Study of the effect of the outer-strike point location on the divertor neutral pressure in JET-ILW using EDGE2D/EIRENE

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Introduction

During the first year of the JET-ILW operation, a substantial effort was devoted to the L-mode domain characterization with the newly installed ITER-Like Wall (ILW), consisting of a W divertor and a Be main chamber. Main experimental results were reported in [1] [2]. This paper presents the results of modelling studies, carried out with EDGE2D/EIRENE code [3], of a couple of two similar aforementioned discharges to investigate on the the effects of divertor plasma configuration and proximity of the low-field side (LFS) strike-point with respect to the LFS pumping plenum when comparing the simulation results with the experimental data of two different divertor configurations at same upstream density. The analysis focuses on the observed differences in the sub-divertor neutral pressures in relation to the deuterium ion fluxes to the divertor plates.

Experimental overview

The considered discharges are 2 MA, 2.15 T, $q_{95} = 3.35$ deuterium L-mode plasmas heated by 1MW of ICRH power providing a total input of $\sim 2MW$. Plasmas with high upper-triangularity, δ_u, of approximately 0.36 were chosen. Deuterium gas fuelling was applied through the high-field side divertor base plate, driving the divertor plasma through low recycling to conduction limited into semi-detached regimes. The two configurations differ only for the outer-strike point (OSP) position which is moved from high-field side (HFS, conf. HT3L) by 8cm towards the low-field side (LFS, conf. HT3R), i.e. closer to the pumping plenum which is about 20cm from

*See the Appendix of F. Romanelli, et al., Proceedings of the 24th IAEA Fusion Energy Conf., San Diego, USA, 2012.

the latter (Fig. 1). The upstream density and temperature profiles are measured by the High Resolution Thompson Scattering (HRTS) system and the downstreams by Langmuir probes; divertor spectroscopy and pressure gauges give information on the neutral fluxes and sub-divertor pressure. During current flattop the upstream density was raised step-wise to incorporate strike-points movements for diagnostic purposes. To facilitate the comparison at same line averaged edge density, Fig. 2 shows the flux to the target, the D_α and the divertor neutral pressure plotted against the edge electron density at the outer midplane. At the same line density, HT3L (shot 80966) has a lower divertor pressure and lower D_α emission than HT3R configuration (shot 80971): this is attributed to the fact that the latter, due to the proximity to the pump duct, is more efficiently pumped. Furthermore the HT3R configuration experimentally shows, at the same upstream conditions, a lower target temperature and a higher target density: those temperatures may be too high, further analysis using spectroscopy is needed [4]. It seems that the neutral exist but when not compressed is possible to go to higher upstream density, i.e. HT3L, without affecting the plasma, i.e. same particle flux to the target. HT3R configuration needs stronger gas fuelling to reach the same $\langle n_e \rangle_{l,edge}$ density. A similar study on low triangularity in low confinement mode plasma is reported at this conference [5].

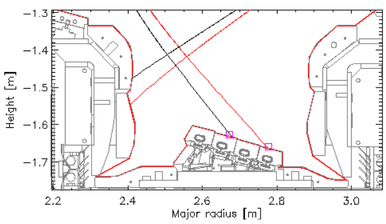

Figure 1: in red HT3R configuration, in black HT3L configuration, in magenta the closest Langmuir probe

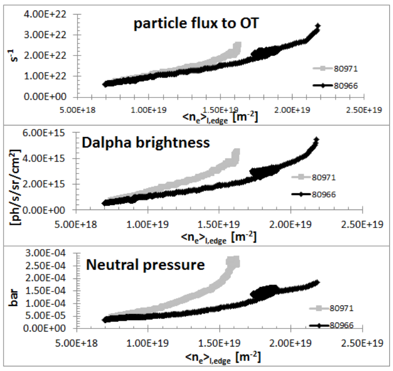

Figure 2: Particle flux, D_α and divertor pressure versus upstream electron density

Modelling results

For the simulation in EDGE2D/EIRENE, the magnetic equilibrium of the shots was taken from EFIT to build the 2D grids. The magnetic equilibria aren't affected by the three density steps. The gas injected, like the experiments, was applied in the private-flux region and simulations were run in feedback density control at the outer-midplane separatrix. Due to EFIT uncertainties, the separatrix position from the HRTS system had to be shifted $\sim 2.4cm$ outwards to force upstream and LFS strike-point electron pressure balance as predicted by the two point model; the upstream profiles for the lowest density case (only) were radially shifted. The power flowing from the core to the SOL was estimated from the core power balance given by the total input power minus core radiation within the 90% of the poloidal flux surface: a net value of 1.3MW was estimated. A reasonable fit with HRTS and Langmuir probes is obtained by assuming a particle diffusion coefficient $D_\perp = 0.5m^2/s$ in the pedestal and near SOL region (i.e. up to $Rsep \pm 1cm$, where $Rsep$ is the radial position of the separatrix at the LFS midplane) and $D_\perp = 1.0m^2/s$ in the mid and far-SOL. The experimental signal for the pressure in the divertor is derived from the Penning gauges measurements which, assuming a divertor temperature $T_{wall} \sim 300k$ and an effective pumping speed in divertor configuration $S_{eff} \sim 120m^3/s$, is converted into a flux. All the simulations were performed using an improved version considering elastic collisions and charge exchange of neutral molecules with bulk ions and also the molecular charge exchange which initiates molecular assisted processes via decaying molecular ions [7]. Specifically, these processes are crucial with respect to the neutral pressure build-up in the high density divertor [6] [8]. Fig. 3 shows measured neutral fluxes: simulations reproduce with good approximation the experimental data at low density while at high density, i.e. in the high recycling regime, the model for HT3L configuration, which is further away from the pump, underestimates the neutral pressure by 50%. Several sensitivity scans have been performed in order to understand the effect of P_{sol}, pump area, albedo and SOL e-folding decay length on the D_α emission, Fig. 3. In particular since the considered discharges are high-triangularity plasmas, grids are narrower than low triangularity cases, so the code was executed on increasing the particle e-folding length from 1cm to 2cm. This change lowers the edge electron density by 10% and increases the pressure and D_α signal by the same amount. The particle flux to the outer target increases as well, so that there is no more agreement with the experimental data for densities greater than $1.2 \cdot 10^{19} m^{-3}$. To match these results the albedo was changed: for HT3R the code pump efficiency has been set to 0.95 whilst HT3L uses 0.75. As the strike point in the HT3L configuration is farther away from the pumping plenum than in the HT3R the recycling factor had to be reduced to reproduce the experimental neutral flux to the pump, Fig. 4.

Figure 3: Neutral flux and D_α emission at the outer target

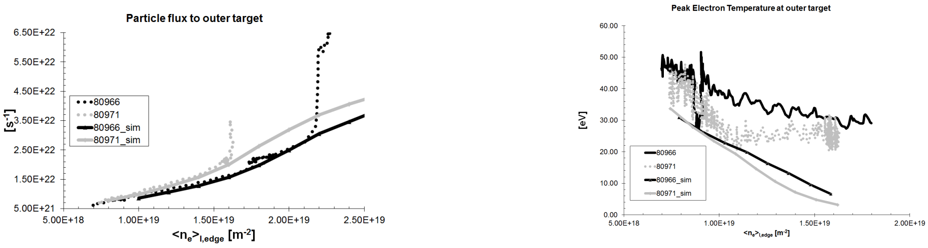

Figure 4: Particle flux and peak temperature at the outer target

Conclusions

This paper used EDGE2D/EIRENE simulations to understand the parameters that have an influence on the difference in neutral pressure in the sub-divertor region for two different plasma configurations. The effects of the pump geometry were also studied. At low densities is it possible to reproduce with EDGE2D the differences of the two divertor configurations as in [9] [10]. The difference between the experiments and the simulated D_α at the outer target was not entirely caused neither by the pump location nor by the albedo. When the discharges move to a high recycling regime or close to detachment it is not possible anymore to follow the experimental data, moreover pressure balance is not guaranteed. Simulations predict that having a strike point closer to the pump duct increases the neutral pressure and lowers the LFS temperature which can be beneficial from the point of view of the divertor power handling.

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