Introduction

The dynamics for the transition to a stationary H-mode regime and for its controlled termination in ITER is expected to be qualitatively different to present experiments. Therefore detailed modelling studies have been carried out with the JINTRAC suite of codes [1] in order to better understand under which ITER-specific conditions these transitions can be achieved, how the plasma evolution to/from H-mode can be optimised, and to assess the problem of possible core W accumulation in these transient phases.

Simulation Setup

JINTRAC core and core-SOL simulations were performed with the JETTO-SANCO and EDGE2-D/EIRENE codes.

- Fully predictive modelling of current density, momentum, plasma ion and electron pressure, main ion, Be and Ne / W impurity density evolution.
- Core transport in L-mode predicted by standard Bohm/gyroBohm model.
- Core transport in H-mode predicted with GLF23 or Bohm/gyroBohm if returned to fit with predictions from GLF23 [2]; sawteeth are modelled with a continuous sawtooth model.
- Neoclassical transport modelled with NCLASS.
- L-H transition model: exponential reduction of anomalous transport in ETB as function of (P_{ped}/P_{ped,max}) or (P_{ped}/P_{ped,max}) determined by scaling from [3].
- ELM-induced transport applied in a time-averaged way (continuous ELM model [4]).
- Extension of ETB into the SOL by a few mm on outer midplane; further away from the separatrix the plasma transport is increased to a constant level ($\xi_p = 1.0 \times 10^{-3}$). DT: $D/T = 0.3 \times 10^{-3}$. Pinch velocities and drifts in the SOL are not included in the simulations.

Optimisation of Density Ramp for Access to High Q$_H$ H-Mode @ 15 MA

Access to high Q$_H$ H-mode at $P_{ped} = 53$ MW requires a delay time before the application of increased pellet fuelling and a moderate ramp rate.

Core ion temperature needs to be kept $\approx 10$ keV to keep alpha heating at a level required to maintain $P_{ped} = P_{scen}$ during the transition.

Increased poloidal flux consumption during the transition to high Q$_H$ H-mode at $P_{scen} = 53$ MW in range of $\xi_p = 3.5$-7.5 ms.

Fast transition to high Q$_H$ predicted to be feasible at increased $P_{ped,max} = 73$ MW at $\approx 50$% reduced $\xi_p$.

Quantitative predictions depend on initial conditions ($n_i$ at start of transition, pre-heating) and uncertainty in $P_{ped}$ scaling.

Control During the Access to High Q$_H$ H-Mode in ITER

Temperature screening of W in ETB is improved if $dP_{ped}/dt$ is reduced by a delayed start of the increased density ramp after the H-mode transition by pellet injection, by low $n_i$ ramp rates and by increased gas puff yield if a higher $n_i$ at the separatrix (cf. [5]).

Moderate DT gas injection at a rate of $\approx 2 \times 10^4$ s$^{-1}$ can help to keep the divertor plasma temperature below $\approx 15$ eV and W sputtering at a negligible level in the ELM-free phase.

W core accumulation during the transition to high Q$_H$ could be thus minimised by simultaneous control of SOL and pedestal density by gas and pellet fuelling.

Conclusions

- Limits for $n_i$ ramp rate / delay time before application of increased pellet fuelling wrt. $P_{ped}$ for the transition from L-mode to high Q$_H$ 15 MA H-mode plasmas in ITER have been established: Delayed start of $n_i$ ramp and moderate $n_i$ ramp rates and injection of gas in addition to pellet fuelling are required to ensure reliable access to high Q$_H$ and to prevent W contamination of the plasma in the transition, a critical issue due to domination of W in SOL.

- $n_i$ increase following H-mode transition in He plasmas is found to be moderate due to inefficient He neutral penetration to the core, allowing for robust access to type-I ELMy H-Modes with $P_{ped} > 40$ MW and efficient W screening. $n_i$ might stay close to the NB shine-through limit.

- Predicted duration for H-L transition at 15 MA / 5.3 T and 7.5 MA / 2.65 T with ELM control during the H-mode termination of reduced ELMy phases (at $P_{ped} > 40$ MW) or at the onset of transition from L-mode to high Q$_H$ could lead to significant W core accumulation and W radiation reducing the transition time to $\approx 1.0$ s.

References


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