SOLPS-ITER drift modelling of Ne and N-seeded H-modes on JET

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Divertor tokamaks using all-metal plasma-facing components need impurity seeding for detachment control under high power conditions. On current devices, nitrogen (N) is commonly observed to be compatible with both divertor dissipation and good core performance. However, recent SOLPS-ITER simulations with full drifts activated [1] indicate that neon (Ne) should be as effective on ITER as a divertor radiator, and that the effect of drifts is less pronounced under partially detached conditions than in present experiments.

A similar code study has also been performed for ASDEX Upgrade (AUG) [2], a machine approximately one third the linear scale size of ITER. Drifts are found to have a much stronger impact on the divertor parameters than in ITER. In support of new experiments planned on JET to examine the relative performance of Ne and N under high power H-mode conditions, the same SOLPS-ITER simulation exercise has been conducted for JET, thus adding a third device, intermediate in size between AUG and ITER, to the modelling database. Importantly, all three cases feature vertical target configurations. The JET simulations use the same approach as for the AUG and ITER modelling: profiles of cross-field transport coefficients chosen to produce an H-mode transport barrier inside the separatrix, and, in the case of AUG and JET, a SOL heat flux width matching the empirical, multi-machine scaling. For fixed values of plasma current, 2.5 MA and toroidal field, 2.7T [3] (cf. 0.8 MA/2.5 T for AUG and 15 MA/5.3 T on ITER), scans are made in SOL power up to P_{SOL} = 20 MW. Direct comparison with the experiment at lower P_{SOL} = 11 MW found good agreement with measured profiles of key parameters at the outer midplane and divertor targets only when drifts are activated.

For the same reduction in peak power density at the outer target and the same fuel throughputs, (Z_{eff} -1) at the pedestal top is found to be 2x higher for Ne compared with N, corresponding to the same impurity ion concentrations at the separatrix for Ne and N, while in the divertor near SOL the concentration of N is higher than that of Ne. Thus, whilst the divertor compression of N is better than Ne, the latter radiates more effectively and demands smaller concentrations in the divertor region.

In general, this simulation exercise across the three devices shows that the drift influence on the divertor plasma steadily decreases with increasing machine size. The predicted relative similarity in performance for Ne and N on ITER is at least partially associated with a physically larger region over which the plasma temperature stays of the order of upstream temperature in the divertor volume, ensuring that impurity ionization to higher charge states stays closer to the targets. However, there are other (non-linear) processes influencing impurity compression, including finite ionization potential effect, drag by the main ion flow and impact of the thermal force [2]. The paper will discuss their relative importance in the context of the JET simulations and the dependence on scale size.

[1] E. Sytova, et al., Nuclear Materials and Energy 19 (2019) 72
[2] I. Yu. Senichenkov, et al., Plasma Phys. Control. Fusion 61 (2019) 045013
[3] C. Giroud, et al., Plasma Phys. Control. Fusion 57 (2015) 035004

This work was partially conducted under the auspices of the ITER Scientist Fellow Network