Impact of nitrogen injection on L-H transitions in JET with Be/W wall

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The changeover of plasma facing components in JET, from C (JET-C) to Be wall and W divertor (JET-Be/W), led to a reduction in plasma effective charge, Z_{eff}, and divertor radiation as Be replaced C as the main intrinsic impurity [1]. A concomitant reduction in the H-mode power threshold P_{L-H}, of order 30-40%, was observed in the high density branch [2].

L-H transition experiments were thus carried out in JET-Be/W with N_2 injection into the divertor region to simulate Z_{eff} and divertor radiation akin to JET-C. The experiments, run at 1.8T/1.7MA and at 3.0T/2.5MA, revealed that both P_{loss} and $P_{sep} = P_{loss} - P_{rad,bulk}$ increase with N_2 injection rate in the high-density branch, approaching JET-C values when the injected N_2 levels correspond to a sizeable increase in nitrogen concentration or $\Delta Z_{eff} \geq 1$. At lower nitrogen injection levels, corresponding to $\Delta Z_{eff} \leq 0.5$, little change in P_{L-H} is observed. This is consistent with radiated power from bolometry: a factor ~2-3 higher divertor + SOL radiation is measured in JET-Be/W + N_2 than in JET-C to achieve similar $Z_{eff} \sim 2$ (while C sources from both divertor and main chamber contribute to Z_{eff} in JET-C, N_2 is injected in the divertor private flux region in the JET-Be/W experiments reported here and is thus in part retained in the divertor). The edge temperature at the L-H transition, $T_{e,edge}$ (defined as T_e at the radial location of the T_e pedestal top in H-mode and measured by ECE), is higher in the pulses with nitrogen seeding while the edge density remains unchanged. Consequently, a deeper edge equilibrium radial electric field E_r well is inferred from the E_r diamagnetic term.

Linear, gradient driven gyrokinetic (GK) simulations with GENE in the JET L-mode edge region have found resistive drift wave turbulence at low temperature [3], [4], which is stabilized by increasing temperature as far as a minimum temperature, T_{min}, while at higher temperatures ITG-TEM turbulence dominates. The value of T_{min} is found to be in the range of the experimental $T_{e,edge}$. When Z_{eff} is increased in the GK simulations from 1.0 – 1.3 (JET-Be/W case) to 2.2 (JET-C or JET-Be/W + N_2 seeding case), at low temperatures the resistive modes become more unstable, while at larger temperatures the ITG-TEM instabilities are stabilized, leading to a shift of T_{min} towards higher temperatures [5]. The enhanced L-mode edge turbulence drive with N_2 seeding at higher Z_{eff} implies that a higher P_{L-H} is expected.

It is assumed that the mean equilibrium $E_r \times B$ shear is a key player for reduction of L-mode edge turbulence leading to the L-H transition. In this framework, the L-H transition observations in JET-Be/W + N_2 can be interpreted by the increase in L-mode edge plasma turbulence with Z_{eff} (/N concentration) and the need for a deeper equilibrium E_r well (thus higher P_{sep}) to trigger the L-H transition. A reduction in the stabilizing SOL $E_r\, x\, B$ shear due to the increase in divertor and SOL radiation with N_2 puffing, following the mechanism proposed by [6], if confirmed, would further compound the above interpretation of the experimental results.

References: [1] S Brezinsek et al., JNM **438** (2013) S303; [2] CF Maggi et al., Nucl. Fusion **54** (2014) 023007; [3] C Bourdelle et al., Nucl. Fusion Lett. **54** (2014) 022001; [4] N Bonanomi et al., Nucl. Fusion **59** (2019) 126025; [5] C Bourdelle et al., Nucl. Fusion **55** (2015) 073015; [6] A Chankin et al., Plasma Phys. Control. Fusion **59** (2017) 045012.