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The EU-DEMO Exhaust Modelling Roadmap – Numerical Implementation and Methods

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A simple extrapolation of the ITER Q=10 H-mode divertor target heat-load specification assuming mitigated type-I ELMs is not sufficient for the exhaust concept required in EU-DEMO provided the increased power level of Pedge = 300MW entering the edge region. The combination of an anticipated reduced power fall-off length of only a few mm in the SOL at a plasma current Ip=20MA whilst keeping the increase of the size of the device at a moderate level to optimize for cost of magnetic field (scaling with major radius, R_DEMO ˜ 1.5 R_ITER) requires an integrated core-edge scenario with a tailored impurity mix inducing an energy dissipation fraction of up to 95% in the edge (of which 30% must occur in the confined region by line radiation). In recent experiments it has been demonstrated that at such high levels of radiation (e.g. located close or at the X-Point in single-null configurations) a transition into a small/no-ELM regime is observed coinciding with controllable strong detachment in the divertor. Modelling of an X-Point radiating regime and the validation of a suitable model is an ongoing task. Improved core physics scenarios for EU-DEMO (not necessarily employing an X-Point radiating regime) require upgrades for the pedestal transport model, or a lifting of other geometrical constraints. For example, the inclusion of a secondary X-Point in the upper-plane allowing strongly shaped plasmas at high beta may cause an additional source of impurities from wall erosion by energetic particles in remote areas and requires further numerical assessments with plasma-wall interaction codes.

The conceptual design phase for EU-DEMO implies a revision of the exhaust modelling roadmap until 2024. For the purpose of identifying a controllable exhaust scenario to be employed in EU-DEMO, the required physics foundation of candidate regimes must be re-assessed by using validated numerical tools. A new baseline reference exhaust model setup is currently being established in the DEMO central team (DCT) in Europe. This contribution summarizes the key aspects of the proposed complete SOLPS-ITER EU-DEMO physics model, including: fluid drifts and neutral kinetics, allowing for charge exchange for impurities enhancing non-coronal radiation levels in the edge. A multi-strand approach employed by the DCT with different levels of fidelity is presented, that seems advantageous to complement the final model to be composed for exploring the boundaries of the EU-DEMO exhaust operational window. Recently, new developments have started of an extension to the SOLPS-ITER code for automatic optimization of the DEMO divertor shape and a status of this work is presented. Finally, an outlook based on very recent activities on the development of fast exhaust models employing advanced machine learning will be given. Employment of such fast pre-trained models seem to be promising for fast integrated scoping studies through systems design codes and future plasma control schemes.

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