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Disruption Mitigation in the Presence of Pre-existing MHD Instabilities

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Experiments on the DIII-D and Alcator C-Mod tokamaks show that disruption mitigation by massive gas injection (MGI) and shattered pellet injection (SPI) of high-Z impurities remain effective in the presence of large pre-existing MHD instabilities. Rotating and locked magnetic islands will precede a large fraction of disruptions in ITER, making their impact on disruption mitigation a critical concern. Experiments on both machines show that such instabilities do not significantly impede the ability of massive impurity injection to mitigate thermal quench (TQ) and current quench (CQ) loads. On DIII-D, SPI significantly increases peak densities relative to unmitigated disruptions, indicating efficient assimilation of the injected impurities, with or without the presence of the modes. Similar results are found for MGI, on both DIII-D and C-Mod. This efficient assimilation of injected high-Z radiating impurities allows effective TQ mitigation, with enhanced radiation fractions and corresponding decreases in divertor heating, as measured by infrared imaging. MGI and SPI are able to accelerate the CQ even in the presence of pre-existing MHD precursors. Reconstructions of the plasma geometry during the CQ show that vertical displacements of the plasma are reduced relative to unmitigated disruptions, for all cases with MGI or SPI, while halo current impulses and resulting vacuum vessel displacements are also significantly reduced. Peak electron density during the CQ, which is an important metric for runaway electron mitigation, is enhanced in the case of impurity injection and do not differ between stable and MHD unstable discharges. Toroidally distributed measurements of the radiated power on C-Mod indicate that radiation asymmetries during the disruption are not significantly higher in plasmas with locked modes. This result implies that measured radiation asymmetries are likely driven by MHD activity which is initiated by the impurity injection process itself, rather than by the pre-disruption instabilities. Overall, these results on DIII-D and C-Mod increase confidence in the existing physics basis for disruption mitigation, and the resulting design of the ITER disruption mitigation system.
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Primary author: Mr SHIRAKID, Daisuke (Oak Ridge National Laboratory)

Co-authors: KUANG, A. (Massachusetts Institute of Technology); TINGUELY, A. (Massachusetts Institute of Technology); PAZ-SOLDAN, C. (General Atomics); LASNIER, C.J. (Lawrence Livermore National Laboratories); COOPER, C.M. (Oak Ridge Associated Universities); BRUNNER, D. (Massachusetts Institute of Technology); HOLLMANN, E.M. (University of California-San Diego); BYKOV, I (University of California-San Diego); BAYLOR, L.R. (Oak Ridge National Laboratory); REINKE, M.L. (Oak Ridge National Laboratory); COMMAUX, N. (Oak Ridge National Laboratory); EIDIETIS, N. (General Atomics); RAMAN, R. (University of Washington); MOYER, R.A. (University of California-San Diego); GRANETZ, R.S. (Massachusetts Institute of Technology)

Presenter: Mr SHIRAKID, Daisuke (Oak Ridge National Laboratory)

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