§11. Vlasov-MHD Simulation Study on Nonlinear Evolution of the Toroidal Alfvén Eigenmode

Todo, Y., Sato, T., Watanabe, K., Watanabe, T.H., Horiuchi, R.

A new simulation method has been developed to investigate the interaction between fast particles and MHD modes[1)]. The background plasma is described by an MHD fluid model, while the kinetic evolution of fast particles is followed by the drift kinetic equation. Both the MHD and drift kinetic equations are solved by a finite difference method. This new method can deal with kinetic interactions of fast particles with nonlinear MHD waves free from numerical noises of particle discreteness. Especially, the particle trapping effect of a finite amplitude wave which suppresses the Landau damping can be followed by this method.

The toroidal Alfvén Eigenmode[2)] (TAE mode) destabilized by energetic alpha particles has been studied using this new simulation method. Excited predominant MHD modes (n=2) and their nonlinear evolutions are examined including generation of n=0 modes. The growth rate of the most unstable n=2 TAE mode is agreeable with that of the linear theory[3)]. After saturation the mode amplitude exhibits an oscillatory behavior with the bounce frequency of alpha particles trapped by the TAE mode[4)] (Figure 1). The bounce frequency is coincident with the linear growth rate. The saturation is found to be caused by the decrease of the power transfer rate from alpha particles to the TAE mode. Thus, we conclude that the growth of the unstable mode is suppressed by the particle trapping effect of a finite amplitude wave. The saturation level is in proportion to the square of the linear growth rate.

The m=0, n=0 quasi-linear mode of the alpha particle distribution is generated through the nonlinear coupling between the n=2 TAE mode and the n=2 mode of alpha particle distribution. This quasi-linear mode spatially flattens the distribution function, removing the free energy source of the instability.

The saturation of the magnetic field fluctuation can reach to a significant level, e.g. 1.8×10^{-3} of the equilibrium field intensity when the initial beta of alpha particles is 2% at the magnetic axis. This indicates a non-negligible alpha particle loss in one slowing time[5)].

This new simulation technique will be useful to investigate other fast particle physics such as the fishbone and sawtooth oscillations, which are under consideration.

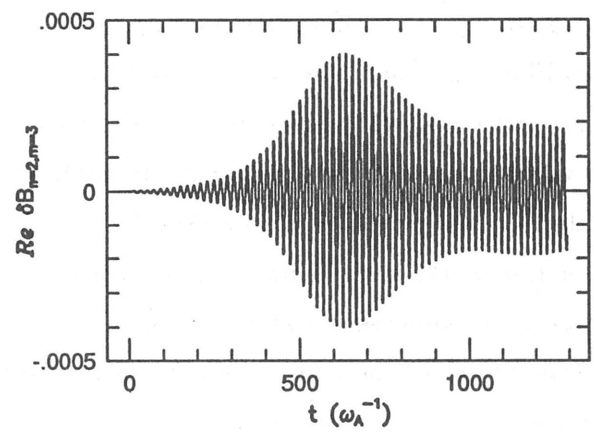

FIG. 1. Temporal evolution of the real part of the $(m = 3, n = 2)$-mode on the $r = 0.35a$ magnetic surface.

References
1) Todo, Y. et al. : *Phys.Plasmas* **2** (1995) 2711.
2) Cheng, C. Z. and Chance, M. S. : *Phys.Fluids* **29** (1986) 3659.
3) Fu, G. Y. and Van Dam, J. W. : *Phys. Fluids* **B1** (1989) 1949.
4) Berk, H. L., Breizman, B. N., and Ye, H. : *Phys. Fluids* **B5** (1993) 1506.
5) Sigmar, D. J. et al. : *Phys. Fluids* **B4** (1992) 1506.