Off-axis Fishbone-like Instability and Excitation of the Resistive Wall Mode (RWM) in JT-60U and DIII-D Devices*

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Advanced tokamak experiments in JT-60U [1] and DIII-D [2] have revealed that in high-beta $q(0)>1$ plasmas, where the resistive wall modes (RWMs) are predicted to be stable by kinetic effects of energetic particles, plasma rotation and a nearby conducting wall, off-axis fishbone-like instabilities often trigger RWMs. The rapid growth of these RWMs prevents high performance operation.

The off-axis fishbone-like instability has some similarities to the classic m/n=1/1 internal fishbone instability in terms of its initial frequency near the energetic ion precession frequency, downward frequency-chirping, and a neutron rate drop of ~20% during each burst. However, there are several unique non-ideal-MHD features in the off-axis fishbone-like instability. The waveform time behavior has strong non-sinusoidal distortion from the q~2 area to the edge, synchronized with bursting energetic particle losses, while the plasma rotation is rapidly reduced within a few milliseconds.

Based on experimental observations the following hypothesis emerges. In plasmas where rotation and kinetic effects are usually sufficient to stabilize the RWM, energetic particles can drive the fishbone instability of several kHz (larger than the inverse of the resistive wall time constant). The reduction of kinetic stabilization due to the resulting energetic particle loss and rapid decrease of plasma rotation makes the plasma more vulnerable to the near-zero frequency RWM. The impact on RWM stability by the off-axis fishbone with its radial and toroidal distortion of the mode structure is assessed by comparing the JT-60U/DIII-D results with theoretical predictions.

[1] G. Matsunaga et al., Phys. Rev. Lett. **103**, 045001 (2009).
[2] M. Okabayashi et al., Nucl. Fusion **49** (2009) 125003.

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