Gas assimilation during thermal quench and runaway beam phase

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The massive injection of material (MMI) - mostly noble gases in the gaseous or frozen state - has been shown to be suitable for thermal quench (TQ) and force mitigation in induced tokamak disruptions. This mitigation method is believed to be also applicable to ITER. In principle, runaway electron (RE) suppression or mitigation in a full current ITER disruption should also be possible by increasing the plasma density sufficiently, i.e. up to the so-called critical density of the order of 10^{21}–10^{23} m^{-3}, depending on the current quench time. But in practice, this density is very large and it has not yet been reached in present devices. In addition, the density increase must occur on a short time scale (< 10 ms in ITER) in the plasma centre – where the REs are confined or are going to be generated - and these requirements call for the development of dedicated injectors. Besides the technological issues, it is unknown whether or under which conditions the plasma can assimilate enough material to suppress the REs. Ultimately, this RE mitigation scheme awaits confirmation.

In this contribution we discuss what can be learned from experiments of massive gas injection induced TQ and during the RE beam lifetime, conducted on the medium size tokamak ASDEX Upgrade. In addition we report on whether simulations can reproduce the experimental observations and then used for extrapolation to an ITER plasma.

ASDEX Upgrade is equipped with fast gas valves close to the plasma, density and radiation measurements. RE beam current up to 400 kA can be created by argon injection into a low density circular plasma. A 2nd massive gas injection into the RE beam can also be performed to study its dissipative effect on the RE current and energy. The assimilation of argon in the pre-TQ plasma is rather large (up to 50 %) but it decays to 10 % after the 2nd injection into the RE beam. The argon (and neon) density rise in the RE background plasma is slow, of the order of tens of milliseconds. This observation is in qualitative agreement with the results of JET experiments: The RE suppression with MGI is not effective on JET, probably because the gas penetration into the beam is slow compared to the vertical movement of the plasma (some tens of milliseconds) [2].
An *effective* radial diffusion coefficient can be inferred from the density measurements on ASDEX Upgrade and transport simulations. However, is the physics behind the diffusion mechanism known? The injection of deuterium pellets into the RE beam does not lead to density increase but to gradual plasma recombination. This observation also awaits an explanation.

In summary, knowing whether RE suppression and/or dissipation is feasible with MMI requires understanding and being able to model particle and energy transport in a cold background plasma interacting with the fast electrons. This contribution begins to tackl this lack of understanding.

[1] G. Pautasso et al., *"What can be learned from ASDEX Upgrade experiments on gas assimilation and its interaction with runaway electrons"*, 2017 PPPL Workshop: Theory and Simulation of Disruptions, Princeton, USA, July 17-19 2-17, https://tsdw.pppl.gov/Program.html
[2] C. Reux et al., Nuclear Fusion, 55 (2015) 093013