H-mode Power Threshold for EC and NBI Heated Discharges in DIII-D and their Dependence on the Input Torque*

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The H-mode power threshold and the validation of H-mode threshold scaling laws is a very important issue for next step fusion devices, such as ITER. On DIII-D, the H-mode power threshold has been determined for plasmas heated by neutral beam injection (NBI) and/or by electron cyclotron heating (ECH) and as a function of the applied torque. For purely NBI heated plasmas, the power required to induce the transition from L-mode to H-mode plasmas (L-H transition) is dependent on the applied beam torque and the edge toroidal plasma rotation. For upper single null (USN) discharges in which the ion grad-B drift is away from the X-point, the L-H transition power threshold is reduced by nearly a factor of 3 by changing from predominantly co-injection (~6 MW) to predominantly counter-injection (~2.2 MW). A similar, but less prominent dependence is observed in lower single null (LSN) discharges, in which the ion grad-B drift is towards the X-point, where the power threshold is reduced by nearly a factor of 2. The threshold power decreases with the edge toroidal rotation. For the first time, the L-H transition has been induced at constant input power below the nominal threshold power by reducing the input torque from all co-beams to balanced beams. At low toroidal rotation, a shear in E_r develops in the L-mode as a result of an increased gradient in the toroidal rotation just prior to the L-H transition and large changes in the poloidal velocity shear of the edge turbulent eddies are observed prior to the L-H transition that may be strong enough to induce the transition.

For EC heating, the H-mode threshold power is comparable to or slightly lower than NBI heating at zero applied torque and at similar plasma parameters. The change in power threshold at different values of the applied NBI torque was performed by applying a small amount of counter and co-NBI on different discharges with dominant EC heating. With both LSN and USN discharges at similar target densities, there does not appear to be a large variation in the H-mode threshold power as the applied torque is changed about the zero torque value. However, with applied co-NBI torque, the threshold power exhibited a larger increase in USN discharges than in LSN discharges. The H-mode power threshold was higher in the USN discharges for all the cases investigated. The implications for ITER are generally favourable given its low expected plasma rotation. However, the detailed assumptions and extrapolations of the H-mode threshold power scaling laws to ITER need to be re-examined in light of these torque and plasma rotation dependencies and for the different heating methods (ECH or NBI) used.

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