Development of long duration plasma scenarios for WEST

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Various physics and technology aspects related to the steady-state plasma operation of magnetic fusion devices have been investigated in the actively cooled Tore Supra tokamak [1]. The use of its long pulse radiofrequency (RF) heating and current drive system in the WEST device (tungsten-W Environment in Steady-state Tokamak) [2] will allow an integrated long pulse programme (up to 1000s) to be conducted with the goal of testing W-divertor components at ITER-relevant heat fluxes (10-20MW/m^2), while treating crucial operational aspects. This includes avoiding W-accumulation in long discharges, monitoring and controlling heat fluxes on the metallic plasma facing components (PFCs) and coupling RF waves in H-mode plasmas. The corresponding plasma scenarios all rely on Ion Cyclotron Resonance Heating (ICRH) and Lower Hybrid Current Drive (LHCD).

Three new ELM-resilient ICRH antennas will replace the previous antennas. Using the hydrogen (H) minority heating scheme with frequency 51-58MHz, the resonance location can be adjusted to cover both the magnetic axis and the high field side. Modelling with EVE/AQL yields a power deposition within r/a=0.4. Roughly equal ion- and electron heating occurs at moderate power (3MW) and H-minority concentration of 6%, whereas electron heating is dominant (70%) at high power (9MW). Increasing the H-minority concentration to 12% further increases the ion heating. The LHCD system, with capability to inject 7MW/1000s, is an essential tool for long pulse scenarios. C3PO/LUKE simulations show that the wave absorption takes place in the region r/a=0.3-0.6. As the pedestal density increases, the wave accessibility becomes limited, resulting in a strong $n_{//}$-upshift leading to off-axis absorption.

Scenario modelling using the METIS code shows that ITER-relevant heat fluxes are compatible with the sustainment of long pulse H-mode discharges in scenarios at high power (up to 15MW/30s at I_p=0.8MA) or high fluence (up to 10MW/1000s at I_p=0.6MA). The predicted bootstrap fraction is 30-35%, and the fraction of LH driven current up to 60%. Advanced tokamak modes investigation will thus be an important research axis for WEST in support of JT-60SA operation preparation.

[1] R.J. Dumont et al., Plasma Phys. Control. Fusion 56 (2014) 075020.

[2] J. Bucalossi et al., Fusion Eng. Des. 89 (2014) 907.