Closure, Drifts, and Energy Dissipation Studies Using the DIII-D Small Angle Slot Divertor

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A Small Angle Slot (SAS) divertor has been installed on the DIII-D tokamak to test concepts of enhanced heat dispersal using a combination of closure and directed recycling flux. In this system, the combination of enhanced neutral buildup and ExB drifts can significantly increase dissipation and detachment and decrease T_e to ~ few eV across the divertor target, conditions necessary for future high duty factor reactor designs. Initial tests have demonstrated SAS can achieve these conditions for an extended range of operation, allowing for significant energy dissipation at substantially lower density ($n_e/n_G \sim 0.4$) compared to open divertors in DIII-D ($n_e/n_G \sim 0.6$). These conditions can be obtained while maintaining confinement enhancement factor H_{98Y2} up to ~30% better than the open divertor at detachment onset, while delaying the degradation in confinement due to enhanced radiation (X-point MARFE) to ~30% higher pedestal densities. Transport/pedestal stability analyses indicate that such confinement improvement is associated with improved pedestal temperature and pressure, primarily due to an increased temperature pedestal width. In-slot neutral measurements confirm significant buildup of neutral pressure in conjunction with the approach to detachment, decreased T_e and enhanced dissipation. These results were obtained with the ion grad-B drift away from the divertor. Measurements with the opposite ion grad-B drift direction (i.e. into the divertor) yield significantly different results. In this case there is little difference between the SAS and the equivalent open lower single null divertor performance: dissipation and detachment occur at similar (higher) densities and result in about the same pedestal pressure.

The asymmetric behavior of these results can be understood in terms of ExB drifts interacting with the localized recycling in the SAS. Initial fluid code (SOLPS/B2-EIRENE) analysis without drifts indicated this geometry should be capable of significantly increasing the local neutral/molecular densities and energy dissipation compared to either vertical or horizontal target configurations. However, the inclusion of ExB drift flows in a closed geometry has two important consequences: the natural (open) flow patterns can be frustrated or damped by small-scale physical structures, and the resulting flow patterns can enhance or diminish the localized recycling fluxes. More recent SOLPS-ITER modeling including drifts is beginning to reproduce the experimental trends when the direction of B_T is changed, both with respect to the target electron temperature profiles, and the temperature behavior for matched density scans. Our ability to control drift directions and strike point location, perform detailed in-slot measurements with novel localized diagnostics, and conduct constrained drift-dependent modeling are all key components of this research.

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