Impact of strong impurity seeding on the radiation losses in JET with ITER-like Wall

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Development of high radiation plasma scenarios with impurity seeding is necessary for operation of burning plasma fusion devices with a reactor-relevant size such as DEMO which should operate at high heating power and radiation fractions close to 95%. The experiments on JET with a fully metallic wall demonstrate the reduction of radiation losses in comparison with the former carbon wall due to the lack of intrinsic low-Z radiators. To reduce the heat loads on plasma-facing components as well as the tungsten sputtering to an acceptable level, low-Z and medium-Z impurities have to be injected into the plasma to convert a major part of the power flux into radiation and to facilitate partial divertor detachment.

Dedicated H-mode impurity seeding experiments with both strike points on the lower vertical targets have been performed during the last JET campaigns with ITER-like wall. The main objective of these experiments was to extend impurity seeding to the highest radiation fraction independently of the confinement mode and with various impurity species (\(\text{N}_2\), Ne and Ar) and input powers. The impact of impurity seeding on the confinement has been studied as well as its dependence on the balance between main chamber and divertor radiation. Type I H-mode characteristics at \(B_T=2.7T\), \(I_p=2.5MA\) \((q_95=3.3)\) in low-triangularity magnetic equilibria (\(\delta=0.22\)) have been examined. Respective scans over a deuterium fuelling range of \(2\times10^{22} \text{ el/s} + 6.5\times10^{22} \text{ el/s} \) and impurity seeding range \(2\times10^{22} \text{ el/s} + 1.3\times10^{23} \text{ el/s} \) with an additional NBI-power of 18MW have been performed. Nitrogen seeding leads to stable and steady state ELM free H-mode with \(\gamma_{\text{rad}}=P_{\text{rad}}/P_{\text{heat}} \approx 75\%\) of radiation fraction with strong radiation in the divertor around the X-point. The observed divertor radiation fraction \(\gamma_{\text{rad}}=P_{\text{rad}}/P_{\text{heat}} \approx 75\%\) is highest for low-Z seeding gases. The spatial distribution of radiation, as well as \(\gamma_{\text{rad}}\), does not show a clear dependence on D\(_2\)-fueling in \(\text{N}_2\)-seeded, type-I ELMy H-mode pulses. The maximum value of \(\gamma_{\text{rad}} \approx 70\%\) in \(\text{N}_2\) seeded pulses was found at \(f_{\text{rad}}=60\%\). The confinement increases from \(H_{98y}=0.6\) in unseeded pulses with \(f_{\text{rad}}=30\%\) to a value of \(H_{98y}=0.75\) at \(f_{\text{rad}}=60\%\) indicating the correlation of the confinement with the maximal divertor radiation fraction. Further increase of \(f_{\text{rad}}\) leads to a moderate confinement degradation.

Seeding with Ar and Ne leads to an H-L transition with \(f_{\text{rad}}\) of \(\approx40\%\) in H-mode and 60% in L-mode. On the other hand, the Ne impurity seeding may trigger radiative instabilities with peak values of 90% \(f_{\text{rad}}\). The experience with Ne is, however, much more limited than with \(\text{N}_2\) and further investigations are required before drawing irrevocable conclusions.

Power load mitigation and divertor detachment at both target plates have been observed with \textit{all} seeding gases.

\(^*\) See the Appendix of F. Romanelli et al, Proceedings of the 24 IAEA FEC 2012, San Diego, USA