Interaction of Fast Wave Accelerated Beam Ions with Ideal Internal Kink Instability in the DIII-D Tokamak*

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In the present work, we show that ORBIT-RF [1] coupled with TORIC [2] simulations on the interactions of beam ion-fast wave (FW) in the DIII-D moderate to high harmonic FW heating experiments can reproduce the observed energetic tails, and we confirm its sawtooth stabilization effect in the context of Porcelli model [3] combined with ideal MHD stability theory.

Delay or suppression of the sawtooth instability when q_0 (central safety factor) drops below 1 has been a critical issue in the conventional tokamak plasma as well as for burning plasma experiment such as ITER. DIII-D experiments using neutral beam injection and FW [5] have demonstrated that beam ions accelerated by FW can significantly modify sawtooth activities, depending on the plasma and wave conditions. We evaluate the kinetic contribution of beam ion tails generated by FW to MHD stability with the distribution function of fast ions with finite orbit calculated from ORBIT-RF. We run ORBIT-RF with FW solutions from TORIC to obtain agreement with neutron rate measurements. The calculated beam ion tails also agree qualitatively with experiments. The ideally perturbed potential energy is calculated using either a numerically fitted formula [5] or the numerical solution from GATO [6]. We evaluate separately the contributions from the ideal unstable mode and trapped ion populations at several refined time slices during one monster sawtooth cycle, and, then apply the Porcelli sawtooth crash criteria and kinetic stabilization models to each equilibrium at the selected times. Simulation results show that FW-accelerated beam ions account for the change of sawtooth behavior in DIII-D moderate to high harmonic FW heating experiments, but, its crucial kinetic stabilizing contribution strongly depends on both magnetic shear at q = 1 surface and the radius of q = 1 surface.

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