INTEGRATED NUMERICAL ANALYSIS OF IMPURITY TRANSPORT AND SOURCES FOR HIGH CURRENT–HIGH POWER BASELINE PULSES WITH T IN JET-ILW

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This study presents a numerical analysis of baseline discharges with a total auxiliary heating of approximately 30 MW, conducted in the ITER-like wall (ILW) corner configuration, without impurity seeding. The analyzed discharges #99268 and #99282 were performed in Tritium (T) plasmas at the same plasma current of 3.5 MA and a toroidal magnetic field of 3.25 T. The primary distinction between the pulses lies in the hydrogen pellet injection rate, which is 25 Hz for pulse #99268 and varies between 35 Hz and 17 Hz during pulse #99282.

Fig. 1 shows the time evolution of heating power, T puff, electron volume-average density (n_e^{VOL}), total radiated power, and pellet flux for both pulses #99268 and #99282, highlighting the intervals during which hydrogen pellets were injected. This data provides an overview of the heating conditions and the pellet injection patterns that are critical for understanding the observed plasma behavior. At times t = 8.6 s, 9.4 s, 9.7 s, and 10.08 s, Fig. 2 presents tomographic reconstructions of the radiated power density for pulse #99268. These reconstructions highlight an increase in radiated power in the plasma core, which reflects changes in impurity transport and the overall plasma behavior as the discharge progresses. The analysis focuses on investigating the mechanisms responsible for the increase in radiated power during these pulses, with particular emphasis on impurity transport and tungsten (W) production. The study examines the W concentration in the plasma, the impact of impurity transport in the core plasma on W production, the level of W sputtering induced by beryllium (Be) and nickel (Ni), and the profile of the effective charge (Z_{eff}).

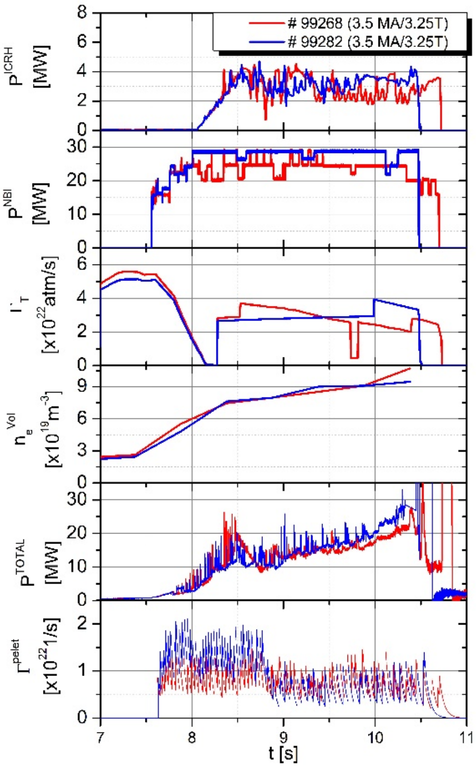

Fig.1. The time evolution of heating power, Tritium puff, electron volume-averaged density (n_e^{VOL}), total radiated power (P^{TOTAL}), and pellet flux for pulses #99268 and #99282.

COREDIV simulations were performed using an integrated approach that couples radial impurity transport in the core plasma with a 2D multifluid model of the scrape-off layer (SOL). The simulations included four impurities: intrinsic Be, W, Ni and extrinsic neon (Ne). The simulations were conducted at four specific times during the discharges: t = 8.6 s, 9.4 s, 9.7 s, and 10.08 s. The simulation setup assumed impurity transport coefficients, with 'ad-hoc' convective velocities used to match the experimental radiated power profiles.

The numerical results presented in Fig. 3 indicate an increase in the density of Ni over time, despite the constant flux input of Ni. In contrast, the W density remains relatively stable throughout the pulse, primarily due to the self-consistently calculated reduction in the W flux by the COREDIV model. The profiles for Ni and W reveal distinct behaviors, with the maximum W density located at r/a ≈ 0.6–0.9, resulting from inward convective velocities in the edge region and outward velocities in the core region.

***** see the author list of 'Overview of T and D-T results in JET with ITER-like wall" by C.F. Maggi et al. 2023 Nucl. Fusion 63 110201

** See the author list of "Overview of the EUROfusion Tokamak Exploitation programme in support of ITER and DEMO" by E. Joffrin et al. 2024 Nucl. Fusion 64 112019

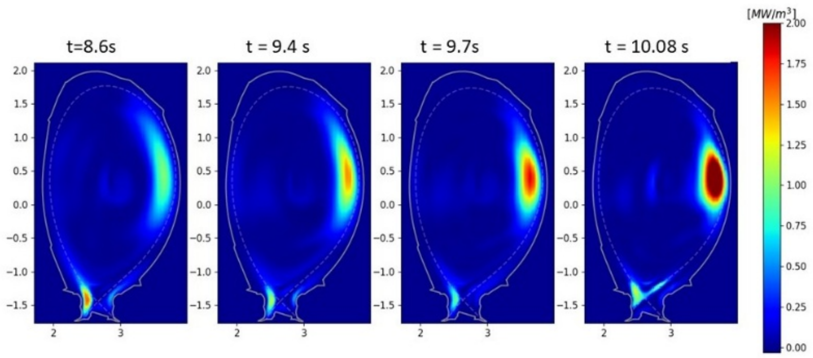

Fig. 2. Tomographic reconstructions of the radiated power density at times t = 8.6 s, 9.4 s, 9.7 s, and 10.08 s for pulse #99268.

Significant changes in impurity inward pinch are observed around t = 10.08 s, likely related to the loss of edge localized modes (ELMs) around t = 9.5 s, which are attributed to excessive radiated power.

In summary, the results from the COREDIV simulations provide valuable insights into impurity transport processes and the role of tungsten in the radiative power increase observed during the discharges. The findings suggest that, while the Ni density increases over time, the W concentration remains constant, primarily due to the effects of impurity transport and the self-consistent modeling of impurity flux dynamics within COREDIV. The Z_{eff} profile has s maximum for r/a=[0.6-0.9]. The simulations show that sputtering of W due to T is negligible. For beryllium ions, the dominant contribution to W sputtering is due to Be^{2+}.

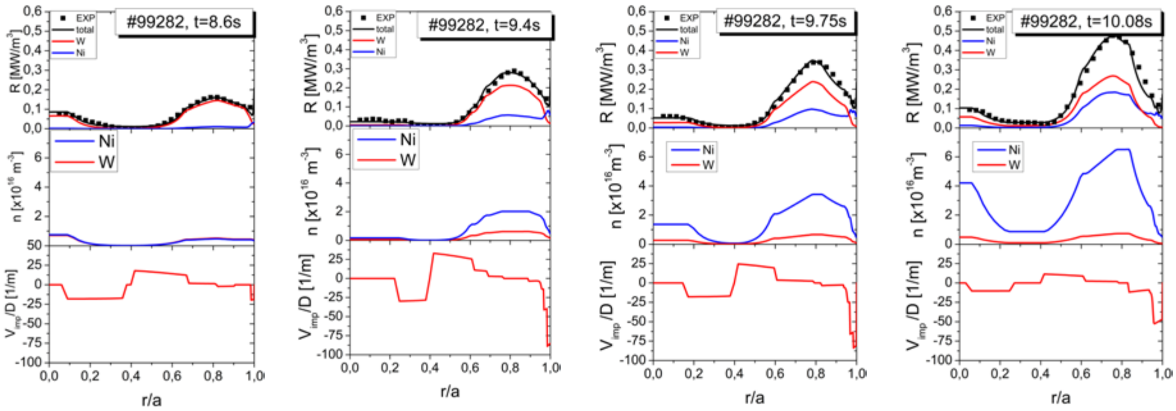

Fig.3. Simulation profiles for Ni (represented in blue) and W (represented in red) radiated power and densities, total experimental and simulated radiated power (represented in black), and value V_{imp}/D profiles in the core plasma for pulse #99282 at four different times t=8.6, 9.4, 9.75, 10.08 s.

The results of this study are consistent with the findings in [1], where radiation control strategies also focused on managing impurities to avoid excessive radiated power. However, the current study provides a more detailed analysis of W transport. Comparing the results for T plasma with those for D and DT plasma reported in Ref. [2] for the Baseline scenario, it can be concluded that the behaviour of DT plasma is similar to that of T plasma. Both exhibits relatively stable W concentrations, despite differences in impurity transport mechanisms, indicating that the main factors influencing the radiative power are similar across these plasma types.

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