Modelling of core confinement in JET Carbon vs. ITER-like wall discharges

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INTRODUCTION AND MOTIVATION

To ascertain the influence of the type of wall may have on core confinement in JET baseline and hybrid plasmas, a comparative analysis has been carried out between Carbon (C) and ITER-like wall (ILW) discharges using JINTRAC (JETTO-\textsc{sanco}) with either Bohn-ryo-Bohm (Bb) or GLF23 transport models, in transport codes designed to include transport barriers (ETB). Neoclassical transport is determined by NCLASS and, when needed, sawteeth are emulated by the Kadomtsev model. Hence, fully predictive simulations have been carried out for comparable C and ILW JET plasmas (with source high-performance phases), trying to fit the experimental density and electron and temperatures in the plasma core region.

M O D E L L I N G T H E C U R R E N T FLAT- TOP P H A S E O F J E T D I S C H A R G E S

Comparing JET C (\#77955) and ILW (\#83479) discharges have been analysed with JINTRAC (\textsc{jetto-\textsc{sanco}) core simulations in fully predictive mode, having been found for this pair of discharges that:

• Standard Bb\textsuperscript{G} (in combination with the continuous ELM model) yields reasonable agreement between experimental and simulated profiles, whereas GLF23 (with plasma rotation taken into account) gives very good agreement with measurements.

• For Bb\textsuperscript{G}, predicted density and temperature profile shapes agree better with measured ones if the ion diffusivity is scaled to fit the measured drop at the outer part of the experimental heat conductivities and particle diffusivities (without pinch) from the Bb\textsuperscript{G} simulations.

• Heat conductivities in the core have thus been found to be reduced by \sim15-30\% in the ILW configuration, which could result from a reduced \textit{Bohm} temperature or an enhanced heat flux from the core to the wall (due to increased W discharge), partially compensated by the proportionality to the logarithmic gradient pressure (increased by up to \sim20\% in the ILW core plasma).

The importance of radiation in ILW plasmas has been assessed by weighting the individual terms in the heat transport equations for both C and ILW discharges, radiation being able to cause a \sim5\ MW reduction in the heat flux reaching the top of the pedestal (TOP). Are the different levels in heat flux to the core of C and ILW discharges responsible for degrading pedestal pressure with the ILW, resulting in poorer overall confinement? To answer this question:

• A test simulation for C shot \#77955 has been run removing the heat flux by an amount equivalent to the radiation in the ILW shot \#83479 (but keeping the original time-averaged ETB transport level), resulting in a near-TOP temperature reduction of 2 to \sim1.5\keV.

• Another test simulation for C shot \#77955 has been run without modifying the heat flux, but imposing instead in the ETB the same increased time-averaged transport coefficients observed in the ILW shot \#83479, resulting in a decrease in TOP electron temperature from 2 to only \sim1.2\keV.

• Hence, both a reduction in heat flux from the core due to increased radiation and an enhanced averaged transport level in the ETB (which may be due to increased IET transport or a change in MHD leading to an increased ELM frequency) result in a lower TOP electron temperature in the ILW case, the former accounting for \sim30\% of the total temperature reduction.

In typical JET-like discharges, core radiation is always a dominant feature, sometimes in a steppenwiese manner, and often the flat-top phase must be terminated after the appearance of a radiation peak causing rapid confinement degradation. The steep increase in radiation may come from a sudden, large W influx (a so-called W event), while the peak may be due to an increased ion density or an increased W accumulation in the core. For a large amount of W, these effects can be reproduced by the modelling:

• JINTRAC runs have been performed with either a moderate W puff with 2.5\10^{19}\textsuperscript{W}\textsuperscript{P}\textsubscript{A}\textsubscript{T}\textsubscript{H} particles reaching the core within 100\ ms, or a large W event modelled by a W puff with twice as many particles passing the separatrix in the same time interval.

• In the first case, the measured increase in radiation of about 3\ MW in shot \#83479 can be roughly reproduced and the small ion-effective-impurity increase of \sim0.05\% (the relative amount of puffed W particles being small) is compatible with the measured variation, other plasma properties such as average temperature and density being unaltered.

• The situation is completely different in the second case, when an increase of \sim8\ MW in radiated power appears to be sufficient to quickly reduce the temperature and facilitate W penetration to the core, triggering the discharge collapse within 1.2\ s. The W density tends to peak at the very core due to an extremely large neoclassical inward pinch velocity.

• W accumulation in the core is seen even without emulating an W event, as in simulations of discharge \#83479, with the concentration added to the experiment (matching the core radiation level) and without prescriving any W influx at the separatrix, the W density (hollow at the beginning) becoming more and more peaked within a couple of seconds, which matches the time scale typically observed in the experiment until the radiation reaches an unsupportable level.

• Simulation scans of W concentration have found that the level of W accumulation strongly depends on the W amount present in the plasma at the flat-top beginning, the core W density evolving slowly if the W concentration is low and the radiated power remains below a critical value of \sim3\ MW, which may be explained by the proportionality between W flux and density, if the W pinch is dominant.