Changes in Core, Edge, and Divertor Plasma Behavior Due to Variation in Magnetic Balance in DIII-D*

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In recent ELMing H-mode experiments on DIII-D we demonstrated important differences in performance between double-null (DN) and single-null (SN) diverted plasmas. Both the pedestal density $n_{e,PED}$ and core plasma energy confinement time τ_E were highly sensitive to departures from magnetic balance, e.g., both decreased 15-30% when the DN shifted to a SN divertor with the $\mathbf{B}\times\nabla B$ drift direction away from the X-point. The particle flux and the electron density at the inner divertor target(s) in the divertors were found to be much more sensitive to variation in magnetic balance than at the outer divertor target(s), e.g., $n_{e,INNER}$ varied by a factor of 5 to 6 between a balanced DN and a SN, while $n_{e,OUTER}$ changed only ≈50%. Modeling of the SOL plasma with the UEDGE transport code has shown that these inner/outer asymmetries were largely the result of $\mathbf{B}\times\nabla B$ and $\mathbf{E}\times\mathbf{B}$ flows in the scrape-off layer (SOL) and private flux regions. Particle recycling at each of the four divertor targets in DN was strongly influenced by both the divertor magnetic balance and the presence of these particle flows. In turn, this distribution in the recycling appeared to play a role in how effectively the SN and DN core plasmas were fueled. ELM behavior was also found to be dependent on the magnetic balance of the plasma. Unlike for SNs, ELM pulse activity was virtually eliminated at the inboard divertor targets for the DN configuration. In general, the impact area of the ELM pulses at the inboard divertor target(s) is smaller than that expected for an ELM pulse confined to flux surfaces in the SOL. This behavior suggests that particle drift(s) in the SOL may be playing a role in the trajectory of the ELM pulse.

While the physics of the DN edge and divertor plasmas appear to be more involved than that of the SN, our analysis of the data suggests possible simplification of several key aspects of future tokamak design. For example, negligible ELM activity may require less protective armor at DN inboard targets and less particle pumping there. This can lead to more efficient use of volume near the centerpost and more effective neutral gas fueling of the main plasma from the high-field side. In addition, precise control over the magnetic balance of the DN also provides a useful tool to regulate the $n_{e,PED}$ and τ_E of the H-mode plasma.

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