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Kinetic Aspects of High-Z Pellet Modeling for Disruption Mitigation

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Injection of high-Z pellets is now a part of the disruption mitigation strategy for ITER. Pellets are seen as favorable to massive gas injection due to deeper penetration of the impurity material into the plasma and the ability to adjust the cooling properties via mixing fractions.

The ablated material surrounding the pellet contains electrons that are much colder and denser than the ambient background plasma. Hot electrons entering the cloud from the background collide with the cold electrons in the cloud. The electron-electron collisional time scales are much shorter for the cold-cold collisions than for the hot-cold collisions. Because of that, the cold electrons can be viewed as thermalized, whereas the hot electron distribution function in the cloud can deviate from Maxwellian significantly. This situation requires a kinetic description of the hot electron distribution function as they slow down and scatter in the ablation cloud.

This talk presents a kinetic model for the power deposition from energetic electrons into the neutral gas shield of an ablating high-Z pellet. For high-Z pellets, the velocity distribution of the hot electrons is nearly isotropic, and we use this feature to develop rigorous solutions to the kinetic equation. We consider a combined effect of elastic scattering and gyro-motion and of the hot electrons. The hot electrons diffuse longitudinally along the field lines when the gyro-frequency is much greater than the elastic collision frequency, and they diffuse radially in the opposite limiting case. In both limits, we calculate the power deposition kinetically as a function of the line integrated gas density. We also show that the sheath potential required to maintain ambipolarity in the cloud scales as $1/Z$ˆ1/3.

When combined with pre-existing fluid models for the ablated flow, our power deposition model gives an ablation rate that scales as $1/Z$ˆ7/6, which is different from the $1/Z$ˆ2/3 scaling reported by other authors.

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