Particle confinement of pellet-fuelled H-mode plasmas in MAST

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In reactor-grade plasmas (e.g. ITER), densities will be mainly controlled by injection of shallow cryogenic pellets. Pellets repetitively perturb the plasma in the pellet deposition zone which includes the edge transport barrier and thus modify the plasma confinement. Such plasmas are rather rare to allow the confident prediction of fuelling requirements and plasma performance in reactors such as ITER. This paper characterises the pellet-induced perturbations in the Mega Ampere Spherical Tokamak (MAST). In particularly the particle confinement of pellet-fuelled H-mode plasmas is quantified. The dataset is restricted mostly to neutral beam heated plasmas and to high field side pellets with relatively small penetration depth. Pellet deposition is captured by images in visible bremsstrahlung and pellet-triggered high resolution Thomson scattering. The pellet-induced density perturbation has a characteristic bell shape with a maximum at minor radius $r = r_{pel}$. Across our dataset $r_{pel}/a = 0.65 - 0.85$. The deposition profiles can be explained only by invoking the ∇B drift of the pellet ablatant. Pellet-increased density is accompanied by a depression of electron temperature consistent with near-adiabatic pellet deposition. This creates a distinct zone just inside r_{pel} with sharp positive density gradient and doubled temperature gradient up to $a\nabla \ln T_e \approx -7$. TRANSP with linear GS2 simulations show that these changes could modify the character of micro-turbulence and thus increase further the penetration of pellet-deposited particles towards the core. These changes also modify the role of the pedestal as a boundary for core transport. The complex post-pellet dynamics of the density profile is characterised by the pellet retention time τ_{pel} determined from 200Hz Thomson scattering. It is shown that τ_{pel} correlates with the behaviour of the edge transport barrier which displays the whole spectrum of responses: (1) plasma remains in L-mode after pellet injection, (2) pellet induces an L-H transition, (3) pellet is followed by an ELM burst and (4) plasma remains in ELM-free H-mode. For the typical and most relevant case (3), τ_{pel} decreases rapidly for $r_{pel} \rightarrow a$, consistent with the increase of effective particle diffusivity towards the edge. For the ITER like case, $r_{pel} \approx 0.8a$, the pellet retention time is about 20% of the energy confinement time. This would require the pellet particle throughput to be ~ 70 Pa m³/s, i.e. close to the ITER design value for steady state operation.

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