JOREK simulations of Shattered Pellet Injection with high Z impurities

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Shattered pellet injection (SPI) is the baseline concept for disruption mitigation system (DMS) in ITER, the aim of which is to introduce huge amount of hydrogen isotopes or impurities into the plasma by injecting pellet fragments [1], thus deplete the large thermal and magnetic energy stored within the plasma homogeneously by radiative losses, so as to prevent localized energy deposition on the device which could cause substantial harm to the device [2]. The radiation asymmetry after the injection has a strong impact on the efficiency of thermal quench mitigation, since it determines the local radiative heat flux onto the Plasma Facing Components (PFC). In turn, the radiation asymmetry itself is strongly influenced by the MHD activity after the injection, as the profile evolution caused by the latter determine the behavior of the former.

The upcoming JET SPI campaign, as well as past DIII-D experiments [3] serve as a verification and extrapolation tool for the future ITER SPI system. To acquire a better understanding of the interplay between aforementioned radiative cooling and MHD activity after SPI in JET, ITER, and tokamaks in general, we numerically investigate both pure neon and mixed neon/hydrogen SPI into ITER L-mode plasmas by the 3D nonlinear reduced MHD code JOREK. We treat the ablation of pellet fragments within the plasma by the Neutral Gas Shielding (NGS) model [4], and assume the Coronal Equilibrium model to estimate the radiative cooling, which produces only negligible deviation from more detailed coronal models provided that the plasma is cooled down fast enough. The fragment size distribution, injection configuration and parameters are all chosen to conform with that of the real system. We demonstrate the two major MHD destabilization mechanism by radiative cooling, namely the axis-symmetric current profile contraction and the helical current profile perturbation at rational surfaces. We also show the excited MHD modes has significant impact on the convective transport of the injected material, thus greatly contribute to the injection penetration. On the other hand, the outgoing heat flux caused by the destabilized MHD modes is found to induce strong radiation asymmetry by sustaining an impurity density gradient along the field line as the local density source competes with the parallel convective relaxation of density.

References

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