Contribution ID: **447** Type: **Oral**

Simulations of energetic particle driven instabilities and fast particle redistribution in EAST tokamak

Tuesday, 23 October 2018 11:05 (20 minutes)

Instabilities driven by energetic particles including fishbones and Alfven eigenmodes, together with fast particle loss and redistribution due to resonant magnetic perturbations (RMPs), have been investigated numerically with codes M3D-K, MEGA, and GYCAVA in EAST tokamak. Firstly, hybrid simulations with the global kinetic-magnetohydrodynamic (MHD) code M3D-K have been carried out to investigate the beam-driven fishbone in EAST experiment. The results are consistent with the experimental measurement with respect to mode frequency and mode structure. Nonlinear simulations show that the frequency of the fishbone chirps up and down with corresponding hole-clump structures in phase space, consistent with the Berk-Breizman theory. In addition to the low frequency fishbone, a high frequency beta-induced Alfven eigenmode (BAE) is excited during the nonlinear evolution. Secondly, two kinetic-MHD codes, namely MEGA and M3D-K, have been applied to study fast ion driven toroidal Alfven eigenmodes (TAEs) in EAST tokamak. Parameter scans show that the frequency and growth rate of TAEs simulated by the two codes agree well with each other. The analysis of the resonant interaction between the TAE and fast ions shows that the TAE exchanges energy with the co-current passing particles with parallel velocity $|v \mid V_{A0}/3$ or $|v \mid V_{A0}/5$, where V_{A0} is the Alfven speed on the magnetic axis. Moreover, the TAE destabilized by the counter-current passing ions has much smaller growth rate than that driven by the co-current ion. Thirdly, the effects of RMPs on the loss and redistribution of passing ions are investigated numerically by the orbit following code GYCAVA for EAST tokamak. The loss fraction and the loss region of passing ions increase with the amplitude of RMPs. For the energetic passing ions, the extra loss induced by RMPs can be comparable to the loss induced by the magnetic drift. The extra loss of passing ions induced by RMPs is related to the drift island structure induced by RMPs and the magnetic drift, and the stochasticity induced by overlap of magnetic islands. The dependence of the loss fraction and loss region on the toroidal mode number of RMPs is related to the safety factor. Finally, the pitch angle and energy of particle can impact the loss of energetic passing ions. These results would provide guidance for future EAST experiments.

Country or International Organization

China, People's Republic of

Paper Number

TH/1-1

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Session Classification: EX/1-TH/1 Energetic Particles

Track Classification: THW - Magnetic Confinement Theory and Modelling: Wave–plasma interactions; current drive; heating; energetic particles