Recent Development of Wide-pedestal Quiescent H-mode on DIII-D

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Wide-pedestal quiescent H-mode is characterized by a pedestal width exceeding the EPED-KBM limit and an Er profile that is shallower and broader than standard QH-mode or H-mode. This natural ELM-stable regime was first discovered when the NBI torque was ramped down from strong counter-Ip towards net-zero in high triangularity, balanced double null QH-mode plasmas in the DIII-D tokamak. Experimentally reducing the NBI torque in the standard QH-mode can effectively trigger the transitions into wide-pedestal QH-mode. Across the transition, the ExB shear profile exhibits unique bi-modal changes: decreases in the edge ($\Psi_S > 0.91$) and increases inside of it. A local flattening is observed in the pedestal profiles (most pronounced in Te) where enhanced density fluctuations are also detected. It is posited that lower ExB shear in the pedestal steep-gradient region enables the destabilization of edge broadband MHD and turbulence, thereby reducing pedestal gradients below the KBM limit, while the higher ExB shear inside the pedestal top enhances core turbulence suppression to improve the overall confinement.

Significant parameter space expansion of the wide-pedestal QH-mode towards more ITER and reactor relevant conditions has been achieved in DIII-D. Recent experiments reveal this regime can operate at a large range of NBI torque (4.1Nm counter- to 1.9Nm co-current) completely covering the scaled ITER-equivalent applied torque, and a range of plasma rotation profiles from co- to ctr-Ip direction. Wide-pedestal QH-mode operation with net-zero NBI torque throughout the discharge [Burrell, APS 2018] and with dominant electron heating (the ratio of ECH: NBI power ~ 3:1) [Ernst IAEA 2018] have also been demonstrated. These results suggest compatibility of the wide-pedestal QH with low NBI torque and low plasma rotation expected in ITER and future reactors.

Wide-pedestal QH-mode has been obtained in not only double null plasma shape but also in ITER-relevant shape (LSN, $\delta_{avg} \sim 0.4$). Plasma shape effects are investigated experimentally and numerically using ELITE. In the experiments using dRsep scan, it is found that the pedestal of the ‘wide-pedestal’ QH decreases in height and width (still wider than that using EPED-KBM scaling) when the plasma shape moves away from DN (dRsep < -1cm) towards LSN but saturates after dRsep < -2.4cm. Peeling-Ballooning instability is not found to be the limiting factor in the simulation using ITER shape and q95=3. However, wide-pedestal QH-mode has not been obtained in USN. Experiments with torque ramp down in USN or with dRsep scan from DN towards USN encounter ELMs at low torque. ELITE calculations show the P-B stability boundary in USN and LSN are quite different even though the shape is almost identical (except one is flipped one upside-down). In the USN configuration, the ion BxVB drift is away from the x-pt and the upper divertor is more closed. The different SOL drift and fuelling could have affected the access to wide-pedestal QH regime. Simulations and new experiments are proposed to further investigate this.

This work was supported in part by the US Department of Energy under DE-FC02-04ER54698\textsuperscript{1}, DE-FG02-08ER54984\textsuperscript{2}, DE-FG02-94ER54235\textsuperscript{3}, DE-FG02-08ER54999\textsuperscript{4}.