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Understanding the MHD challenges for ITER Q=10 operation at reactor relevant conditions.[1]

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DIII-D experiments to assess options for Q=10 operation in ITER without harmful core MHD nor ELMs have advanced both achieved parameters and understanding of present limitations. Q~10 performance is achieved in low collisionality (ν*) ELM-stable plasmas with small co-Ip NBI torque using RMP ELM suppression, and small counter-Ip NBI torque using QH-mode edge. Both ELM control approaches are limited by core instabilities, while the edge regime is strongly affected by local edge torque density. A rotation threshold for RMP ELM suppression corresponds to a critical radius for the ExB rotation zero-crossing, and this threshold can be crossed at widely varying net NBI torques. An ITER-relevant net NBI torque on DIII-D tends to produce a less ITER-relevant negative local edge torque density, with severe penalty for ELM suppression. In the QH-mode approach, negative edge torque density correlates with increased edge ExB shear obtained at low density, leading to improved confinement at low net NBI torque, and Q>10 equivalent performance at q_{95}~3. However, low ν* and low q lead to pressure peaking instabilities. The character of edge fluctuations in QH-mode is key to simultaneous low torque and low q_{95} operation: broadband fluctuations are compatible with low rotation, while a coherent edge harmonic oscillation (EHO) tends to lock to the wall. A recent discovery is that the plasma-wall separation gap controls the character of the edge fluctuations: smaller gap leads to higher-n EHO at low NBI torque; even smaller gap leads to broadband fluctuations. Too small an outer gap brings back ELMs, with the threshold gap depending on NBI energy, likely through a gyro-radius dependence of fast-ion-wall interactions. A large RF-heating fraction could overcome present limitations by reducing negative edge-torque density, wall interactions, and pressure peaking from strong core fueling.

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