Orbit-following simulations of fast-ion transport and losses due to the Alfvén eigenmode burst in the Large Helical Device

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The evaluation of fast-ion confinement is indispensable for the prediction of heating efficiency in a fusion reactor. The fast-ion confinement depends not only on the collisional transport in an equilibrium magnetic field but also on fast-ion driven instabilities such as Alfvén Eigenmodes (AEs) which induce the fast-ion transport and losses. It is an important issue to clarify the fast-ion transport due to the instabilities.

A hybrid simulation code for nonlinear magnetohydrodynamics (MHD) and energetic-particle dynamics, MEGA, can simulate recurrent bursts of fast-ion driven AE instabilities including the energetic-particle source, collisions, and losses in a non-axisymmetric three-dimensional magnetic configuration such as the LHD[1]. The multi-phase simulation, where MHD hybrid simulation and classical simulation are performed alternately, was applied to the LHD experiment using the MEGA code. It was found that two groups of AEs with frequencies close to those observed in the experiment are destabilized alternately. The alternate appearance of multiple AEs is similar to the experimental observation[1].

On the other hand, the role of each AE in fast-ion transport in the LHD has not been clarified yet. Therefore, orbit-following simulations of fast-ion transport and losses with time-dependent electromagnetic perturbations are performed to clarify the roles of AEs and a low-frequency MHD mode observed in the kinetic-MHD hybrid simulation of AE bursts in the LHD.

Figure 1 shows fast-ion pressure profiles and time evolution of fast-ion loss rate in orbit-following simulations with the time-dependent AE amplitude following the kinetic-MHD hybrid simulation result. The fast-ion pressure profile flattening in the kinetic-MHD hybrid simulation can be reproduced by an orbit-following simulation with only the primary single AE (Fig. 1 (a)). The effects of the other modes are negligible on the fast-ion pressure profile flattening. The fast-ion losses in the kinetic-MHD hybrid simulation can be reproduced by an orbit-following simulation when the low-frequency MHD mode is considered in addition to the multiple AEs (Fig. 1 (b)). This indicates the important role of the low-frequency MHD mode in the fast-ion losses observed in the kinetic-MHD hybrid simulation.

In this conference, the analyses of the orbit-following simulations with a single AE of the constant amplitude as well as time-dependent amplitude will be shown. We will discuss the effect of each AE on fast-ion transport.

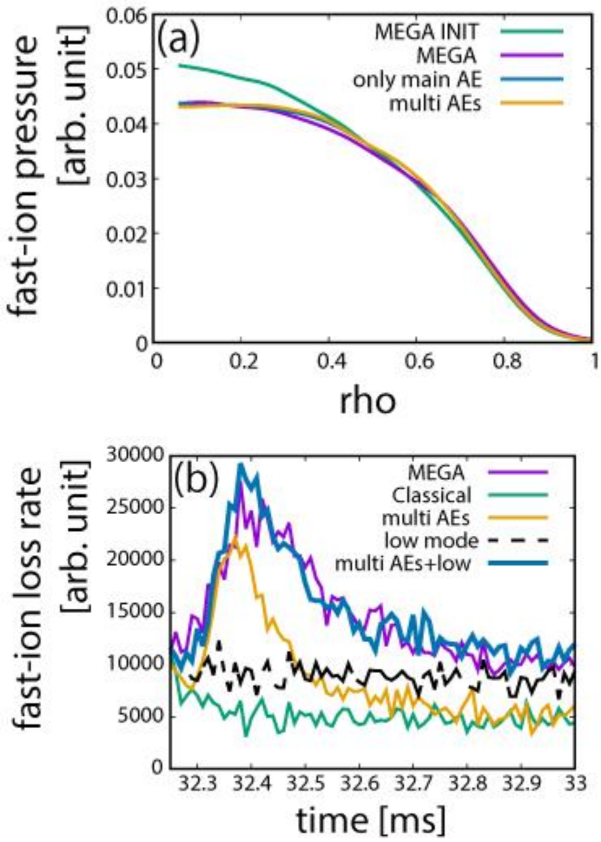

Figure 1 (a) Fast-ion pressure profiles in time-dependent AE amplitude simulations. In panel (a), the green (MEGA INIT) and purple (MEGA) lines represent the fast-ion pressure profiles before and after the AE burst in the MEGA simulation, respectively. (b) time evolution of fast-ion loss rate in the time-dependent AE amplitude simulation including the low-frequency MHD mode. In panel (b), the green line represents the fast-ion loss rate in the classical simulation without MHD perturbation.

References

[1] Y. Todo, et al., Physics of Plasmas 24, 081203 (2017).