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Development of the q=1 Advanced tokamak Scenarios in HL-2A

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Advanced tokamak scenario with central q close to 1 has been achieved on HL-2A tokamak. An ITB has been observed during the nonlinear evolution of a saturated long-lived internal mode (LLM) or fishbone activities in HL-2A discharges as the q-profile formed a very broad low-shear region with qmin ˜ 1. Such steep ion temperature-gradient zone locates around r/a=0.5-0.6 with Ti>Te. The observed normalized ion temperature gradient (R/LTi) is of 10.6, which exceeded the value for a level without ITB of~6.5. Here, R is the major radius and LTi is the scale length of the Ti gradient defined by LTi= aTi/(dTi/dρ). When the barrier forms, the turbulence is significantly reduced around ITB foot(r/a=0.6), as measured by reflectometry in figure 2. The simultaneous excitation of the ITB and the bursting internal mode can only occur if the q-profile in the core remains flat in the plasma central region. This confirms the role played by the central internal kink instabilities in the production of ITBs in reversed or weak shear plasmas.

It was found that the q min reaching an integer value (q =1) throughout the ITB period, and there is a correlation between the emergence of the ITB formation and the evolution of central magnetic shear due to the perturbation of m=1/n=1 LLM or fishbone activity. A possible explanation for the LLM or fishbone being able to trigger or sustain ITBs is that the interaction between MHD instabilities and fast ion leads to a redistribution of the resonant fast ion. Based on this assumption, dedicated experiment have attempted to reproduce the stationary advanced scenario with q0 close to 1 by applying extra ECRH for enhancement of the fishbone activities. With strong fishbone activities enhanced by application of ECRH, this scenario does exhibit a clear prolonged ITB during the stationary phase of the discharge, extending the domain of existence of ITB form 10 confinement times to 20 confinement times, and the confinement enhancement factors over ITER89P L-mode scaling, form HITER89-P=1.7 to a new level of HITER89-P=2.1.

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