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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 maintainedminimizing 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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