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MHD modeling of dispersive shell pellet injection for disruption mitigation in DIII-D

NIMROD 3D MHD modeling of dispersive shell pellet (DSP) injection into DIII-D supports anticipated strengths of the concept for disruption mitigation, e.g. high radiated energy fraction, and finds unanticipated benefits for runaway electron (RE) loss during a two-stage current redistribution [1]. DSP, a concept demonstrated on DIII-D [2], comprises a thin shell of low-Z material (diamond in DIII-D) that slowly ablates as it passes through the edge plasma and releases a radiating payload in the core (boron dust). The ideal scenario has radially inward heat flux as the plasma cools from the inside out—with the outer flux surfaces maintained—minimizing heat conducted to the divertor. Calculations with varying constant rates of shell ablation find that with the total ablated carbon quantity reduced to 25% of the carbon content of the DIII-D shells, simulations show no perturbation to the flux surfaces prior to payload delivery. Further, even quantity of shell carbon that does not perturb flux surfaces produces a >1keV pre-payload drop in the central Te by dilution cooling (with no loss in plasma stored energy), so that the observed Te drop in experiments may not indicate a premature thermal quench (TQ) onset. The current density initially redistributes to form a current ring just outside the payload delivery region and a negative current ring near the boundary. At the end of the TQ, the negative current ring disappears in a large amplitude MHD event (dB/B>10-2) producing an increase in the total plasma current ("Ip spike"). This scenario resembles the two-stage flux-trapping current redistribution described by Wesson [3] to explain the observed delay in the Ip spike in JET. Drift orbits calculations for tracer REs show a fast loss at the time of the Ip spike, when field-line connection-lengths to the wall drop by two or more orders of magnitude. Thus, the inside-out cooling scenario may be advantageous for RE seed losses. Initial results of predictive simulations with more realistic temperature and density dependent shell ablation rates will also be presented.

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[1] V.A. Izzo Nucl. Fusion (2020) https://doi.org/10.1088/1741-4326/ab8544
[2] E.M. Hollmann, et al, PRL 122, 065001 (2019).
[3] J.A. Wesson, D.J. Ward, M.N. Rosenbluth, Nucl. Fusion 30, 1011 (1990).

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