Effect of drifts on SOL plasma in DTT Double Null configuration

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Introduction

Extreme conditions are predicted for the next generation devices as DEMO that can cause severe damages to the plasma facing components (PFCs). Possible benefits could arise from the adoption of Alternative divertor Configurations (ADCs) [1,2] which are currently under investigation. In particular, the Double Null configuration represents one of the possible candidates, as shown for instance in numerical studies performed with SOLDEGE2D-EIRENE [3]. Drifts can play an important role in determining the actual Scrape-Off Layer (SOL) conditions by acting on the plasma transport and detachment as seen in the present device[4-7]. In this contribution, we will discuss the role of the drifts in a Connected Double Null (CDN) configuration in DTT (Divertor Test Tokamak) [8] by analyzing the change in the divertor plasma conditions and the effect on the power asymmetry.

DTT Connected Duoble Null Scenario

The DTT facility under construction in Italy will act as a testbed for the most promising ADCs and should give important indications for the DEMO design in terms of power and particle exhaust [8]. SOLPS-ITER [9] simulations with the full set of currents and drifts and fluid neutrals have been carried out to investigate the role of the drifts on the divertor plasma in a CDN reversed field configuration with a plasma current of 5.5 MA and major radius R= 2.14 m. It should be noticed that the present value of the major radius in the DTT design is R= 2.19 but the study here presented is carried out for the previous value. The $V_{\nabla B}$ drift points towards the upper divertor. The flow pattern of the V_{ExB} drifts is in counterclockwise direction, thus redistributing particles from the inner to the outer divertor in the bottom part of the machine and vice versa in the upper part. A pure D plasma is taken into account. The input power is P_{in} = 8 MW and the upstream outboard separatrix density is $n_{e,OMP} = 5 \times 10^{19}$ m ^{3}. The external neutral puff Γ_D on the right SOL is optimized to get the desired value of $n_{e,OMP}$. Neutral losses are emulated with a leakage factor of 1% on the Private Region boundaries. The cross-field transport coefficients are set constant and equal to D=0.05 m^2/s, χ = 0.15 m^2/s to get a power

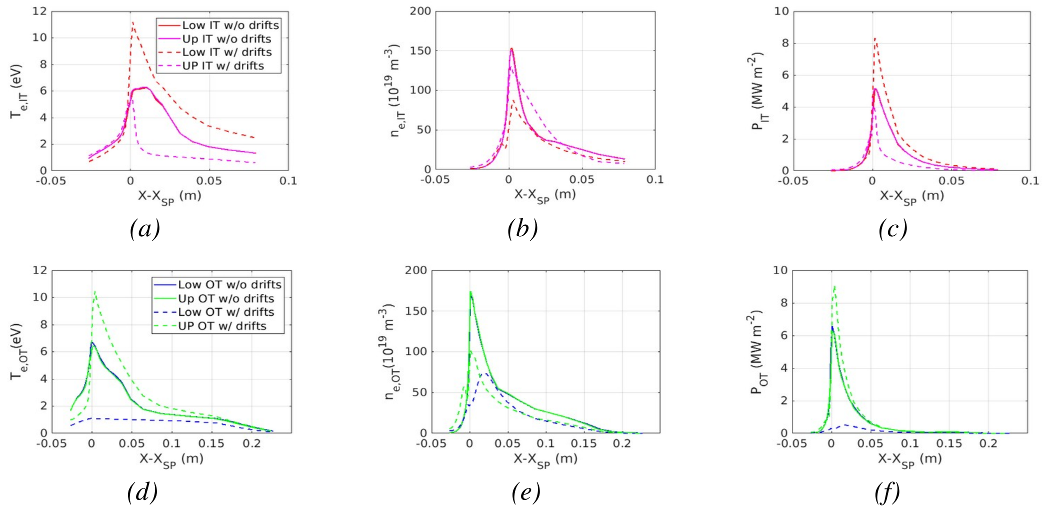


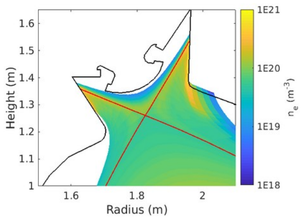
Figure 1:Radial profiles along the targets of the electron temperature T_e(a,d), electron density n_e(b,e) and power flux onto the target P(c,f). The profiles onto the inner targets (red and magenta) are shown on the top while the outer targets profiles (blu and green) are on the bottom. Solid lines denote SOLPS-ITER simulations of the DTT CDN scenario without drifts whereas dashed lines refer to cases with full drifts and currents activated.

decay length of λ_q = 1.5 mm at the outboard equatorial plane.

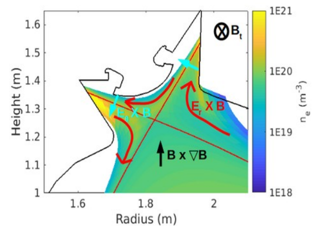
Effect on divertor plasma conditions

The assessment of the effect of drifts on the plasma divertor conditions has been performed by comparing the numerical results obtained with and without drifts and currents. Figure 1 shows the profiles along the targets of T_e, n_e, and P. The figures on the top depict the profiles on the inner targets while the bottom one refers to the outer targets, both on upper and lower divertors. In the case of drifts switched off (solid lines), an up-down symmetry is observed. Indeed, an overlap of profiles is present. This behaviour is related to the symmetry with respect to the equatorial plane of the CDN DTT scenario both in terms of magnetic equilibrium and wall structure. On both inner and outer divertors, the plasma is close to detachment with a peak of T_e ~ 6 eV and manageable values of P_{peak} ~ 6 MW/m^2.

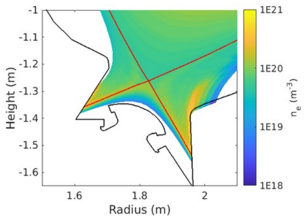
The presence of drifts (dashed lines) drastically changes the scene since a strong up-down asymmetry appears. The outer target profiles of T_e show a detachment of the lower divertor together with an increase in $T_{e,peak}$ ~ 10 eV in the upper one. In the lower outer divertor, the $n_{OT,peak,low}$ shifts towards the far SOL, $P_{peak,OT.low}$ strongly reduces, and a flattening of the P_{OT} occurs. On the contrary, $P_{peak,IT,up}$ increases. On the inner divertor, we see the same trend with an increase in $T_{e, IT,low}$ and $P_{peak,IT,low}$. However, the effect is reduced here, and both upper and lower inner divertors remain attached. This behaviour is consistent with the physical picture defined by the V_{ExB} drifts flow pattern. Figure 2 shows the contour plot of n_e in the divertor regions with drifts turned off (left) and on (right). Let us focus on the lower divertor. The combination of E_rxB (red arrows) poloidal and $E_\theta xB$ (cyan arrows) radial drifts tends to move



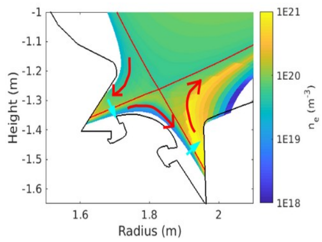
(a)



(b)



(c)



(d)

Figure 2: Contour plots of the electron density n_e (a,b)in the upper and (c,d) lower divertor regions. SOLPS-ITER simulations of the DTT CDN scenario without drifts are shown on the left column while the right column refers to cases with full drifts and currents activated. The red arrows show the $\mathbf{E}_r\mathbf{x}\mathbf{B}$ poloidal drift and the cyan arrows the $\mathbf{E}_\theta\mathbf{x}\mathbf{B}$ radial drift. $\mathbf{B}x\nabla\mathbf{B}$ (black arrow) is directed upwards.

particles from the inner divertor to the outer one. A high density region appears, and the outer divertor detaches. The same phenomenon is seen in the upper part of the machine even if this effect is less pronounced. Also, in the case of drifts, the external D puff has been increased by a factor of 4 since of the higher loss of neutral particles crossing the private region boundary.

Effect on the power asymmetry

The analysis on the power asymmetry has been performed by considering the heat fluxes crossing the divertor entrance in the 4 divertors, as shown in Fig. 3. To examine the different contributions, the heat fluxes have been decomposed in different terms: electron and ion conduction and convection, convected by currents (Pfirsch-Schlüeter and thermoelectric) and convected by drifts. The simulations without drifts (bottom row) show an up-down symmetry in the power fluxes, mainly electron conduction. An asymmetry P_{outer}/P_{inner} ~2 is present. In the case of drifts and currents, an up-down asymmetry builds up, i.e. $(P_{up}/P_{low})_{OT}$ = 1.87 and $(P_{low}/P_{up})_{IT}$ = 2.8. The convective terms increase with negative values due to a particles backflow. In line with the observation in [10], the contribution of the currents is small, i.e. 8.6% of the power. In particular, the thermoelectric current carries 5% of the power due to the low T_e targets difference. Drifts convected term accounts for 5% of the heat flux.

Conclusions

The analysis of the DTT CND scenario has shown that drifts play an important role and are essential to define the divertor plasma conditions even with the high value of the toroidal field (B = 6T). An asymmetry sets up between the lower and upper divertors caused by the drifts

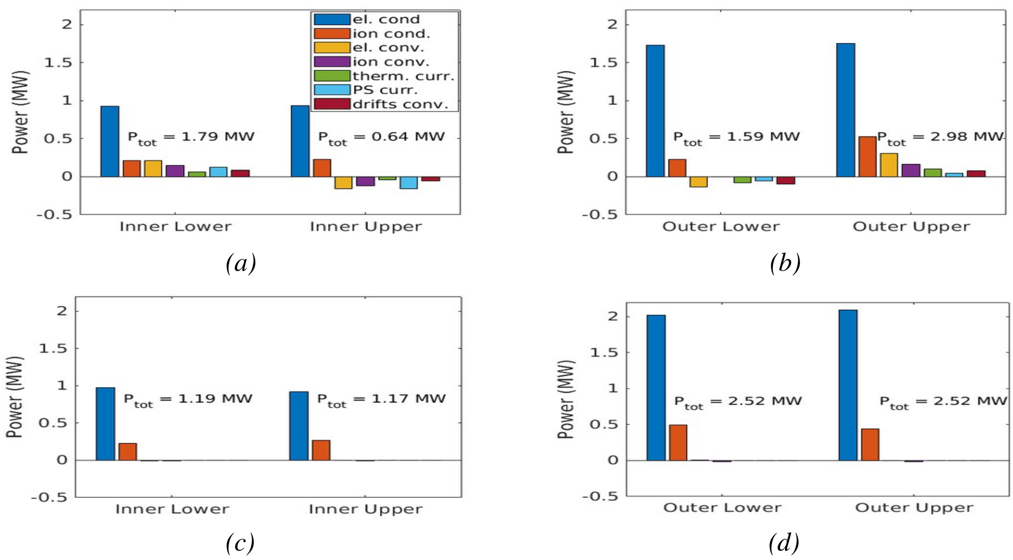


Figure 3: Calculated power fluxes crossing the 4 divertor entrances in the DTT CDN scenario divided into the different components. Top row shows the results of simulations with drifts and currents activated while bottom row to simulations without these terms. The positive values correspond to flux directed towards the targets.

flow pattern. Eventually, the particles redistribution leads to a detachment of one of the divertors. Furthermore, the power sharing between the upper and lower divertors is strongly affected due to an increase in the convective terms, albeit drifts and currents terms are small. A more detailed analysis is foreseen in future works by considering a kinetic description of the neutral particles and the external impurities in the full power scenario.

Acknowledgments

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