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Transition and Interaction of Low-Frequency MHD Modes during Neutral Beam Injection on HL-2A

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Fishbone instability not only can lead to loss of energetic particles, but also can trigger other low-frequency MHD modes, such as tearing mode/neoclassical tearing mode (TM/NTM) and the long-lived mode (LLM), then to effect the confinement of the fusion plasma. Meanwhile, the TM/NTM is a very important MHD mode, which can cause serious confinement degeneration and will be the principal limit on performance in large tokamaks, like ITER. It is also found that the LLM can lead to confinement degradation and flatten the toroidal rotation. The obvious reduction of plasma stored energy can be observed usually in the presence of such perturbation. It has been found that fishbone instabilities as seed magnetic island can trigger the 2/1 and 3/2 NTMs on ASDEX-U and NSTX. Recently, simulations according to the discharge parameters and equilibrium on NSTX and MAST have been done, and the results are in agreement with experiment phenomena. The low-frequency MHD modes, such as fishbone, LLM and TM/NTM modes had been identified on HL-2A. In this paper we will present the new experimental results about transition and nonlinear interaction of these low-frequency MHD modes.

The transition from fishbone to LLM has been observed, and the fishbone triggering TMs has been presented during NBI on HL-2A. It is found that the LLM localizes at r=4.5cm, but the two TMs occur at r=16.3cm and r=21.5cm. The frequencies of fishbone and its harmonic decrease from f˜30-10 kHz and f˜60-20 kHz, respectively, during t=655.5-657.5 ms. And the two TMs, with initial frequencies about f˜10 and f˜20 kHz, follow fishbone and its harmonic at t≈657.5 ms. And the two TM frequencies drop from f˜10-1.5 kHz and f˜20-3 kHz, respectively, during t=657.5-660 ms. At last, the two TM frequencies keep as f˜5 kHz and f˜10 kHz. Note that the mode numbers of two TMs are m/n=2/1 and 3/2, respectively.

The nonlinear couplings of LLM and TMs are observed by the multi-channel ECE signals. It's observed that the 1/1 LLM and 2/1 TM provide the same frequencies, with f˜5 kHz, but they localize at different radial position during t=661.0-667.0 ms. And the matching conditions are satisfied between two TMs and LLM, i.e. fTM1+fLLM=fTM2 and nTM1+nLLM=nTM2, indicating that the one of the TMs may be induced by the coupling between the other two modes through the wave–wave non-linear interaction.

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