JET contribution to the research on long pulse operation

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In its baseline mode of operation (400s duration), ITER will face a significant number issues related to steady state such as long term retention, material erosion and migration, plasma facing components (PFC) life time, power/energy handling, etc … Although JET is not designed as a steady state device (no actively cooled plasma facing components, and no ECRH system), the exploitation of the ITER-like wall (Be components in the main chamber and W in the divertor), has recently addressed a number of those issues and also explored the feasibility of high bootstrap current fraction discharges in a metallic wall. This paper will review the most relevant contributions of JET-ILW to long pulse operation.

After JET campaigns, it has been shown that no flaking deposit has occurred and the amount of dust retrieved was below 2g, i.e. 2 orders of magnitude less to what has been observed in JET-C. In addition, with the metallic wall, the absence of chemical erosion for Be prevents the accumulation in remote areas. The primary impurity source in JET-ILW is strongly reduced with respect to JET-C resulting in a lower divertor material deposition by more than one order of magnitude. The impurity migration measurements have also been successfully modeled by the WALLDYN code showing qualitative agreement with the Be deposition patterns and quantitative agreement with the measured retention rates.

The fuel retention is much reduced in JET-ILW by typically one order of magnitude. However, the remaining amount is still not negligible and would lead to long term retention of 0.3g per discharges of 400s in ITER, this could limit the duration of discharges in ITER and thus removal fuel techniques could be necessary. However, these findings on erosion and retention can be modified when using impurity seeding required for detachment and divertor radiation. Ensuring a sufficient target component lifetime and minimize W erosion and source for long pulses means achieving a target temperature less than 5eV and a power handling below $10MW/m^2$. Already in JET, extending pulse duration requires operating in detached (or semi-detached) conditions in a controlled way using extrinsic seeded gases. JET has addressed therefore this issue and developed stable high radiation discharges for 5s with N_2 seeding with 75% radiation fraction in detached conditions. Using the favorable effect of nitrogen on pedestal confinement observed recently, integrated discharges close to the ITER projected performance have been achieved in JET-ILW for 7s with $H_{98}(y,2)\sim0.85$, $\beta_N\sim1.6$, $<n>/nGW\sim0.85$, Zeff~1.6, and with very low divertor target power loading (<3MW.m-2).

Long pulse operation also requires discharges with high level of non-inductive and bootstrap current. This has also been explored recently in the JET-ILW. Although these high β (3-3.4) scenarios are still transient, confinement factor up to 1.4 have been achieved and the no-wall limit assessed for the first time in a metallic wall using resonant field amplification.

* See the Appendix of F. Romanelli et al., Proceedings of the 25th IAEA Fusion Energy Conference 2014, Saint Petersburg, Russia.