# Post-pellet injection plasma transport modelled by the XGC suite of codes

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Pellet injection is required to fuel high-$Q$ ITER plasmas [1] and is also one of the methods foreseen to mitigate the intermittent heat fluxes caused by edge localized modes (ELMs) in ITER [2]. Optimizing the characteristics of pellet injection such as injection geometry, velocity and pellet size for both missions is essential since the total fuel throughput in ITER is limited due to the associated tritium re-processing needs. Hence, experimental and modelling studies have been carried out in tokamaks to optimize fueling and ELM triggering such as in the DIII-D tokamak [3]. These have been accompanied by numerical simulations with non-linear magnetohydrodynamics (MHD) codes to understand the physics behind those experiments [4]. However, the transport models in such studies are simple (e.g. anomalous diffusion coefficients are used to represent turbulent transport) and kinetic simulations are required since pellet ablation and redistribution creates steep gradients along (in the initial ablation process) and across the field that can have a significant impact on plasma transport.

To study this phenomenology we have developed a pellet source model for the global total-$f$ gyrokinetic particle-in-cell suite of codes XGC [5]. To test this pellet source model, we have used the axisymmetric, neoclassical version of XGC on a circular geometry. In these simulations, we have found that geodesic acoustic modes (GAMs) are induced in the plasma by the radially/poloidally localized pellet source. We thus conjecture that interactions between such GAM oscillations and plasma turbulence might be responsible for enhancing the radial transport after pellet injection in accordance with the post-pellet particle transport enhancement seen in experiments [6]. To prove this conjecture, we have implemented this pellet source model within the non-axisymmetric version of XGC so that we can investigate the effects of plasma turbulence on the post-pellet plasma redistribution processes including radial, poloidal and toroidal pellet source localization effects. In the work presented here, the code is applied to typical DIII-D plasma conditions where pellet injection was previously explored (e.g. shot no. 131498) to consider realistic plasma and boundary conditions and to enable comparison with previously published experimental and modelling studies [3, 4].

Figure 1 shows the result of a pellet-injection simulation in DIII-D using the axisymmetric, neoclassical version of XGC. A 1.3 mm pellet, which is assumed to be surrounded by a cloud of deuterons and with a poloidal radius of $a_c$ = 25 mm, is put at ($R$, $Z$) = (2.188 m, 0) which corresponds to the normalized poloidal flux of $\psi_N \sim 0.9$. Figure 1 (left) shows the time evolution of the flux-surface averaged electron density $n_e$. The initial conditions correspond to the arrival of the pellet in neoclassically relaxed stationary plasma conditions. The ensuing density perturbation causes GAM oscillations in the radial electric field $E_\psi$ as shown in Fig. 1 (right). The frequency of these GAM oscillations is found to be 48-56 kHz which agrees with the values found by an eigenvalue solver [7]. Despite these GAM oscillations, Fig. 1 (left) indicates that radial particle transport is limited due to the absence of plasma turbulence. In this paper, the results of a pellet-injection simulation using the non-axisymmetric version of XGC including turbulence will be also presented.

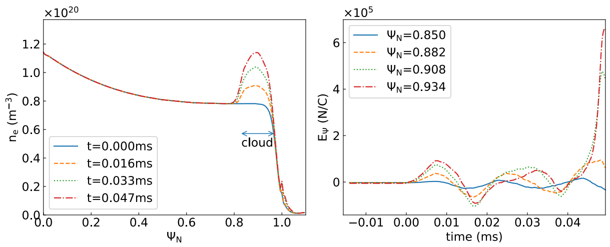


Fig. 1 Time evolution of (left) the flux-surface averaged electron density $n_e$ at $t$ = 0, 0.016, 0.033 and 0.047 ms with a double-headed arrow indicating the location of the pellet cloud, and (right) the flux-surface averaged radial electric field $E_\psi$ at $\psi_N$ = 0.850, 0.882, 0.908 and 0.934.

The corresponding author (S. Togo) is supported through the Monaco/ITER postdoctoral fellowship program. The views and opinions expressed herein do not necessarily reflect those of the ITER Organization. This research used resources of the National Energy Research Scientific Computing Center (NERSC), a U.S. Department of Energy Office of Science User Facility operated under Contract No. DE-AC02-05CH11231.

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