Exploration of Innovative Divertor Configurations for Power Handling and Detachment Front Control *

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The challenges that will be facing the divertor in a tokamak-based fusion reactor prompt 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. Results are presented for plasma convection, dubbed “the churning mode” [1], associated with a divertor null point which is investigated in a numerical model based on toroidally symmetric reduced MHD. For a higher-order null, and larger plasma pressure at the null point, the convective motion is found to be stronger, enough to affect the distribution of thermal energy in the divertor, which is consistent with snowflake divertor experiments results [2]. On the other hand, using a UEDGE model of tokamak edge transport for the X-point target divertor configuration with parameters of an ADX-like tokamak [3] demonstrates existence of a fully detached yet stable divertor operation over a range of parameters. As the input power is reduced to a threshold value, the outer leg transitions to a stable fully detached state with the detachment front localized near the secondary X-point. 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 a fully detached stable divertor regime is maintained over a factor of 5-10 variation in the input power. For an otherwise similar standard vertical plate divertor, a much smaller detachment operational window is found, which suggests that for a tokamak with radially extended outer divertor legs a stable, fully detached divertor operation may be realized.

[1] D. D. Ryutov et al., Phys. Scr. 89 (2014) 088002; [2] W. Vijvers, Nucl. Fusion 54, 2, 023009 (2014); [3] B. LaBombard et al., Nucl. Fusion 55, 053020, 2015

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