Modeling of disruption mitigation by massive gas injection

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Disruption mitigation is mandatory for ITER in order to reduce electromagnetic forces on the structure, mitigate heat loads and avoid the generation of runaway electrons. Massive Gas Injection (MGI) is currently one of the main mitigation methods considered for ITER. MGI experimental results on present tokamaks are encouraging, but the settings of the ITER MGI system remain to be optimized. In this context, a modeling capability is highly desirable.

We present here modeling results investigating the mechanisms that play a key role in MGI penetration into the plasma and the resulting disruption. First, we investigate the MHD activity triggered by the MGI and causing the thermal quench. In this aim, the 3D MHD non-linear code JOREK has been modified to include a simplified model for neutrals. In every simulation, a cold front propagating from the edge until the q=2 surface is observed. Then, among the wide range of parameters which has been investigated, resistivity is in particular found to determine the type of MHD activity in the simulations. With a high Lundquist number ($S=2 \times 10^7$ when $S_{JET}=10^8$), tearing modes and the internal kink mode are dominant. With a low Lundquist number ($S=10^5$), the kink mode is absent but the flows related to tearing modes are much stronger and lead to finger-like structures.

In order to improve JOREK simulations, one has to model accurately the edge cooling phase. As a preparation work, this physics is investigated with a new 1D fluid code, IMAGINE, which includes full atomic physics and convective transport of neutrals. One aim is to identify possible simplifications in view of improving JOREK MGI model. The simulated domain comprises the gas reservoir, the vacuum tube and the plasma. In our JET MGI simulations, the gas propagation into the vacuum injection tube is similar to the experimental observations with the formation of a rarefaction wave and a velocity of $3 \times c_{sa} Ar$ for the first particles. The gas penetration into the plasma is associated to a cold front, whose velocity depends essentially on the injected amount and on the forces on the gas (friction, braking effects, ...). The velocity of the front is found in reasonable agreement with that experimentally determined in JET.