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Transition of SOLPS-ITER modelling from Tokamaks to Linear Devices: application to a deuterium plasma in GyM

Controlling plasma-wall interactions (PWI) is a key challenge in the field of nuclear fusion, as it directly impacts the efficiency, safety, and operational reliability of future reactors. Linear Plasma Devices (LPDs), such as GyM, play a crucial role in studying PWIs by replicating charge-exchange neutral fluences characteristic of ITER's main chamber. Projectile energy is tuned via electrical target biasing [1].

The SOLPS-ITER code, comprising the B2.5 and EIRENE modules, is employed to reproduce experimental trends of electron density and temperature observed in GyM for a deuterium plasma. Originally developed for simulating the Scrape-Off Layer in toroidal devices, the code has been successfully applied to non-hydrogenic plasmas in GyM, including argon and helium [2]. The work on SOLPS-ITER provides experimental code validation in a regime with limited existing literature. Also, it helps to reveal physical mechanisms whose details are not completely apparent from measurements, and to potentially predict scenarios beyond experimental reach.

The first part of this study outlines the modelling process adopted for GyM, highlighting the major differences compared to the far more popular tokamak case. The B2.5 code solves plasma fluid equations in a 2D field-aligned grid for electron and ion populations, while EIRENE performs kinetic transport calculations for neutral species. These codes can function independently or iteratively coupled, ensuring self-consistent plasma-neutral interactions. A key challenge in adapting SOLPS-ITER to LPDs lies in the transformation of the curvilinear coordinate system used for tokamaks into a cylindrical framework suitable for linear devices. In this transition, the toroidal magnetic field component, dominant in tokamaks, is absent, leading to significant modifications in the transport equations, particularly affecting drifts and parallel transport processes.

Electron density and temperature radial profiles obtained with SOLPS-ITER for a deuterium plasma are displayed and the comparison with GyM experimental trends demonstrates agreement with the measured density profiles well within 20%. Langmuir probes were employed to acquire data for the comparison, and plasma parameters are available along the radial direction at three distinct points on the machine axis. Experiments were performed by varying the external power, pressure, and magnetic configuration. The modelling procedure for the power deposition in the plasma is described. The output of this work will provide a plasma background that can serve as the basis for further development of an integration with the ERO2.0 code, enabling the study of the impact on plasma-facing material properties.

Adopting a simplified framework for studying plasma parameters is essential, as it enables faster results that can complement experimental data and SOLPS-ITER trends. In this context, a brief introduction to a 0D model for a deuterium plasma in GyM is provided. This model describes the evolution over time of density and temperature through a set of ordinary differential equations.

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