Fishbone instability and nonlinear dynamics in HL-2A plasmas

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Fishbone mode was first reported in 1983 on PDX[1], and it can be driven unstable by energetic beam ions in tokamaks. This mode is dominated by a large amplitude m/n=1/1 component, and it usually induces significant fast ion losses. It has been widely studied in experiment and theory regarding its fascinating details, especially about nonlinear dynamics. The HL-2A tokamak has reported abundant fishbone phenomena, such as frequency jumps, V-font-style sweeping, run-on fishbone, sawbone and e-fishbone[2]. To understand fishbone linear stability and nonlinear dynamics in realistic tokamak plasmas, the global kinetic-MHD hybrid code M3D-K[3,4] is used in this work. Firstly, a equilibrium with monotonous q profile with $q_0<1$ is analyzed. With different energetic particle parameters, linearly, either sawtooth or fishbone mode can be excited, and nonlinearly, fishbone mode may also lead to a sawtooth crash. Secondly, fishbone instability with different q profiles is studied, especially for low shear q profiles. Since this mode is strongly dependent on both MHD components and kinetic effects, the magnetic shear is a key critical parameter for the mode stability. Lastly, nonlinear simulation results of fishbone are presented, which might be relevant to the V-font-style sweeping observed in the experiment.

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