ABSTRACT:

First demonstration of novel technique for disruption mitigation by core impurity deposition using shell pellets on DIII-D

N.W. Eidietis[1], E.M. Hollmann[2], P.B. Parks[1], R.A. Moyer[2], N. Alexander[1], J.L. Herfindal[3], V.A. Izzo[2], A. Lvovskiy[4], D. Shiraki[3]

[1] General Atomics, PO Box 85608, San Diego, California 92186-5608, USA
[2] University of California - San Diego, 9500 Gilman Dr, La Jolla, CA 92093-0417, USA
[3] Oak Ridge National Laboratory, PO Box 2008, Oak Ridge, TN 37831, USA
[4] Oak Ridge Associated Universities, Oak Ridge, TN 37831, USA
email: eidietis@fusion.gat.com

Disruption mitigation by core impurity deposition using novel shell pellet technology has been demonstrated for the first time on DIII-D. This provides a new method of "inside-out" radiative cooling of the plasma, which NIMROD non-linear MHD simulations predict to (i) provide high impurity assimilation and radiated energy fraction to protect the divertor from conducted thermal loads, (ii) allow the use of low-Z impurities to moderate the current quench rate and associated forces, and (iii) create globally stochastic field lines at high densities to suppress runaway electron seed formation. This transforms the physics mechanisms and the prospects for safe mitigation of disrupting plasmas for ITER and the tokamak generally. The shell pellet technique utilizes a thin, minimally-perturbative shell to transport the enclosed radiating impurity (boron dust) to the plasma core before dispersal, delaying the onset of global MHD that is typically initiated by conventional edge-cooling techniques (e.g. massive gas or shattered pellet injection), where most of the particles do not reach the core. Imaging provides clear evidence of the boron dust impurity payload being deposited deep within the plasma core, with inverted T_e profile data providing evidence for an "inside-out" mitigation process. Pellet deposition depth is consistent with existing 1D modeling. Mitigation metrics are shown to improve with increased pellet velocity and deposition depth, with decreased heat loads to the divertor, and reduced current perturbations in the quench, and increased impurity particle assimilation fractions approaching unity, indicating the importance of core impurity deposition. Future work and the design of ITER-relevant shells are discussed. These initial experiments provide a first proof-of-principle that this new mitigation technology may address major shortcomings in the edge-cooling shattered pellet injection presently planned for ITER and provide an effective solution for future fusion reactors.

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