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Edge Bootstrap Current and High ℓ_i Advanced Tokamak Operational Mode

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Both high normalized beta, $\beta_N = \beta(\%)\, B(T)\, a(m) / I(MA)$, and high confinement enhancement, $H = \tau_E / \tau_{E-ITER89P}$, have been robustly observed in high internal inductance (ℓ_i) discharges on the DIII–D and other tokamaks. These high performance, high ℓ_i discharges are obtained by transient inductive means. However, in steady state, high ℓ_i is undermined by the combinations of the large edge bootstrap current resulting from the finite edge pressure gradient in the H–mode and the finite value of the central safety factor $q(0)$ required by MHD stability. The goal of the present study is to determine whether a moderately high value of ℓ_i and high beta values are compatible and, in particular, without the requirement of wall stabilization. We have used the TOQ equilibrium code to construct self-consistent bootstrap equilibria of typical DIII–D H–mode pressure profiles and a peaked current profile. The high-n ballooning stability of these simulated discharges was examined by the BALOO code, and the kink stability by the MARS and GATO codes. We have found stable steady-state equilibria with moderately high value of ℓ_i ($\ell_i \sim 1.0$) and β_N of about 4.0, and a bootstrap current fraction of 65%–70% for the full-size DIII–D configuration. The β-limit is consistent with the semi-empirical scaling law of $\beta_N < 4\,\ell_i$ A modest central current drive will be required to sustain such discharges in steady state. Strong plasma shaping will also be needed to achieve the high β operational scenario without wall stabilization.

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