Conventional and non-conventional fishbone instabilities driven by circulating energetic ions

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Fishbone activity was observed in many experiments on tokamaks and spherical tori. It was observed also in some experiments on stellarators. Although fishbone oscillations were discovered in an experiment with trapped energetic ions, in many cases fishbones are associated with circulating ions. Conventional fishbone instability is a rigid kink displacement with the mode numbers $m = n = 1$. But recently it was found that $m \neq n \neq 1$ fishbones are possible, too [1]. Furthermore, the radial structure of the fishbone mode and its frequency characteristics may considerably differ from those of conventional fishbones [2].

The purpose of this work is to present both an overview on circulating-ion-induced fishbone instabilities and new material on this matter. In particular, a new non-conventional fishbone instability of plasmas with small shear in the core region is predicted. This instability is essentially an energetic particle mode (EPM). It arises in plasmas with on-axis safety factor, q_0, close to low-order rational (including integers) and occupies shear-free central core surrounded by the region with finite shear. The frequency of this "infernal" fishbone mode is $\omega \sim k_{0\|} v_\alpha$, with $k_{0\|} \propto m/n - q_0$ the parallel wave number in the shear-free core and v_α the velocity of the injected ions. It is shown that the predicted infernal fishbone mode may be responsible for the *m=2* fishbone oscillations accompanied by strong drops of the neutron emission during tangential neutral beam injection in the NSTX spherical torus. In addition, in this work we consider "doublet fishbones" – an instability characterized by two frequencies [2] and other fishbone instabilities. The mentioned "doublet fishbones" occur in plasmas with a non-monotonic radial profiles of the safety factor, $q(r)$, and energetic ion pressure, $p_\alpha(r)$. Doublet fishbone instability seems to explain unusual fishbone oscillations observed in the ASDEX Upgrade tokamak and reported in Ref.[3].

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References

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