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Alternate disruption mitigation methods for fast time response & core impurity deposition

ITER could benefit from a new generation of disruption mitigation systems with fast response time, high-velocity radiative payload injection for core deposition, and very high overall system reliability. Systems under current investigation such as the Electromagnetic Particle Injector (EPI), the two-stage gas gun, and the Shell Pellet concept may offer some or all of these capabilities.

Because the ITER plasma is projected to have about 40x more stored energy than present experiments, realistic 3D MHD simulations, benchmarked against present experiments are an essential step to project to ITER. In support of this requirement, the NIMROD and M3D-C1 codes are being used to study the radiative payload penetration requirements and the response of the tokamak plasma for payload deposition deep inside the q=2 surface.

The EPI relies on electromagnetic propulsion of a metallic sabot to velocities > 1km/s within 2ms, at which point the sabot releases well-defined microspheres of a radiative payload or a shell pellet [1]. Initial experimental tests from the prototype system, in a tokamak deployment configuration, have demonstrated sabot velocities of 600 m/s within 1.5 ms, consistent with calculations, giving confidence that larger ITER-scale injectors can be developed.

The two-stage gas gun [2] is capable of 3 km/s, but payload acceleration time and operational reliability to fire intact pellets in a disruption mitigation configuration require development and testing. At present, the ENEA-two-stage fueling pellet injector being tested at ORNL has an acceleration time of ˜16ms, and could be improved with optimization.

The shell pellet [3], which would be used as the payload in the above concepts, uses a hardened outer shell to protect a dispersive radiative payload. The primary objective is to deposit the radiative material within the core without current channel contraction, resulting in a radiative collapse of the core and an inside-out thermal quench (TQ). The basic concept has been demonstrated in DIII-D. Diamond shells were used to deliver a dispersive boron powder payload to the core of DIII-D discharges. Clear evidence for boron powder dispersal in the core during the TQ was observed. Shell pellet modeling with NIMROD is being compared with DIII-D experimental results [4]. Future work will try to continue to demonstrate the shell pellet concept more clearly by utilizing higher-Z payloads and lower-Z shells to provide stronger core dissipation and lower current channel shrinking.

The capability for inducing a direct inside-out TQ, rather than relying on MHD induced impurity mixing to initiate the TQ, should provide more control over the TQ. With systems that inject radiative payloads of well-defined shape and velocity, the 3D MHD modeling of payload penetration should be easier and more precise, permitting reliable benchmarking against present experiments and projection to ITER.

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