Contribution ID: **1** Type: **Contributed Poster**

Assimilation of a Composite Hydrogen/High-Z Plasmoid

Tuesday, 19 July 2022 13:00 (20 minutes)

Pellet injection is used in tokamaks and stellarators for fuelling, ELM pacing, diagnostics, and disruption mitigation. Injection of shattered pellets is a critical part of the envisaged ITER disruption mitigation system.

A highly localized plasmoid initially expands predominantly along the magnetic field lines. These assimilation dynamics play a critical role in determining the post-pellet plasma energy balance: the energy transferred to the expanding plasmoid is split between the plasmoid electrons, ions, and the radiative losses in the presence of high-Z impurities. If the plasmoid is heated at a constant rate, the ions accelerated by the ambipolar electric field acquire half the total energy transferred to the plasmoid in the absence of radiation losses.

In the present work, we study the plasmoid expansion dynamics for hydrogen-neon mixed pellets. The initially very dense plasmoid is shown to be opaque to line radiation for cases of high impurity content. For low impurity content, the friction force acting on the cold impurity ions transports the impurity together with the hydrogen, which simplifies the analysis. We calculate the radiated energy fraction for ITER-relevant plasmoid parameters.

A distinctive feature of our model is a coupled hydrodynamic description of the cold plasmoid and a kinetic treatment of the ambient electrons and ions. In particular, we describe the reduction of the plasmoid heating rate due to the effect of the ambipolar potential on the hot electrons.

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Session Classification: Posters

Track Classification: Mitigation