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Optimizing Stability, Transport, and Divertor Operation Through Plasma Shaping for Steady-state Scenario Development in DIII-D[1]

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Recent studies on DIII-D have elucidated key aspects of the dependence of stability, confinement, and density control on the plasma magnetic configuration, leading to noninductive operation (i.e., total inductive flux change ≈ 0) for >1 s with pressure 30% above the free boundary limit. Achieving fully noninductive operation requires high β, good confinement, and density control through divertor operation. Plasma geometry affects all of these. Ideal MHD modeling of the $n = 1, 2$, and 3 external kink stability suggests it may be optimized by adjusting the shape parameter known as squareness (ζ). Experiments confirm stability varies strongly with ζ in qualitative agreement with the modeling. Optimization of $n = 1$ stability also seems to raise pedestal stability. Adjusting ζ above and below the midplane independently allows for small changes in the magnetic divertor balance about a double-null (DN) configuration. Energy confinement is found to be sensitive to this balance, with 20% higher confinement observed in a balanced DN compared to a slightly unbalanced case. However, adequate density control requires a small imbalance to achieve densities necessary for efficient external noninductive current drive. The best density control (20%-30% below the balanced DN case) is obtained with a slight imbalance toward the divertor opposite the ion grad(B) drift direction. Consistency of modeling with these observed effects requires inclusion of $E \times B$ drifts in the divertor. Simultaneous optimization has been applied to achieve noninductive current fractions near 1 for over 1 s with $\beta_N \sim$3.5-3.7, bootstrap fraction >65%, and good confinement.

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