

Plasma Flows and Detachment in Innovative Divertor Configurations*

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One of the most critical engineering constraints for future tokamaks is the peak heat load on the plasma facing components, which prompts the search for innovative divertor configurations that use non-standard magnetic geometry and additional X-points. The present computational investigation reveals profound effects that innovative divertor geometry can have on plasma flows and detachment in the divertor. Plasma convection, associated with a divertor null point, dubbed “the churning mode” [1], is investigated in a numerical model based on toroidally symmetric reduced MHD equations. It is found that plasma pressure profile and poloidal magnetic flux evolve in a spiraling pattern near the divertor null-point, see Fig. (1); for a higher-order null, and for larger plasma pressure at the null point, the convective motion is stronger, enough to affect the distribution of thermal energy in the divertor, which is consistent with the results of recent snowflake divertor experiments [2,3].

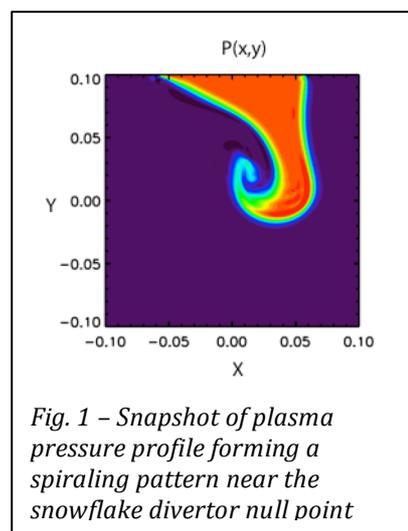


Fig. 1 – Snapshot of plasma pressure profile forming a spiraling pattern near the snowflake divertor null point

On the other hand, using the tokamak edge transport model in UEDGE for a X-point Target

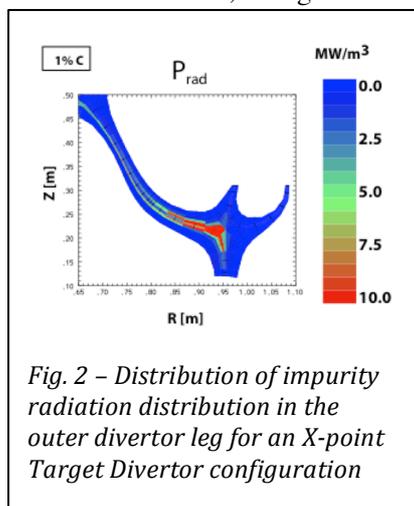


Fig. 2 – Distribution of impurity radiation distribution in the outer divertor leg for an X-point Target Divertor configuration

Divertor configuration [4] demonstrates existence of a stable fully detached divertor operation. As the input power is reduced to a threshold value, the outer leg transitions to a fully detached state with the detachment front localized near the secondary X-point in the outer leg, see Fig. (2); reducing the power further results in the detachment front shifting upstream but remaining stable. As the power is lowered further the detachment front eventually moves to the primary X-point, which is associated with an X-point MARFE; however for the X-point Target Divertor a fully detached stable divertor regime is maintained over a factor of 5-10 variation in the input power while for an otherwise similar standard vertical plate divertor a much smaller detachment operational window is found. These results suggest that a stable, fully detached divertor operation can be realized for a tokamak with radially extended outer divertor legs.

[1] D. D. Ryutov et al., Phys. Scr. 89 088002 (2014); [2] W.A.J. Vijvers et al, Nucl. Fusion 54, 2, 023009 (2014); [3] V.A. Soukhanovskii et al., J. Nucl. Mat. 438 S96-S101 (2013); [4] B. LaBombard et al., Nucl. Fusion 55, 053020 (2015).

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