Role of low-Z impurities in L-H transitions in JET

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Experiments in JET with the ITER-like Be wall and W divertor (JET-ILW) have highlighted a sensitivity of L-H transitions on low-Z plasma impurity composition: reduced effective charge, $Z_{\text{eff}}$, from JET-C to JET-ILW and concomitant reduction in L-H power threshold, $P_{\text{L-H}}$, in the high density branch, together with the appearance of a minimum in $P_{\text{L-H}}$ vs density [1]. $P_{\text{L-H}}$ denotes the net power across the separatrix, i.e. after subtraction of the bulk radiation. We explore two mechanisms that may explain an increase in $P_{\text{L-H}}$ with low-Z impurity concentration (or $Z_{\text{eff}}$ as its proxy): i) the effect of impurities on the stability of the background edge turbulence and ii) changes in divertor and scrape-off layer radiation patterns, affecting the edge temperature and/or heat fluxes regulating the L-H transition.

Linear gyrokinetic calculations of JET-ILW edge profiles at the L-H transition show that the primary instability is of resistive nature and thus can be stabilized by increased temperature, hence power [2]. The growth rates are lower at lower $Z_{\text{eff}}$. When $Z_{\text{eff}}$ is increased in the calculations, from typical JET-ILW values of 1.0-1.3 to a representative JET-C $Z_{\text{eff}}$ of 2.0, the minimum in density of the threshold temperature, $T_{\text{th}}$, is shifted towards lower values and $T_{\text{th}}$ is larger in the high density branch [2], in qualitative agreement with the changes in $P_{\text{L-H}}$ observed between JET-ILW and JET-C [1]. In the model, a mean E×B shear is required to suppress the edge turbulence and thus lead to the L-H transition. The ExB shearing rates derived from the experimental profiles using the force balance equation for $E_{r}$ are found to be of order of the minimum growth rates of the unstable modes ($\sim 2 \times 10^{4}$ s$^{-1}$ for the 1.8T data).

Recently, new experiments were carried out in the almost C-free JET-ILW, in which $N_{2}$ was injected into the divertor region prior to the L-H transition to achieve edge radiating properties and $Z_{\text{eff}}$ values similar to those of JET-C. Because $N_{2}$ puffing raises the L-mode target density, the low density branch of $P_{\text{L-H}}$ could not yet be accessed. This is planned for scheduled L-H experiments at higher magnetic field, where access to the low density branch is favoured in JET-ILW [1]. $P_{\text{L-H}}$ increased with $N_{2}$ injection level, at densities close to and above the minimum in $P_{\text{L-H}}$, $P_{\text{L-H}}$ approached JET-C values at $N_{2}$ levels corresponding to an increase in $\Delta Z_{\text{eff}} \sim 1$. At lower $N_{2}$ levels ($\Delta Z_{\text{eff}} \sim 0.2-0.5$) little change in $P_{\text{L-H}}$ was observed, suggesting threshold type behaviour with edge impurity concentration. The dynamics relating the movement of the N radiation front from inner divertor to X-point prior to the transition, divertor re-attachment after the sawtooth heat pulse and the L-H transition will be discussed.