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Passing Energetic Ions Driving Fishbone Instability in Tokamak Plasmas

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After the first report in the poloidal Divertor Exportment (PDX) plasmas [1], fishbone instabilities were commonly observed in tokamak plasmas with energetic particles induced by NBI heating and/or RF heating. In PDX, with perpendicular NBI, it is understood that the fishbone instability is driven through the resonance with the trapped energetic ions' toroidal precessional drift frequency. In the Princeton Beta Experiment (PBX), fishbone instability driven by passing energetic ions was first reported. Recently, numerical study for NSTX shows that trapped and passing energetic ion can contribute to drive fishbone mode together [2]. In ITER, energetic ions are mostly passing particles. It may be more important to understand fishbone instability driven by passing energetic ions. In this study, a generalized energetic ion distribution function and finite drift orbit width effect are considered to improve the theoretical model for passing particle driving fishbone instability [3]. After consider the finite drift orbit width, the results show that with q_0 close to the unit, there would exist two branch fishbone driven by passing energetic ions, as shown in Fig. 1: high and low frequency fishbone.

For the high frequency fishbone, the wave particle resonance condition is $\omega = \omega_\phi$. With purely passing energetic ion with zero drift orbit width, the δWk is solved analytically. The driving term is the same as in previous work [4], while the damping term is corrected by keeping a few high order term. For generalized energetic ion distribution function, the fishbone dispersion relation is solved numerically. Numerical results show that broad and off-axis profile can significantly increase βc and decrease frequency for the mode. Bigger critical energy and pitch angle can reduce the βc, and finite drift orbit width effect has weak effect on the mode stability for PBX parameters.

For the low frequency fishbone, the wave particle resonance condition is $\omega = \omega_\phi - \omega_\theta$. Previously [5], the mode frequency was determined by the thermal plasma component (ω_i^*). In this work, the fishbone dispersion relation is solved self-consistent. This result can help to understand the fishbone in HL-2A tokamak [6].

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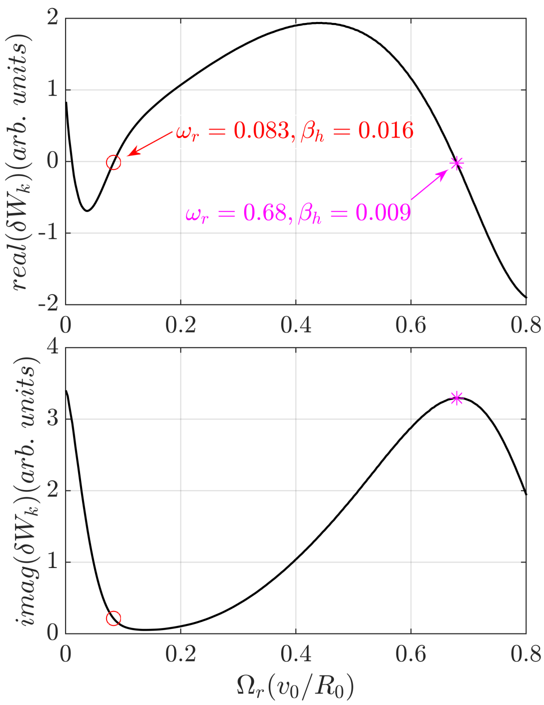

Figure 1 δWk as a function of mode real frequency.