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Tokamak Pellet Fueling Simulations using 3D Adaptive Mesh Refinement[1]

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We present results of fully 3D extended MHD simulations of fueling pellets injected into tokamaks. The physical processes of pellet injection in high temperature tokamaks span several decades of space-time scales, which has prevented effective simulations of these events in the past. The large disparity between pellet size and device size, the large density differences between the pellet ablation cloud and the ambient plasma, and the non-local electron heat transport all pose severe numerical challenges. Block structured local adaptive mesh refinement (as in Ref.[1]), extended to use the equilibrium magnetic coordinates, is employed to mitigate the problems due to the large range of spatial scales. Generalized upwinding techniques are employed to deal with sharp gradients. A critical component is the modeling of the highly anisotropic energy transfer from the background hot plasma to the pellet ablation cloud via long mean-free-path electrons along magnetic field lines. The modeling includes a semi-analytical kinetic treatment of the transport of electron energy flux through the ablation cloud[2]. The ablation process is included using an analytical model[3]. We discuss the phenomenology of the mass redistribution processes involving the density equilibrating along field lines and transport across surfaces (in the large-major-radius direction) due to interchange instabilities caused by the large local pressure at the pellet. The clear benefit of high-field-side injection relative to low-field-side injection is demonstrated and explained. Experimental comparisons are discussed along with an assessment of applying these techniques to ITER.

[1] R. Samtaney et al. Comp. Phys. Comm., 164:220–228, 2004.
[2] R. Ishizaki et al. Phys. Plasmas, 11:4064–4080, 2004.
[3] B. V. Kuteev. Nucl. Fusion, 35:431–453, 1995.

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