Effects of divertor geometry on H-mode pedestal structure near divertor detachment in the DIII-D tokamak

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Dedicated experiments performed in DIII-D have found that divertor geometry significantly affects the H-mode pedestal profiles, especially near divertor detachment. Consistent with SOLPS modeling, the more closed divertor, i.e. both the upper-ceiling divertor with dome-baffle structure and the Small-Angle-Slot (SAS) divertor, tends to facilitate the achievement of divertor detachment at lower upstream density and higher pedestal temperature than an open (flat plate) divertor [1]. In both attached and detached plasmas, the more closed divertor results in the lower density and higher temperature at the top of the pedestal, due to lower pedestal fueling based on SOLPS and OEDGE analysis.

This different pedestal fueling and neutral distribution resulting from divertor closure could significantly displace the density pedestal from the temperature pedestal. For the closed divertor, increasing gas puffing and injected heating power gradually shifts the density pedestal profile radially outward away from the temperature pedestal profile. Such relative shift can reach up to 50% of the pedestal width in detached plasmas, which may suggest decoupling between the particle and thermal transport. However, the open divertor density and temperature pedestal profiles are aligned in both attached and detached plasmas.

Approaching detachment, the different divertor closure could deviate the pedestal width away from the empirical and theoretical $\beta_{p,ped}$ scaling [2]. During the attachment phase the pedestal width agrees with the scaling for all the divertor configurations. During the detachment phase, the pedestal width is strongly (30%) reduced for the open divertor. In contrast, for the closed divertors, the pedestal is significantly wider by up to 50% than the scaling. With such wider pedestal and lower pedestal fueling, the divertor detachment can be achieved while retaining high pedestal performance for the closed divertor.

In particular, it was found that high confinement is maintained with divertor detachment using SAS divertor in DIII-D, which features a gas-tight slot structure and an ITER-like slant target configuration. The SAS exhibits a significantly (~30%) higher confinement than the open divertor, and maintains good confinement while the divertor is detached throughout the density ramp during the discharge. In contrast, the open divertor exhibits further confinement degradation when the divertor starts to detach, with a pronounced drop right after the rollover of the ion saturation current measured by the target-embedded Langmuir probes.

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