

Validation of Extended-Magnetohydrodynamic Modeling of KSTAR Disruption Mitigation with Collisional-Radiative Impurities

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Future tokamaks will require disruption mitigation systems (DMS) to prevent machine damage during the uncontrolled loss of plasma confinement. Massive impurity injection, particularly shattered pellet injection (SPI), is the leading candidate for a DMS. Validated, predictive models are needed to project these systems to future devices, which require models for the macroscopic plasma evolution as well as the injected impurity dynamics. To simulate these conditions, the M3D-C1 extended-magnetohydrodynamics code has traditionally been coupled to a coronal non-equilibrium model for impurity ionization and radiation, which is formally valid only in the low-collisionality limit. We present an overview of the M3D-C1 code as well as an upgrade to the impurity model by coupling M3D-C1 to the full ADAS model. This provides a density-dependent, collisional-radiative model for ionization and radiation and greatly expands the number of impurities that can be considered by M3D-C1. We show that for neon, the collisional-radiative model predicts significantly less line radiation than the coronal model, resulting in longer thermal quench times and increased density & material assimilation in SPI simulations. We also present M3D-C1 modeling of several realistic SPI scenarios on the KSTAR tokamak. The results are compared to data for single and dual-symmetric injection of neon-doped pellets as well as dual, time-staggered injection with a pure-deuterium pellet followed by a neon-doped pellet. We find that the simulations generally underpredict the density after neon-doped injection but overpredict the density after pure-deuterium injection. While the radiation in the staggered injection modeling agrees very well with experiment, simulations of neon-doped injection without the initial pure-deuterium injection generally see a radiation spike that is too rapid and too toroidally distributed. We explore the effects of the localization of the plasma source, equilibrium plasma rotation, and coronal versus collisional-radiative impurities on these results. Future work will seek to determine the sources of these discrepancies.

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