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EX/11-1: Evidence of Zonal-Flow-Driven Limit-Cycle Oscillations during L-H Transition and at H-mode Pedestal of a New Small-ELM Regime in EAST

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Small-amplitude edge localized oscillations have been observed, for the first time, in EAST preceding the L-H transition at marginal input power, which manifest themselves as dithering in the divertor Dalpha signals at a frequency under 4 kHz, much lower than the GAM frequency. Detailed measurements using two toroidally separated reciprocating probes inside the separatrix demonstrate a periodic turbulence suppression accompanied by an oscillation in Er as the shearing rate transiently exceeds the turbulence decorrelation rate. Wavelet bicoherence analysis shows a strong three-wave coupling between edge turbulence in the range of 30˜100 kHz and low-frequency Er oscillations. Just prior to the L-H transition, the Er oscillations often evolve into intermittent negative Er spikes. The Er oscillations, as well as the Er spikes, are strongly correlated with the turbulence driven Reynolds stress, thus providing a direct evidence of the zonal flows for the L-H transition at marginal input power. Furthermore, near the transition threshold sawtooth heat pulses appear to periodically enhance the dithering, finally triggering the L-H transition after a big sawtooth crash. The zonal flow induced limit-cycle oscillations were observed not only prior to the L-H transition but also at the H-mode pedestal following the transition, or in the inter-ELM phase. In addition, a high-frequency-broadband (50-500 kHz) turbulence has been observed in the steep-gradient region of the H-mode pedestal in EAST, which exhibits an initial growth phase with small-amplitude axisymmetric magnetic perturbations. This high-frequency turbulence is modulated by the low-frequency zonal flows, resulting in small-ELM-like transport events. Good confinement (H_98˜1) is achieved in such a "small-ELM"regime, even with heating power close to the L-H transition threshold. The growth, saturation and disappearance of the zonal flows are correlated with those of the high-frequency turbulence, with the energy gain of the zonal flows being of the same order as the energy loss of the high-frequency turbulence, thus strongly suggesting a causal link between them. A novel predator-prey model, incorporating the evolution of zonal flows, pressure gradient and turbulences at two different frequency ranges, has been developed and successfully reproduced the key features of this newly observed small-ELM regime.

Country or International Organization of Primary Author

China

Primary author: Mr XU, Guosheng (China)

Presenter: Mr XU, Guosheng (China)

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