Simulation studies of neon pellet ablation clouds for plasma disruption mitigation in tokamaks.

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A leading candidate for the ITER plasma disruption mitigation system is the Shattered Pellet Injection (SPI) [1] that performs fragmentation of a large, frozen, neon-deuterium pellet before its injection into a tokamak, and forms a stream of small fragments into plasma, causing a thermal quench. In this work, we report numerical studies of properties of ablation clouds formed by the injection of a single neon pellet into a tokamak. Simulations of a large number of pellet fragments are in progress.

Simulations use the numerical pellet ablation model [2] based on the FronTier code. The main features of the model include an explicit tracking of the solid pellet - ablated gas interface, kinetic models for the energy deposition of hot electrons into the ablation cloud, a pellet surface ablation model, atomic processes in the cloud, radiation losses, an improved electrical conductivity model, and MHD in the electrostatic approximation.

Verification studies have been performed by comparing spherically-symmetric simulations with a semi-analytic model that improves the Neutral Gas Shielding model [3]. Good agreement of pellet ablation rates and properties of the ablation flow at the sonic radius have been achieved. Simulations are also in agreement with theory on the scaling laws for the pellet ablation rate G, namely $G \sim T_e^{5/3} r_p^{4/3} n_e^{1/3}$, where r_p is the pellet radius, and T_e and n_e are the temperature and density of the background tokamak plasma.

In the presence of MHD forces and atomic processes, the dense, cold ablated material gradually ionizes and streams along magnetic lines, forming a narrow ablation channel. Simulations study the dependence of ablation channel properties and the pellet ablation rate on the magnetic field strength, and parameters of the background plasma, including the pedestal.

References

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