Advances in multi-megawatt, long pulse operation in Tore Supra


1CEA, IRFM, F-13108 Saint-Paul-lez-Durance, France.

Achieving long-duration discharges in ongoing magnetic fusion devices is an essential step towards a future fusion reactor. Integrating all technological elements required for long pulse operation (superconducting magnets, actively cooled plasma facing components, long pulse heating and current drive systems), the Tore Supra tokamak routinely addresses the physics and technology issues related to this endeavour and as such, brings essential information on critical issues for ITER. So far, long discharges with LH (lower hybrid) power ~3MW have been performed in a relatively narrow operating window in terms of line-averaged density (\(<n_l>\sim1.7\times10^{19}\ m^{-3}\)) and plasma current (\(I_p\sim0.5\ MA\)). In order to expand this domain of parameters, a recent upgrade of the Tore Supra H&CD capabilities has been conducted, including a new CW (continuous wave) LHCD (LH Current Drive) system, which is now able to deliver ~10MW/1000s at the generator.

During the last experimental campaign, components of this LHCD system including an ITER relevant launcher (Passive Active Multijunction, PAM) and CW/3.7 GHz klystrons, have been extensively qualified, and then used to develop steady-state scenarios in which the LH, ion cyclotron (IC) and electron cyclotron (EC) systems have been combined in fully stationary shots (duration ~150s, injected power up to ~8MW, injected/extracted energy up to ~1GJ). Injection of LH power in the 5.0-5.7MW range has allowed to extend the domain of accessible plasma parameters to \(<n_l>\sim3.0\times10^{19}\ m^{-3}, I_p\sim0.7\ MA\ (\beta_p\sim0.6, \beta_N\sim0.7)\) with high non-inductive current fraction (~80%). These discharges also exhibit steady electron internal transport barriers (ITB).

We report here on various issues relevant to the ITER operation, ranging from operational aspects and limitations related to the achievement of long pulses in a fully actively cooled fusion device (e.g. overheating due to fast particle losses), to more fundamental plasma physics topics. The latter include a beneficial influence of IC heating on the MHD stability in these discharges, which has been studied in details. Another interesting observation is the appearance of oscillations of the central temperature with typical periods of the order of one to several seconds, caused by a non-linear interplay between LH deposition, MHD activity and bootstrap current in the presence of an ITB.