Experiments on rapid shutdown using shell pellets in DIII-D*

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Injection of hollow shell pellets filled with a dispersive payload is a possible method for rapid shutdown of future large tokamaks to avoid wall damage during a disruption. Preliminary shell pellet experiments have been performed in the DIII-D tokamak by firing shell pellets with 0.4 mm thick walls into stable H-mode discharges. Three types of pellets were tested: small (OD ~ 2 mm) polystyrene shells filled with either pressurized (10 atm) argon gas or with boron powder; and large (OD ~ 10 mm) polystyrene shells filled with boron powder. Pellet trajectories and burn through rate are estimated from fast visible camera data. The small shell pellets did not disrupt the plasma and were observed to burn up at normalized radius r/a ~ 0.5, consistent with ablation rate calculations. Also, slowing from 350 m/s to 100 m/s was observed, which is not well-understood at present, but could possibly result from temperature gradients in the plasma. Successful delivery and rapid (<15 ms) dispersal of the small pellet payloads into the plasma core was observed. Neither plasma current contraction nor strong MHD onset was observed as a result of the small shell burn up in the plasma edge, consistent with calculations. For the large shell pellets, an initial velocity of 200 m/s was used. Unlike the small pellets, no clear indication of pellet slowing in the plasma was observed, although the precise velocity was more difficult to determine because of the larger ablation plume. The large shell pellets did cause a disruption, initiating an MHD instability and thermal quench upon reaching the q=2 surface. Unlike the small shell pellets, the large pellets did not release their payload in the plasma; instead, the outer shell was burnt only about 1/4 way through after passing through the entire plasma. These experiments indicate that the walls of future large pellet shells will need to be reduced to a thickness of 0.1 mm to achieve payload deposition in DIII-D.

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