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Fast ion instabilities in DIII-D hybrid discharges

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Significant variations in MHD activity and fast-ion transport are observed in high-beta, steady-state hybrid discharges with a mixture of Electron Cyclotron (EC) waves and Neutral Beam Injection (NBI). For neutral-beam-only heating, many Alfven Eigenmodes (AE) are observed at frequencies of 100-250 kHz that cause a ˜35% degradation in the neutron rate. With both NBI and EC, the AE activity is usually suppressed and replaced by low-frequency fishbone-like bursts. It has been suggested that the change in MHD activity occurs because qmin dropped close to unity during EC current drive, and this hypothesis is supported by kinetic/MHD hybrid simulations for a pair of DIII-D hybrid shots [Z. Z. Ren, G. Y. Fu et al., Phys. Plasmas 25, 122504 (2018)]. However, experimental cases exist where the MHD activity changes significantly, but the q profile apparently does not. A recently compiled database shows that change of the perpendicular fast-ion pressure is the main factor responsible for the transition in mode activity. The database suggests that appearance of fishbone-like bursts occur when Phot/Ptot is larger than 0.55, where Phot is the central energetic particle pressure and Ptot is the central total pressure. The gradual decrease of q in some EC cases also facilitates the appearance of fishbones. The simulations with kick model for hybrid shots confirm that the drive for low-frequency fishbones is mainly trapped particles, while AEs resonate with fast ions in a large portion of phase space. An increase of plasma temperature in hybrid discharges generally results in a larger fast ion population, which increases the drive of fishbone instability. The destabilized fishbones redistribute fast ions, and then affect the drive of AEs. This hypothesis is also supported by the observation that fishbone-like bursts are rarely seen in counter-NBI hybrid shots. Kinetic/MHD hybrid simulations are being performed to check the hypothesis.

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