The resilience of highly dissipative exhaust scenarios at JET to seed impurity mixes and divertor geometry

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The engineering limits in a fusion power plant, FPP, with radiation damages expected to be between 20-50 dpa require the power load to the divertor target plates to be limited to $\sim 10 \, \text{MW/m}^2$. With impurity radiation and neutrals contributing strongly to the peak power load onto the target plates, the power flux carried by charged particles is restricted to be below $5 \, \text{MW/m}^2$. With an ITER like lower single null divertor the power dissipation, $f_{\text{diss}}$, between the core plasma and the divertor target plates is then required to be $> 90\%$ of the total loss power. The total dissipation accounts for losses from radiation, perpendicular transport and CX processes. While ITER is expected to radiate 30\% of the loss power in the core, a FPP may be required to radiate up to 70\% on closed field lines \cite{1}. The required power load restriction combined with the desire to enhance the life time in view of erosion ($T_e < 5 \, \text{eV}$) would imply completely detached divertor targets and only small/tiny or no ELMs.

On JET with metal PFCs highly dissipative regimes with completely detached divertor targets and small and no ELM regimes have been achieved using a variety of seeding species \cite{2,3}. For example with Ne seeding at heating powers of up to $\sim 35 \, \text{MW}$ ELM free L-M-mode transitions were obtained with an $H_{98y}$ of up to 0.95. However, for Ne seeding only during M-mode phases the targets were completely detached with target $T_e < 3 \, \text{eV}$. For the loss of Ne as seeding impurity the experimentally observed dynamics of the re-attachment process will be reported. Varying the admixture of Ar and $N_2$ alters the ratio of core to divertor radiation but not the achievable $f_{\text{diss}}$ with completely detached divertor targets. For the same fueling gas throughput confinement in unseeded JET ILW discharges with an open horizontal divertor is improved ($H_{98y} \sim 0.95$) compared to vertical target geometry ($H_{98y} \sim 0.7$). However, with $N_2$ as well as with Kr seeding the maximum achievable $f_{\text{rad}}$ are equal for both configurations ($f_{\text{rad}} \sim 0.75$ for $N_2$), with confinement being equal and degraded compared to horizontal targets but similar to unseeded vertical targets condition ($H_{98y} \sim 0.7$).

\cite{1} M. Wischmeier et al., J. Nucl. Mater. 463 (2015) 22, \cite{2} S. Glöggler et al., Nuclear Fusion 59 (2019) 126031, \cite{3} M. Bernert et al., Nucl. Mat. and Energy 12 (2017) 111

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