3-1. Fusion Plasma Simulation

§1. Simulation of Alfvén Eigenmodes Destabilized in ITER Plasmas

Todo, Y.,
Bierwage, A. (Japan Atomic Energy Agency)

The energetic-particle transport and losses enhanced by Alfvén eigenmodes (AE modes) are an important concern for burning plasmas, for example, ITER plasmas. It has been pointed out that energetic alpha particles and beam ions with the maximum energy 1 MeV may lead to the destabilization of toroidal Alfvén eigenmode (TAE modes) with toroidal mode number $n\sim10$ in an ITER-like plasma1). It was found in nonlinear hybrid simulations of energetic particles interacting with magnetohydrodynamics (MHD) fluid that AE modes with low toroidal mode number $n=2\text{-}3$ are unstable and the redistribution of alpha particles is benign for ITER-like plasmas2,3). Recently, a hybrid simulation code MEGA participated in a benchmark test of the ITPA Energetic Particle Physics Topical Group, and a good agreement was found in growth rate of a TAE mode among the nine codes including the MEGA code. The finite Larmor radius effect that reduces the energetic particle drive to AE modes has been implemented in the MEGA code. In this work, we investigated the AE modes and the associated energetic particle transport in ITER plasmas. It is important for the prediction of AE modes in ITER to investigate realistic equilibrium using sufficient numerical resolution. We employ the equilibrium data that are constructed with the ASTRA and EFIT codes and provided on the ITER IDM data folder. The numbers of grid points for the MHD fluid are *(256, 256, 512)* for cylindrical coordinates *(R, φ, z)* that are larger by factor of 2.5 or 5 in each direction than our previous work3). The numbers of the grid points used are sufficient to resolve the spatial profile of AE modes with $n\sim10$ and higher.

We investigated the evolution of Alfvén eigenmodes and the associated energetic particle transport, and also the ideal MHD instabilities for the ITER operation scenarios using the MEGA code. The particle simulation method with the finite Larmor radius effects was applied to both the alpha particles and the beam deuterium particles. For a steady state plasma with 9MA plasma current, it was found that beta-induced Alfvén eigenmodes (BAE modes) with low toroidal mode number ($n=3,\ 5$) become dominant in the nonlinear phase, although many toroidal Alfvén eigenmodes (TAE modes) with $n\sim15$ are the most unstable in the linear phase. Figures 1 and 2 show the spatial profiles and the frequencies of the $n=15$ TAE mode and the $n=3$ BAE mode, respectively. Redistribution of energetic particles with $\delta\beta_\alpha \sim \delta\beta_{beam} \sim 0.07\%$ takes place in the nonlinear phase. When the toroidal mode number of the fluctuations are restricted to $n\leq8$, the redistribution is substantially reduced. This suggests that the resonance overlap between the TAE modes with $n\sim15$ and the low-n BAE modes enhances the energetic particle transport. For another ITER plasma with 15MA plasma current, a MHD instability with $n=3$ results in a significant redistribution of alpha particles with $\delta\beta_\alpha \sim 0.3\%$. When the safety factor profile is uniformly raised by 0.1, only a benign MHD instability takes place, and the energetic particle transport is negligible.

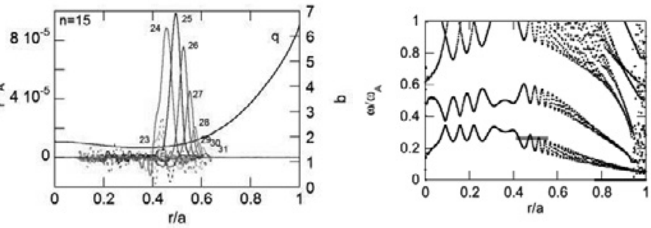

Fig. 1. *Spatial profile of n=15 TAE mode with ploidal mode numbers labeled in the figure (left) and the n=15 Alfvén continua with the frequency of the TAE mode shown by red line (right).*

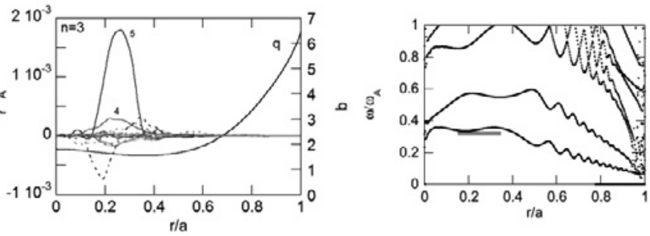

Fig. 2. *Spatial profile of n=3 BAE mode with ploidal mode numbers labeled in the figure (left) and the n=3 Alfvén continua with the frequency of the BAE mode shown by red line (right).*

1) Gorelenkov N. N. *et al.*:Nuclear Fusion **45** (2005) 226.
2) Vlad G. *et al.*:Nuclear Fusion **46** (2006) 1.
3) Todo Y.: J. Plasma Phys. **72** (2006) 817.