Improvement of Core Barriers with ECH and Counter-NBI in DIII–D*

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Additional tools have been brought to bear on the challenge of core transport barrier control in the DIII–D Tokamak. An ECH/ECCD (electron cyclotron heating and current drive) preheat method has been developed to tailor the target current profile prior to formation of a beam-heated barrier, with resulting q profiles similar to those produced by neutral beam preheat. The flexibility of this method allows better control of the early current profile development to better optimize the final barrier characteristics. An interesting feature observed during the ECH preheat phase is the appearance of a strong, highly localized transport barrier in the electron temperature profile ($T_e(0) \leq 6$ keV) when a low density (1×10^{19} m^{-3}), low current ($\geq$500 kA) plasma is heated with $P_{ECH} = 0.5$ MW (launched for counter-ECCD) and $P_{NBI} = 0.5$ MW. The upper limit to the electron thermal diffusivity in this barrier is calculated as $\chi_e \leq 0.2$ m^2/s. Later in these discharges, application of high power counter neutral beam injection (counter-NBI) can trigger formation of a core barrier evident in the thermal (both electron and ion), momentum and particle diffusivities. These barriers tend to be broader than those created in similar conditions with co-NBI. This is attributed to a favorable combination of the rotation and pressure gradient contributions to the $\mathbf{E}\times\mathbf{B}$ shearing rate $\omega_{\mathbf{E}\times\mathbf{B}}$. Increasing or broadening the pressure profile results in larger $\omega_{\mathbf{E}\times\mathbf{B}}$, allowing access to reduced transport over a broader region. In similar co-NBI discharges, these two terms oppose so that $\omega_{\mathbf{E}\times\mathbf{B}}$ may become small at large radii, thereby retarding barrier expansion. Another feature of the counter-NBI discharges is the appearance of a finite power threshold for barrier formation, in contrast to the negligible threshold previously reported with co-injection. This also appears to be a consequence of the modified $\mathbf{E}\times\mathbf{B}$ shear dynamics with reversal of the toroidal rotation.

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