.: Phys. Plasmas **17**, 022106 (2010).

2) Nishimura S., Todo Y., Spong D.A., Suzuki Y., and Nakajima N.: "*Simulation study of Alfvén-eigenmode-induced energetic ion transport in LHD*", Plasma and Fusion Research, (2013) in press.